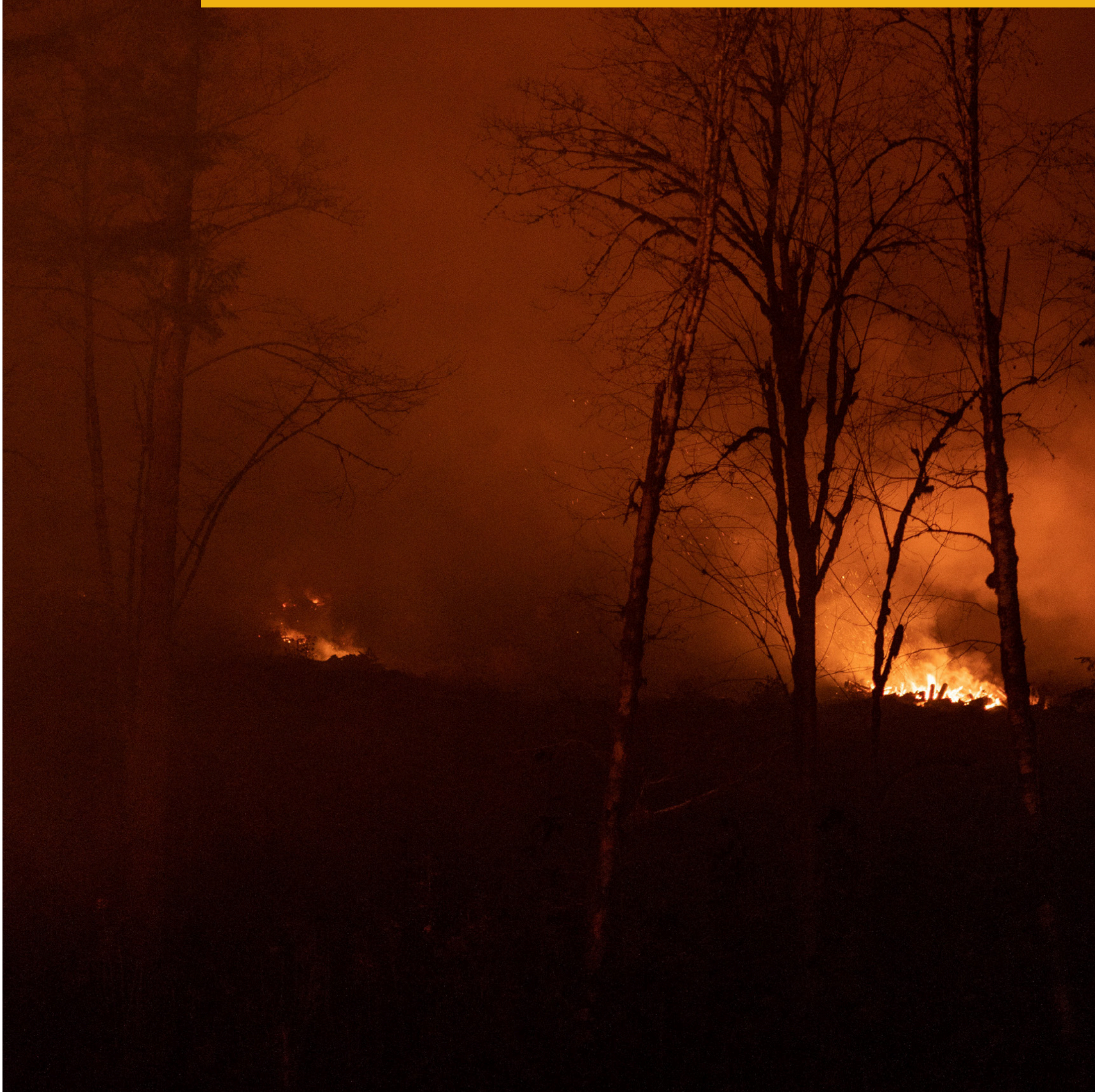
HEINRICH BÖLL STIFTUNG
ECONOMIC + SOCIAL ISSUES

VOLUME 23

A Societal Transformation Scenario for Staying Below 1.5°C

A study by Kai Kuhnhenn, Luis Costa, Eva Mahnke,
Linda Schneider and Steffen Lange



konzeptwerk
neue ökonomie

A SOCIETAL TRANSFORMATION SCENARIO FOR STAYING BELOW 1.5°C

HEINRICH BÖLL STIFTUNG
PUBLICATION SERIES ECONOMIC + SOCIAL ISSUES
VOLUME 23

A Societal Transformation Scenario for Staying Below 1.5°C

A study by Kai Kuhnhenn, Luis Costa, Eva Mahnke, Linda Schneider, Steffen Lange

Edited by the Heinrich Böll Foundation and Konzeptwerk Neue Ökonomie

The Authors

Kai Kuhnhenn has worked with Konzeptwerk Neue Ökonomie e.V. for seven years. Previously he worked with the Federal Environment Agency (UBA) in the field of energy and climate, focussing on policy evaluation, sufficiency measures and reviewing IPCC reports, for more than eight years.

Luis Costa is an engineer turned researcher interested in the topics of climate impacts and the elaboration of open energy models – in particular considering the effect of changing lifestyles. Luis graduated with a Diploma degree in Environmental Engineering from Universidade de Trás-os-Montes e Alto Douro (2006) and received his PhD from the University of Greifswald (2013).

Eva Mahnke works as a freelancer in communication and public relations, focusing on climate policy, degrowth and issues of sustainability. Previously she worked as a journalist on climate policy. Eva has an academic background in ethics, economy and political sciences.

Linda Schneider is Senior Programme Officer for International Climate Policy at the Heinrich Boell Foundation in Berlin. Her work focusses on false solutions in climate and biodiversity. She is also an activist in the climate justice movement and the Right to the City movement in Berlin.

Steffen Lange is a researcher at the Institute for Ecological Economy Research (IÖW), affiliated scholar of the Resource Economics Group at the Humboldt University Berlin and associated researcher at the Department of Social-Ecological Transformation at the Technical University Berlin. His research focuses on digital transformation, the relationship between economic growth and environmental throughput, rebound effects and concepts for sustainable economies.

A Societal Transformation Scenario for Staying Below 1.5°C
A study by Kai Kuhnhenn, Luis Costa, Eva Mahnke, Linda Schneider, Steffen Lange
Volume 23 of the Publication Series Economic & Social Issues
Edited by the Heinrich Böll Foundation and Konzeptwerk Neue Ökonomie 2020

Proofreading: Anne Wegner
Layout and design: feinkost Designnetzwerk, S. Langer (predesigned by blotto design)
Printing: ARNOLD group, Großbeeren
Cover photo: Cristofer Jeschke (– unsplash)

This publication can be downloaded from: www.boell.de

CONTENT

FOREWORD

Can we still limit global warming to 1.5°C? And if so, what pathways can society take in transiting towards a climate-just economy?

The Intergovernmental Panel on Climate Change (IPCC) has always played an important role in shaping what is perceived as necessary, possible or impossible in terms of climate action. In particular, the 2018 IPCC Special Report on Global Warming of 1.5°C had a remarkable impact on climate policy discourse in both international and national policy debates. One important yardstick emerging from it was the need for global emissions to reach net-zero by 2050. To achieve this target and limit global warming to 1.5°C, the IPCC'S 2018 message was that emissions needed to be cut in half by 2030. These targets helped the global climate movement raise awareness around the climate crisis and the need for immediate and drastic action.

Climate economic mitigation scenarios figure prominently in most of the IPCC reports. These mitigation scenarios are usually products of «Integrated Assessment Models» (IAMs), which are run by a rather small scientific community. While they are useful in what they can contribute to the discussion – like delivering tangible temperature and emissions targets –, they also come with their own limitations, problems, and obscurities: These IPCC scenarios are very much shaped by what is currently often assumed to be economically and socially feasible, without considering new lines of societal change and progress.

One important problem with those scenarios is that virtually all rely on continued global economic growth until 2100 (the time period usually covered in such scenarios). However, in both the models and the real world, unabated economic growth is difficult to reconcile with ambitious climate goals – certainly when currently considering the closing window still left for limiting global warming to 1.5°C. The consequence of adhering to the growth paradigm is that mitigation scenarios have to rely on high-risk technologies such as geoengineering, CCS and nuclear energy to reach mitigation goals. In many cases, such scenarios even assume the temperature will «overshoot» the 1.5°C goal at least temporarily – with unknown consequence for humans and ecosystems and at the risk of hitting irreversible tipping points in the climate system during that overshoot period.

At the Heinrich Böll Foundation and the Konzeptwerk Neue Ökonomie, we realised the importance of broadening the discussion's perspective and considering societal pathways that are currently not included in either the IPCC reports or the public debate. These pathways will be crucial if we not only aim to limit climate change but, at the same time, want to tackle the manifold social and ecological global crises. They differ from known scenarios in that we envision the Global North as embarking on a trajectory of de-growing their economies and for wealth and income to be drastically redistributed.

Together with researchers from engineering and the natural and social sciences, we decided to develop the «Societal Transformation Scenario» – a global climate mitigation scenario that explores the climate effects of limiting global production and consumptions and of envisioning a broader societal transformation to accompany these transformations.

We hope that the scenario sparks new conversations about climate mitigation pathways, conversations that do not revolve around questions about technology and cost but that deal with the much more pressing matter of achieving a good life for all.

Berlin, November 2020

Barbara Unmüßig
President Heinrich Böll Foundation

Linda Schneider
Senior Programme Officer International Climate Policy Heinrich Böll Foundation

Andrea Vetter and Kai Kuhnhenn
Konzeptwerk Neue Ökonomie

ABSTRACT

During the COVID19 crisis, many economic activities have shut down, with resulting reductions in production and consumption leading to declining greenhouse gas (GHG) emissions. Although this «degrowth by disaster» should by no means serve as an example for a preferable strategy to combat climate change, it raises two questions – 1. is a reduction of production and consumption an effective way of curtailing GHG emissions and 2. if so, can we imagine a scenario where this reduction is not accompanied by crises and social hardships?

We argue that current global mitigation scenarios fail to explore the possibilities of reduced economic activity in the Global North. Instead they focus on technological solutions, some of which pose severe ecological and social risks, such as geoengineering and nuclear power. In light of these risks, we argue that changing our path – e.g., changing our consumption and production – is safer than relying on technological bridges to be available before we drive over the cliff.

Such a change in consumption and production in the Global North is depicted in the Societal Transformation Scenario (STS) within a fundamental socio-ecological transformation: A transformation that is primarily about producing and consuming less but also about fulfilling concrete human needs and serving common welfare – fostering cooperation, care, solidarity and sustainability to achieve a good life for all. Important (first) changes in this regard are taxing resources instead of labour, making social services growth-independent, reducing working hours, introducing basic incomes and a maximum wage, decelerating life and democratising (economic) decision-making. Although these changes might not have a direct impact on GHG emissions, they are prerequisites to increasing human well-being while reducing material consumption. They are the reason for people not only accepting a reduction in consumption but also being inspired to move beyond a system relying on everlasting economic growth at an expense to humans and the environment.

Alas, the effect on GHG emissions can only be calculated when the envisioned change is translated into mundane changes in consumption parameters. We decided to concentrate on some key areas: travelling by car and plane, freight transport, (heated) living space, number of energy consuming appliances and food/meat consumption. For each of these parameters, we present a reduction pathway and examples of much reduced activity either in the recent past or in some areas of the world. We also spread light on real world examples of effective measures and policies that have been implemented to reduce these parameters. Starting from the assumption that the countries of the Global North are foremost responsible both for historical emissions and for reducing emissions in the present, we do not assume a reduction in consumption for countries of the Global South but rather an increase in these

parameters there, leading to a convergence of their consumption patterns with those of the Global North, or even a higher consumption by 2050. Regarding technological change, the STS depicts ambitious increases in efficiency and renewable energies with a phase-out of nuclear power and no geoengineering options.

The GHG mitigation of the STS potential is calculated using the Global Calculator, a relatively simple, transparent modelling tool. The reasoning behind this choice is that we believe that our mitigation path should be the subject of open democratic debate. Integrated Assessment Models – the black-box tools usually used to create global mitigation scenarios – tend to impede such discussions since they are obscure and hide ethical questions in their algorithms.

The Calculator's results for the STS show a large decline in energy demand in the Global North and a reduction of global GHG emissions of roughly 50% from 2020 to 2030 and a further 22% (12.7 Gt CO_2eq) by 2050. Due to the assumed dietary shift, large agricultural areas can be carefully restored to natural ecosystems or managed more sustainably, in the process serving as CO_2 sinks of roughly 4 Gt CO_2 per year. The cumulative CO_2 emissions remain within the carbon budget that gives us a 2/3 chance of staying within a temperature increase of 1.5°C.

1 Why we need a Societal Transformation Scenario

The COVID19 pandemic has resulted in many economic activities slowing down and consumption being reduced, leading to declining greenhouse gas (GHG) emissions. This «degrowth by disaster», albeit an unsavory alternative for combatting climate change, raises two questions – 1. is a reduction of production and consumption an effective way to curtail GHG emissions and 2. if so, can we imagine a scenario where this reduction is accompanied not by crises and social hardships but by a transformation that actually increases human well-being?

The motivation for writing this paper is that we are worried that even today's most progressive climate mitigation scenarios – although providing valuable information – do not present a sustainable, safe and participatory path to preventing a runaway climate crisis. What are the reasons for our worries? Our analysis shows that the current mitigation scenarios (a) neglect the opportunities of reducing emissions through reductions in economic activity, (b) rely on technological solutions rather than societal change and (c) include dangerous technologies such as nuclear energy and «negative emissions» technologies.

The Global North's energy-intensive and resource-intensive mode of production and living is a key driver of GHG emissions. Mainstream climate policy relies on a sufficient decoupling of economic growth and emissions, that is a decoupling that leads to the emission reductions needed to achieve a certain climate goal – i.e. to stay below a 1.5°C increase in global mean temperature.[1] According to available knowledge and empirical evidence, such a decoupling appears impossible, or at least very unlikely.[2] In this situation, the precautionary principle advises opting for economic trajectories without growth.[3] Still, most climate mitigation scenarios foresee ongoing economic growth on a global scale – leading to at least a doubling of gross domestic product (GDP) in industrialized countries between now and the next century.[4] Reduc-

1 Antal, M. and Van Den Bergh, J., 2016. Green growth and climate change: Conceptual and empirical considerations. Climate Policy, 16(2), 165–177; Lange et al., 2020. Digitalization and energy consumption. Does ICT reduce energy demand? Ecological Economics, 176, 106760.

2 Parrique, T. et al., 2019. Decoupling debunked: Evidence and arguments against green growth as a sole strategy for sustainability. European Environmental Bureau.

3 Petschow, U. et al. 2018. Gesellschaftliches Wohlergehen innerhalb planetarer Grenzen: Der Ansatz einer vorsorgeorientierten Postwachstumsposition (UBA Texte 89/2018). Umweltbundesamt.

4 A 1% growth rate is, for example, given for high-income countries in Leimbach et al., 2017. Future growth patterns of world regions – a GDP scenario approach, Global Environmental Change, Vol. 42, 215-225.

ing economic activity to decrease demand for energy intensive services and products is an effective and much safer way of reducing our emissions than many technological options.[5]

However, the current debate circles almost entirely around technological change and does not take into account the huge potential of societal and economic change. Many examples at the local, regional and even national level show that societal change can reduce energy-intensive consumption and production while contributing to more socially just, more ecologically sustainable and, in many more ways, more liveable societies.[6]

Ignoring the potentials for societal change means, we are currently relying on the ability to extract huge amounts of GHG emissions from the atmosphere in the future. Mitigation scenarios included in the IPCC Special Report on 1.5°C of global warming account for several hundred to more than one thousand gigatons (Gt) of CO_2 being removed from the atmosphere over the course of the 21st century [100-1,000 Gt].[7] In 2017, global CO_2 emissions stood at around 40 Gt. Mainstream mitigation pathways assume that ten to thirty times our current global annual emissions can simply be sucked from the atmosphere and safely stored away.

Yet, all of these technologies are speculative at this point, particularly when it comes to their ability to be scaled up. No one knows whether they will actually work or what the risks and impacts will be.[8] Figuratively speaking, the world is currently driving in a straight line of ever-increasing demand and production, simply hoping that, by the time the road ends, a bridge will have been built. What is being ignored is the exits from this road. And even if the technologies work – and there is a bridge – they will not come without consequences: Even the most accepted geoengineering options, such as using Bioenergy with Carbon Capture and Storage (BECCS) and large-scale monoculture afforestation, would lead to soil degradation, biodiversity loss and ecosystem destruction and would fuel conflicts over land, including human rights violation.[9]

---

5 Figge, F. et al., 2014. Sufficiency or efficiency to achieve lower resource consumption and emissions? The role of the rebound effect. Journal of Cleaner Production, 69, 216–224.

6 O'Neill, D.W. et al., 2018. A Good Life for All within Planetary Boundaries; Raworth, K., 2017. Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist.

7 Minx, J.C. et al., 2018. Negative emissions – Part 1: Research landscape and synthesis. Environmental Research Letters, Vol. 13, No. 6; Rogelj et al., 2018. Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.

8 Smith, P. et al., 2016. Biophysical and economic limits to negative CO_2 emissions. Nature Climate Change 6, 42–50; Anderson et al., 2016. The trouble with negative emissions. Science, Vol. 354, Issue 6309, 182-183; European Academics Sciency Advisory Council, 2018. Negative emission technologies: What role in meeting Paris Agreement targets? EASAC policy report 35.

9 ETC Group, Biofuelwatch and Heinrich Boell Foundation, 2017. The Big Bad Fix. The Case Against Climate Geoengineering, https://www.boell.de/en/2017/12/01/big-bad-fix-case-against-geoengineering

This technology-focused make or break attitude dominates IPCC reports. With time running out for reducing global GHG emissions, more and more climate scenarios rely on a large-scale use of negative emission technologies to stay within the 1.5°C limit. We believe there is no necessity to rely on those risky and unsustainable technologies, neither must nuclear energy be relied on if countries in the Global North reduce their high level of consumption and continuous economic growth. This path is presented in our «Societal Transition Scenario» (STS), which is based on a change in the way society organises production and consumption. This change includes not only technological progress but also changes in governance, culture and individual behaviour. The STS is a first draft of a climate mitigation scenario depicting an alternative future, an outline that must be underpinned by further scientific research, practical knowledge and a spirit of confidence that reshaping society to the benefit of all people and the environment is possible.

In addition to being a precautious path, reducing production and consumption can also be the more democratic path when achieved through a bottom-up process with mutually agreed, effective instruments and measures controlled and contributed to by many and adapted to the respective regional context. In contrast, pinning hopes to large-scale negative-emissions technologies would most likely force a reliance on governments and profit-oriented capital-intensive companies to prevent a catastrophic climate crisis.

Our approach

We developed the STS by imagining a socio-economic transition that we translated into scenario assumptions. These assumptions include reducing consumption and production in certain energy-intensive sectors of the economy – which leaves room for other, less energy-intensive sectors to flourish.[10] The societal transformation we imagine is more than just a «blind» reduction of consumption and production. We envisage a democratically controlled structural transformation that leads to social, economic and ecological justice, including a greater well-being and a better quality of life for all. This vision is reflected in our scenario parameters, i.e. we deliberately chose consumption parameters whose reduction within a socio-economic transformation will not threaten the fulfilment of basic material needs while allowing for an improved fulfilment of non-material needs (see Section 7).[11] The consumption reductions are conceivable and lead to substantial emission reductions. The STS prescribes neither specific solutions or ways of life nor a concrete toolkit of environmental and social

10 Gran, C., 2013. LOW GROW for Germany: modelling the macroeconomics of degrowth; Kallis, G., 2015. The Degrowth Alternative. Great Transition Initiative; Lange, S., 2018. Macroeconomics Without Growth: Sustainable Economies in Neoclassical, Keynesian and Marxian Theories. Metropolis.

11 At this point the question might arise «what are people's needs and who decides what is?» In general, this must be the object of democratic debate. It should be clear, however, that these needs comprise more than material consumption. For a good concept on human needs see Ekins, P., and Max-Neef, M., 2006. Real Life Economics.

policy instruments for doing so. Instead it aims to show the potential of an alternative mitigation pathway.

We are aware that many assumptions we make about the future are highly subjective. That is why we emphasised transparency in our approach. We hope that this combination – focusing on consumption parameters and being transparent in our assumptions – will result in a lively discussion, already constituting a relevant change – away from debates about technological possibilities and towards questions of how to live in the future.

To calculate the effects of the STS, we use the Global Calculator (see Section 4). It is a tool whose goal is much in line with ours and allows the discussion to be opened to people outside the scientific community. The Global Calculator may be less complex than other climate models, but it is also much more transparent.

2 The bias towards growth and technology fixes in most climate scenarios

Climate modelers face an ambitious task – in a world that is more dynamic and accelerated than ever before; they are being asked to foresee the future of mankind until the year 2050/2100 and beyond. To do so, they extrapolate changes experienced within the last decades, i.e. within a lifetime. For the energy system, these changes have been mostly technological – the invention of nuclear and renewable power generation, improvements in energy efficiency, an increase in energy demand and an ongoing trend towards more, bigger and more connected devices. They are, however, not God-given but the result of a growth-focused economic approach that employs technical advances as a tool to generate profits.[12]

The problem with this approach is that it neglects the possibility of fundamental changes in societies and economies and instead affirms the existing economic system. Accordingly, the mitigation scenarios cited by the IPCC all assume ongoing economic growth (of 1 to 2.8%[13]) on a global scale. These assumptions of Integrated Assessment Models (IAMs, see Box 1) have important implications: Since economic growth is a major driver of emissions, many of the scenarios fail to reduce emissions sufficiently to stay within a temperature rise of 1.5°C without resorting to geoengineering technologies. Reliance on geoengineering technologies in the climate mitigation scenarios leads to these technologies being increasingly considered a last-ditch option for avoiding catastrophic climate change. The potential of fundamental societal changes, on the other hand, is neglected for a number of reasons, such as the nature of the models, the mindset of the research community, etc.[14]

---

12 Altvater, E., 2005. Das Ende des Kapitalismus, wie wir ihn kennen. Westfälisches Dampfboot; Lange, S., 2018. Macroeconomics Without Growth: Sustainable Economies in Neoclassical, Keynesian and Marxian Theories. Metropolis.

13 Leimbach, M. et al., 2017. Future growth patterns of world regions – A GDP scenario approach, Global Environmental Change, Vol. 42, 215-225; Cuaresma, J.C., 2015, Income projections for climate change research: A framework based on human capital dynamics, Global Environmental Change.

14 For a systematic analysis of the reasons that lead to a disregarding of less production and consumption as a mitigation strategy see Kuhnhenn, K., 2018. Economic Growth in mitigation scenarios: A blind spot in climate science, https://www.boell.de/en/economic-growth-in-mitigation-scenarios

This trend of neglecting the possibility of societal change is continued with the IPCCs Special Report on «Global warming of 1.5°C.»[15] With regards to economic growth, the report (with one exception – see below) fails to address behavioural change that would result in a meaningful reduction of economic activity although it clearly states that «[p]ast growth of energy consumption has been mainly driven by population and economic growth» (IPCC 2017, p. 141).[16]

Instead, the report almost exclusively focuses on technological options. New strategies in the cited scenarios are the electrification of the industrial, building and transport sectors, the large-scale deployment of renewable-based Power-2-X[17] technologies and the exploration of new biomass-energy options such as algae. These options have three problems: (1) They rely on renewable electricity, in sum leading to a required level of supply manifoldly above current levels, which may be unrealistic and brings its own set of social and environmental problems.[18] (2) Many have not been tested on the necessary scale. (3) Most of them are also not sustainable when employed on a large scale taking into account their negative impacts on biodiversity loss, soil degradation, land use and overuse of scarce water resources. In addition, the material footprint of those options has to be taken into account as exploiting the necessary resources will massively affect the livelihoods of people and communities.[19]

Finally, most of the scenarios cited by the IPCC include geoengineering technologies, namely significant amounts of carbon captured from fossil and biogenic sources (BECCS, bioenergy with carbon capture and storage). BECCS is not only devastating to the environment and fuels land conflicts; it is also insecure and risky[20] (see Annex 2).

---

15 IPCC, 2018. Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., Zhai, P. et al. (eds.)].

16 Rogelj, J. et al., 2018: Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development.

17 Power-2-X is a shorthand for Power-2-gas and Power-2-liquid, meaning the production of liquid or gaseous fuels. The process foresees the production of hydrogen through the electrolysis of water using (excess) electricity from renewable sources. The hydrogen is then either used directly or is combined with carbon, producing hydrocarbons such as methane or gasoline.

18 Capellán-Pérez, I.; de Castro, C.; Arto, I., 2017. Assessing vulnerabilities and limits in the transition to renewable energies: Land requirements under 100% solar energy scenarios. Renewable and Sustainable Energy Reviews, Vol. 77, 760-782.

19 For impacts of synthetic fuels and biomass see Oeko Institute, 2017. An outline of sustainability criteria for synthetic fuels used in transport, https://www.oeko.de/fileadmin/oekodoc/Sustainability-criteria-for-synthetic-fuels.pdf.

20 ETC Group, Biofuelwatch and Heinrich Boell Foundation, 2017. The Big Bad Fix. The Case Against Climate Geoengineering, https://www.boell.de/en/2017/12/01/big-bad-fix-case-against-geoengineering

Box 1: About Integrated Assessment Models (IAMs)

Integrated Assessment Models (IAMs) are models commonly used for generating climate mitigation scenarios. They combine natural science and socio-economic components: The climate science components project the climate change impacts of rising GHG emissions; the socio-economic components are used for calculating the most cost-efficient mitigation measures for reaching a specific GHG emissions target, such as complying with the 1.5° or 2°C limits. Although IAMs can model the status quo of the economy and are appropriate tools to produce short-range and medium-range forecasts of GHG emissions and their impact, they have the disadvantage of being highly complex, obscure tools. They include algorithms to perform socio-economic choices. The logic behind these choices is buried deep within the models, thus making controversial discussion and democratic debate on model assumptions and results difficult.[21]

More fundamentally for the purposes of this work, IAM's operate along strong economic assumptions related to consumer preferences of individual households, profit maximization of firms and the existence of a commonly agreed global carbon price. These aspects can hinder the exploration of alternative mitigation scenarios where public preference is shifted towards less consumption.

Welfare function

One such socio-economic choice of Integrated Assessment Models (IAMs) has to do with the underlying «welfare function».[22] This function serves to determine which mitigation measures to employ. The concept of welfare is limited to the maximization of consumption/income per person, measured on a monetary basis. The function means that the «cheapest» option to reduce emissions is chosen first, the second «cheapest» option is chosen second and so on, until the mitigation target is met. Measures that might improve welfare in a more general sense, i.e. not measurable on a monetary basis, but at the same time reduce income/consumption are picked last, regardless of their mitigation effects or co-benefits.

21 Kuhnhenn, K., 2018. Economic Growth in mitigation scenarios: A blind spot in climate science.

22 See Michael Jakob, M. and Edenhofer, O., 2014. Green growth, degrowth, and the commons, chapter «Different Conceptions of Social Welfare and their Normative Implication for Economic Growth» for a more comprehensive critique of the welfare function, Oxford Review of Economic Policy, Vol. 30 (3), 447-468.

Cost estimates
IAMs do not model a reduction of consumption for an additional reason. According to the IPCC, «[g]lobal IAMs often do not fully and explicitly represent all the various measures that could improve end-use efficiency».[23] In particular, IAMs rely on cost estimates, which are more readily available for supply-side measures (i.e. measures that influence how energy and food is supplied, such as a shift from coal to renewables) than for demand-side efficiency measures (such as better building insulation), or even for sufficiency measures (such as reducing floor area per person). Thus demand-side measures are often missing or underrated in the models.

Heading in the right direction: the Low Energy Demand scenario

The Low Energy Demand scenario (LED) is the only exception to the IPCC report's failure to address behavioural change that would result in a meaningful reduction of economic activity.[24] It features prominently in the IPCC report and includes some behavioural changes, such as a global convergence of residential floor space and some ‹dematerilization› due to social innovations such as car sharing. It excludes geoengineering technologies but includes limited amounts of carbon sequestration by restoring natural ecosystems and soil carbon sequestration. The LED scenario primarily focuses on reducing energy consumption by improving energy efficiency. While it heads in an interesting direction, it fails to fully explore the vast reduction that could be achieved through societal change, thus not taking into account the huge potential of energy sufficiency measures. Instead, scope and scale of the assumed behavioural changes are limited, and the desirability and the possibility of continued economic growth as such is not discussed. In addition, the scenario relies on nuclear energy with its high risks and unsolved waste-storage problems. A comparison of scenario results between the LED and STS is given in Box 7 in Section 6.

23 Rogelj, J. et al., 2018: Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development, 154.

24 Grubler, A. et al., 2018. Low energy demand scenario for meeting the 1.5°C target and sustainable development goals without negative emission technologies, Nature Energy 3, 515-527.

Box 2: Limitations of global emission models

In general, models to calculate global emissions are relatively crude instruments. Due to the complexity and size of the real world, any attempt to reproduce its inner workings is extremely difficult. Thus, the results of global emission models, regardless of their character, come with myriads of reservations. These reservations stem from the models' assumptions and high levels of abstraction. While we try to justify our assumptions as much as possible, the level of abstraction leaves many questions unanswered.

These include:

- Are the necessary physical resources available and can they be obtained in time and in the right place?
- Are the necessary social skills available in each region/country/county/household?
- Do the respective cultures and political frameworks in each area facilitate or impede change?
- Will there be enough skilled labourers in the places where they are needed?
- What are the impacts of climate change on the scenario?[25]

In light of these questions, scenarios of global emission models have to be interpreted as rough sketches, which will have to be much more detailed when their story lines and results are deemed desirable and implementation is planned.

25 The Global Calculator (as most models) does not consider feedback from climate warming. While this omission obviously weakens the scenarios credibility, we regard this as less crucial since, in our scenario, global warming is limited.

3 Scenario philosophy: key premises

The Societal Transition Scenario is based on the following four key premises:

1) *Countries of the Global North are foremost responsible and have to act*
The underlying premise of the STS is the ethical conviction that the countries of the Global North bear a specific responsibility for reducing their emissions due to their historical contribution to climate change. From 1850 to 2017, the share of cumulative emissions from Annex I countries[26] is estimated to have been more than 60%.[27] Their wealth is based on utilizing the lion's share of the atmospheric carbon sink. That is a strong argument for proposing a reduction of consumption in materially wealthy, early industrialized countries to make space for self-determined socio-economic pathways in the Global South (for some thoughts on the problems associated with working as a team of authors exclusively from the Global North, see Box 5).
2) *Consumption and production in the Global North must be reduced*
Being convinced that a sufficient decoupling of economic growth from GHG emissions is unlikely to happen in the future (see Section 1), we focus on reducing consumption and production in countries of the Global North as a way to reduce emissions. While reducing these factors will most probably lead to a decrease in GDP, this is not a goal in itself. We are further convinced that a substantial reduction in consumption cannot result from a sum of individuals changing their behaviour; it has to be achieved by reshaping key infrastructures of societies and by regulative frameworks, economic principles and incentive structures guiding behaviour within society. For different sectors (mobility, housing, food), we provide a first rough collection of instruments for achieving just those aims,

26 The United Nations Framework Convention on Climate Change (UNFCCC) divides countries in three main groups according to differing commitments: Annex I countries (the industrialized countries that were members of the OECD in 1992, plus countries with economies in transition [the EIT Parties], including the Russian Federation, the Baltic States, and several Central and Eastern European States), the Annex II countries (OECD members of Annex I, but not the EIT Parties) and the Non-Annex I parties (mostly what is commonly referred to as developing countries). For a list of Annex I and Non-Annex I countries, please consult https://unfccc.int/parties-observers (last visited: 1 October 2020). In the STS, the wealthy Global North is represented by the Annex I category of countries under the UNFCCC. The Non-Annex II category represents countries of the Global South. Please also see Box 5 for more explanation.

27 According to Gütschow, J. et al., 2019. The PRIMAP-hist national historical emissions time series (1850-2017). v2.1. GFZ Data Services. https://doi.org/10.5880/pik.2019.018

underlining that the answer to the question of which measures and policy instruments will be implemented should always be the result of inclusive democratic processes and lead to a swift, but not rushed, socially just transformation.

3) *A good life for all is possible with less consumption and production*
The kind of reduction we model with the STS for the countries of the Global North countries (focusing on reducing emission-intensive economic sectors), if done properly, will not lead to a loss of life satisfaction there. Growth is neither a good indicator of quality of life[28] nor a realistic and effective strategy to alleviate poverty (in the countries of the Global North).[29]
We do, of course, not imply that just any reduction of economic activity will benefit societies in Annex I countries. In contrast, a reduction of GDP without further changes would lead to social hardships since the current system of wealth distribution and social welfare relies on economic growth to fulfil human needs.[30] What the STS instead envisages is a comprehensive socio-ecological transformation that involves radical redistribution of wealth and labour and a change of welfare systems, economic principles and lifestyles. As part of this transformation, emission-intensive or otherwise unsustainable areas of economic activity will shrink while others, such as education, health care and culture are re-envisaged sustainably and should be strengthened and flourish.

4) *Exclusion of nuclear energy and «negative emissions» technologies*
As an additional premise, the STS excludes any mitigation options that lead to disproportionate environmental degradation and destruction, including nuclear energy[31] and so-called «negative emissions» technologies. This exclusion also means that we advocate a sensitive and responsible approach in building up

---

28 Despite an array of theoretical backlash and empirical evidence, economic growth is still considered an indicator for quality of life. A scaling down of parts of our economy resulting in a lower GDP is generally associated with recession, unemployment and social uprising. This association, however, neglects the possibility of a shift towards a needs-oriented economy in which harmful parts of the economy decrease and an ambitious welfare policy is based on a stronger redistribution of wealth from the rich to the poor, leading to a better life for the majority. See, for example, Layard, R., 2006. Happiness: Lessons from a New Science; Helliwell, J. et al, 2019. World Happiness Report 2019. Cole, A., 2010. The Politics of Happiness, Australian Quarterly Vol. 78(5), 21-24; Stiglitz, J.E. et al., 2010. Mismeasuring Our Lives: Why GDP Doesn't Add Up: The Report of the Commission on the Measurement of Economic Performance and Social Progress.

29 Economic growth is often seen as a necessary development path to alleviate poverty. There is enough empirical evidence, however, that imitating the Western growth model leads not to positive developments for everyone but to a deepening exclusion of poorer social classes. The notion of «development» presuming a normative superiority of the Western lifestyle compared to other modes of living must be viewed critically.

30 Pineault, E., 2016. Growth and Over-accumulation in Advanced Capitalism: Some Critical Reflections on the Political Economy and Ecological Economics of Degrowth. Working Paper.

31 For an overview of the dangers of nuclear energy (accidents, waste, proliferation) see Wheatley, S. et al., 2016. Reassessing the safety of nuclear power, Energy Research & Social Science, Vol. 15. The following interactive map gives an overview on the health and environmental problems of nuclear energy (including nuclear weapons): IPPNW, 2019. Hibakusha Worldwide. https://hibakusha-worldwide.org renewable energy capacity as exploiting the resources needed for those technologies affects both the environment and communities.[32]

32 Please consult the Environmental Justice Atlas for more information on conflicts around different resources. It can be found at: https://ejatlas.org/. There are currently more than 40 conflicts around rare earth medals, and more than a dozen around Lithium.

4 Methodology

As described above, calculating climate mitigation scenarios up to 2050 or 2100 is incredibly difficult due to the number of parameters influencing GHG emissions and to the inherent uncertainty of socio-economic systems. These parameters include not only technical aspects such as the efficiency of power plants but also ethical and moral considerations that culminate in the question of «How do we want to live in the future?». We are convinced that this debate should be key in guiding policy instruments for designing a common future and preventing a dangerous climate change. Controversial questions such as «Must we rely on large-scale negative emission technologies and nuclear energy?» should be discussed at a broad societal level. Accordingly, models must be used that allow for exploring a broad range of alternative technological and socio-economic scenarios.

For these reasons, we opted to use the Global Calculator, a relatively simple but transparent model that can be understood and used by a wider public. The Global Calculator models what is thought to be physically and technically possible and not what is most cost effective. It is based on scientific and engineering data and was built in collaboration with a wide range of organisations.[33]

The Global Calculator[34] is a model of the world's energy, land and food system running up to the year 2050. It allows options for tackling climate change to be explored and to see how they interact. That is, the users make choices in these systems, the calculator then calculates the associated impact. It was designed to inform businesses, governments and non-governmental organisations about options for cutting CO_2 emissions and allows the nexus between different lifestyles and emissions to be grasped more easily than when using IAMs. It was developed to promote an ‹energy literate› debate between a wide range of stakeholders across different climate-relevant sectors. With its help, we illustrate the huge potential behind societal change. Data used in the Global Calculator comes from a range of sources such as the IEA, FAO and the University College London TIAM model.

33 The Global Calculator was developed by the UK Department of Energy and Climate Change (DECC), Climate-KIC, World Resources Institute, Chinese Energy R&D International, the International Energy Agency (IEA), Ernst & Young, Climact, Imperial College, London School of Economics, Climate Media Factory, Potsdam Institute for Climate Impact Research, Rothamsted Research, the Walker Institute, National Oceanography Centre and the Natural Environment Research Council. The Global Calculator spreadsheet and supporting documentation is available under (and subject to the terms of) the Open Government Licence (www.nationalarchives.gov.uk/doc/open-government-licence/version/2/). The web tool is published under (and subject to the terms of) the Creative Commons Licence (attribution, non-commercial, see: http://creativecommons.org/licenses/by-nc/4.0/legalcode)

34 https://www.gov.uk/government/publications/the-global-calculator

Figure 1: Conceptual model of the Global Calculator

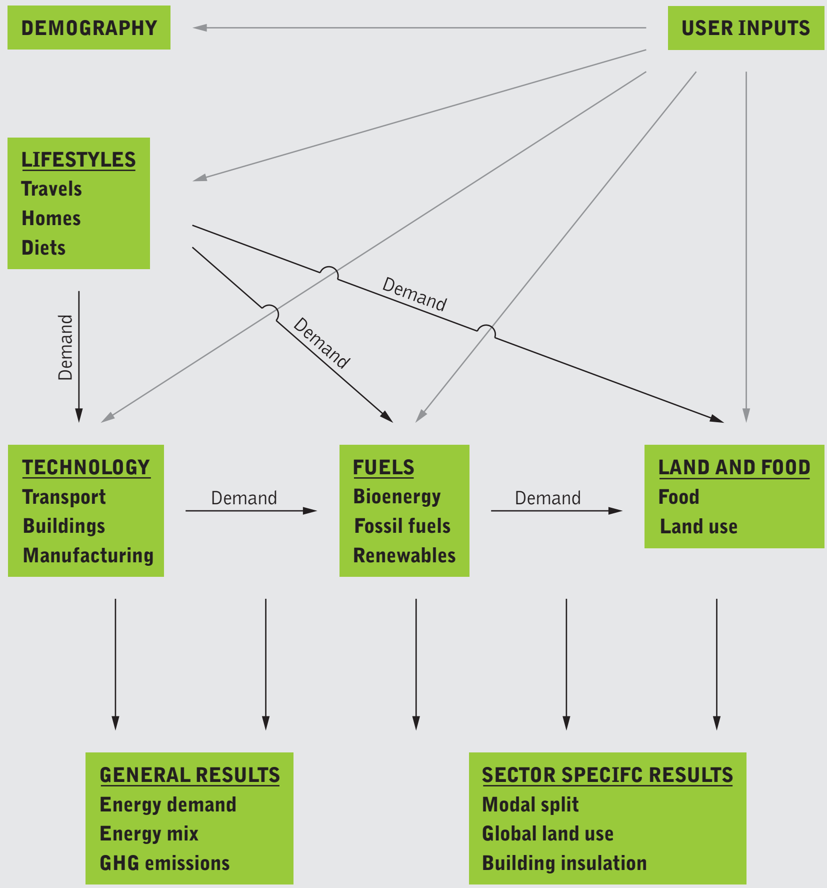


Figure 1 shows the structure of the model. The average global lifestyle can be adjusted through assumptions made in the three sectors travels, homes and diets. Consumption parameters, together with the assumptions on population numbers, result in demands for services and products. The model features a technology module that translates these demands into energy demands. It also features a fuels module that calculates how the direct energy demand (e.g., gasoline for driving cars) and the indirect energy demand (e.g., the energy needed to produce a washing machine) are met. The land and food module, similarly, calculates how the demand for food and biomass is met.

Please note that the user is not only able to determine the parameters needed for these calculations but indeed must determine those parameters since the model is, to put it bluntly, a slide ruler and calculations are restricted to basic arithmetic operations.[35] In other words, the calculator does not contain an internal decision-making procedure like Integrated Assessment Models (IAMs) do, the drawbacks of which are described in more detail below. Finally, the fuels module calculates general results including energy production and GHG emissions, while the technology, land use and food modules produce further sector-specific results.

The described calculations take place for every year from 2011 to 2050. From then on, the user can choose to assume stable emissions or a further reduction relative to the emission reduction of the previous 15 years, i.e. 2036-2050. For our calculations, we decided to have 2020 (and not 2011) as the starting point, which meant calibrating the major parameters using the most recently available data.

In comparison to IAM's, the Global Calculator is a much simpler, more transparent model that can be understood and used by a wider public. While the use of IAMs is the rule – and they are indeed useful in some respects – they are highly specialized tools that are understood and run only by a very small scientific community. Further drawbacks justifying our choice can be found in the comparison below and Box 1 on IAMs above.

Box 3: Howe we use the Global Calculator

We have adapted the Global Calculator for the purpose of this paper in two ways.

Annex I and Non-Annex I countries
Since we wanted to assume a reduction of consumption in materially wealthy countries, we decided to split the model on the consumption side in two: one consumption module for Annex I and one for Non-Annex I countries. The STS foresees an ambitious reduction of consumption and production for the former while assuming a continuation of past trends with a further growth of consumption and production in the latter. This growth results in a conversion of consumption patterns in the long run (see Section 5).

In contrast to that demand side split, we did not split the model between Annex I and Non-Annex I-countries on the supply side. Treating Annex I and Non-Annex I together in terms of supply leads to the following problem: Let us say we decrease the consumption of a product such as cars in Annex I countries. Now if the productive system is of global nature or there are no big differences between the car factories in Annex I and Non-Annex I countries, everything is fine. But if cars are produced more efficiently in Annex I countries, then we overestimate the mitigation effect. Similarly, if cars are produced less efficiently in

35 To increase the facility of use, the web-based version of the model condenses some of the parameters and proposes four levers with different levels of ambition. Additionally, it features the ability to choose a number of predefined pathways as starting points.

Annex I countries, we underestimate the mitigation effect. We still think that our approach is justifiable since:

a) in some sectors, such as food production, the specific emissions are probably somewhat similar between Annex I and Non-Annex I countries.
b) we are envisioning a scenario where the products with the highest emissions (e.g., cars with high fuel consumption) and productive systems (e.g., lignite power plants) are the first to be stopped. It is beyond the scope of this study to represent this assumption in the model – it simply reduces averages, e.g., the average car is used less and an average KWh of electricity is saved –, the result of which is that we are generally underestimating the effect of reduced consumption, and in reality reduced consumption could save even more emissions.

Modification of lifestyle levers

The Global Calculator's lifestyle levers allow for different levels of ambition. On the demand side, we modified the lifestyle levers in the categories travel, homes and diet to fit the objectives of this work. The new levels for those levers (see Table 2) were determined separately for Annex I and Non-Annex I countries. As a result, the ambition level chosen for Annex I countries goes beyond that of the original Global Calculator, which only portraits ambition on a global scale.

The demand for energy and products generated from the split between Annex I and Non-Annex I countries is summed up and reintroduced in the model sheet representing the global energy supply, and corresponding projections of sectoral energy use and emissions are retrieved.

We made use of the model spreadsheet version v.3.99.0, available on the Global Calculator website.[36] We did not alter the model's original lever levels for technology and fuels, efficiencies and energy supply capacities, leaving the global energy supply settings on Level 3.

Exceptions are nuclear supply, which is phased out; carbon capture and storage (CCS), which is not used, and the use of bio-energy crops, which is considerably constrained. For land and agricultural practices, we keep the levers on Level 1, which broadly means a halt on agriculture intensification and maintenance of current yield levels (see Section 5.8 for more detail).

36 http://tool.globalcalculator.org/

Comparison of Integrated Assessment Models and the Global Calculator

The Global Calculator and IAM differ in several ways, which are summarised in Table 1 and described in detail in the following sections.

Table 1: Comparison between the Global Calculator and IAMs

Global Calculator	Integrated Assessment Models (IAMs)
Low Complexity – high transparency	High complexity – low transparency
Reproducible and adaptable	Black box
No economic optimization	Economic optimization
No cost estimates	Cost estimates
No geographic regions	Representation of geographic regions
Calculation up to 2050	Calculation up to 2100 or further

Inclusive discussion on our common future: Transparency, adaptability, reproducibility in climate models

An inclusive discussion is underpinned by working with scenarios and models that are reproducible and adaptable by a larger group of interested people. Due to their complexity, IAMs are a far cry from that. In contrast, the Global Calculator can be understood and used by decision-makers, civil society and anyone else interested in taking part in the debate.[37] It offers an online tool where key societal developments may be modelled in line with pre-defined levels for the different sectors. And it enables a more transparent and democratic debate as the whole model can be downloaded as a spreadsheet to be investigated, scrutinized and changed by others.

Example: The discount rate

The discount rate is one example of the complexity and obscurity of IAMs. It is used to compare current costs and benefits with future costs and benefits. The economic logic says, for example, that, since the economy is continually growing, environmental destruction in the future is preferable to that destruction now since, by then, we

37 Unfortunately, the Global Calculator is only available online in its original version. Our adaptations to it – basically splitting the consumption model in two (Annex I and Non-Annex I countries) are not yet well enough documented to be published. In general, we think that the Global Calculator is a step in the right direction but not the optimal tool, which should be even more accessible and adaptable, featuring several components that can be changed and expanded.

will have the economic means to better repair this destruction or protect us from it.[38] This consideration is not in line with many peoples' belief that we should act now to avoid disastrous consequences for future generations. It is also unjust for it is future generations that are supposed to take care of the consequences of current actions. The Global Calculator in contrast does not feature a discount rate since it does not offer optimization – the user must decide which mitigation measures are to be implemented at what point in time.

Needs instead of cost estimates

IAMs feature more information than our approach in two areas: cost estimates and representation of geographic regions. For cost estimates, we are sceptical whether any statements related to mitigation pathways costs for the next 80 years are meaningful. First, cost estimates rely on prices, which are hard to predict for the near term let alone for longer time frames. Second, IAMs stay within a cost-benefit analysis, thus obscuring any aspect that is not translated into monetary values. This restriction may be misleading and even dangerous for two reasons. For one, even if prices might indicate ecological scarcity (and there is good reason to avoid monetizing nature as this can lead to damaging consequences),[39] ecological destruction might be outweighed by other monetarily measured «values».[40] Furthermore, we are convinced that needs is a much better indicator of how desirable a scenario is than are costs. From an ethical viewpoint, it is much more important to determine what is needed to safeguard basic human needs and rights than to know how much a specific emission reduction pathway will cost in the long run. Thus in Section 7, we focus on describing how needs can also be satisfied, sometimes even better, in a world with less material consumption.

Economic optimisation vs. choice

In contrast to IAMs, the Global Calculator does not include a pre-defined decision-making tool, such as the welfare function, aiming at economic optimisation (see Box 3). Thus, it forces the users to choose and justify how to decrease emissions. Having to choose how to decrease emissions highlights that any such decision should be the object of democratic debate.

38 For instance, it is preferable to have coal power plants run longer since the costs of decommissioning plants now exceeds the costs of substituting them with renewable power production later on.

39 Parks, S. and Gowdy, J., 2013. What have economists learned about valuing nature? A review essay, Ecosystem Services, Vol. 13, e1-e10.

40 Fatheuer, T. et al., 2016. Inside the Green Economy – Promises and Pitfalls.

Box 4: The role of GDP

The Global Calculator is not driven by economic parameters but by physical quantities, such as: How much meat is consumed? How much land is needed for the production of this food? How much do we travel? How much CO_2 is emitted per km?
In theory, it would be possible to calculate the amount of goods and energy produced and multiply those numbers with some kind of price, but we believe this would be a crude and unnecessary estimate: crude since the model only approximates the actual production and service sector output, and unnecessary since the question should be «Can we imagine a good life with the given amount of physical goods and services? and not «Do these goods and services add up to a monetary value that seems satisfactory?

Fundamental changes up to 2050: our model horizon

While IAMs usually involve calculations until 2100 or even beyond, the Global Calculator stops at 2050 and gives the user the choice to foresee stable emissions from then on or a further reduction relative to the change of the previous 15 years. This approach might seem too basic and limiting, but we believe it is justified for two reasons.

1) To limit warming to 1.5°C or 2°C, most changes have to occur before 2050.[41]
2) The further away the future, the more uncertain the calculations. In that sense, limiting the model to 2050 can be seen as admitting that calculating global developments for more than 30-40 years is a scientifically difficult, if not questionable, endeavour.

41 Rogelj, J. et al., 2018: Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development.

5 The Societal Transformation Scenario (STS)

The STS aims at depicting a pathway to stay within a global warming of 1.5°C limit without making use of «negative emissions» technologies and with a parallel phase-out of nuclear energy. While not neglecting any technical means of increasing efficiency[42] and decarbonizing the energy sector within a complementary technological transition (see Section 5.8), the STS focuses on analysing the effect of more sufficient lifestyles leading to a reduction of consumption and production in certain energy-intensive sectors: transport, housing and food. Showcasing the effectiveness of societal change, the STS offers one possible pathway for a 1.5°C compatible society.

From Section 5.1 onward, we go into the detail of our approach within the sectors. For each sector, we first describe the status quo and current trends then how we envisage the sectors developing in the STS. This description is accompanied by some key arguments, prevailing trends and/or best-practice examples to justify the feasibility of the assumptions. We then state how our assumptions are translated into the model's parameters. Finally, we sketch policy instruments that are already being discussed to reduce consumption and production in the respective sectors.

From our point of view, the reductions we model, underpinned by ambitious policy instruments, must be regarded as being embedded in a broader vision of a re-imagined society, which we outline in Section 7.

Box 5: The dilemma of modelling a pathway for the Global South as a team of authors from the Global North

For the STS, we divided the world into countries of the Global North and those of the Global South. We decided to do this by using the categories of Annex I (Global North) and Non-Annex I countries (Global South) of the UNFCCC.

42 Modeling efficiency improvements usually results in reductions in consumption that, in the real world, are often offset by rebound effects, that is by an increase in consumption of energy services due to, e.g., monetary savings. This offset does not hold when modeling the impact of reductions in consumption itself, which is why we do not discuss rebound effects.

We are aware that the dichotomy of Annex I countries and Non-Annex I countries might be regarded as an oversimplified model of the world; an oversimplification in particular when taking into account the role of the emerging economies and their contribution to climate change, their individual economic capabilities and the role of global elites and global middle class with their emission-intensive lifestyles. The reason we decided to stick to the Annex I/Non-Annex I differentiation is that it continues to play a role in the international climate negotiations, such as in the way countries have to perform emissions accounting. Furthermore, the Principle of ‹Common but Differentiated Responsibility›, which relies on the Annex I/Non-Annex I categorisation, as enshrined in the 1992 UNFCCC Convention is still a crucial point of debate within the international climate policy sphere.[43] The categorisation, therefore, reflects the different levels of historical responsibility for climate change. Yet there is an ongoing complex and ethically challenging debate about just shares in reducing GHG emissions, for each country and for income groups within countries, which is difficult to represent in a model such as the present one.[44]

This debate outstanding, the STS may be seen as exemplifying a just pathway incorporating sufficiency measures and societal change for climate mitigation. It exemplifies our respect towards the need for an autonomous socio-economic pathway in the countries of the Global South as reflected in the debates around the term ‹post-development›.[45] Considering the long history of people from the Global North making assumptions on how the Global South should ‹develop› while at the same time exploiting its people and resources, we – as a team with a European perspective – find it difficult to make any assumptions on the future of the Global South (or in our case, Non-Annex I countries), which has a right to a self-determined future. Since we want to calculate global emissions, however, there is no way around this dilemma. As a solution, we decided not to reduce the demand for transport, floor space and meat in Non-Annex I countries but have them converge to the levels of the Global North in 2050 and in some cases surpass those. For us, as authors from the Global North, the STS is meant to show one way to meet the historical responsibility of the Global North and simultaneously avoid applying the concept of ‹developed› nations prescribing anything to nations that need ‹to be developed› or told how to behave in the future. This is not to say that we do not need intensive debates about a socio-ecological

43 United Nations Framework Convention On Climate Change. UNFCCC. 1992, Article 3.1. «The Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof…»

44 See for example: Kartha, S. et al., 2018. Whose carbon is burnable? Equity considerations in the allocation of a «right to extract». Climatic Change 150, 117–129.

45 Ziai, A., 2007. Exploring Post-Development: Theory and Practice, Problems and Perspectives.

transformation of societies both in the Global North and Global South – and there are very fruitful debates.[46]

We realize that this choice can be criticized from two different viewpoints: On the one hand, one could argue that it is not fair that people from the Global South cannot increase their consumption freely in the way and to the disastrous levels of the current Global North. On the other hand, the picture of «catching up» can be vastly misinterpreted as stemming from a rather conservative view that still considers the Global South to be «underdeveloped» and in need of «development» towards the presumably more advanced Global North. We are surely not of this opinion and, in contrast, believe that the Global North should adapt many of the principles and practices originating from the Global South, such as buen vivir[47] or ubuntu.[48]

5.1 Selection criteria for consumption parameters

To increase transparency and decrease complexity, we concentrated on altering a few selected consumption parameters that result in less consumption and production. The selection criteria for these were

- **impact on the fulfilment of human needs**[49]
  We deliberately chose parameters whose reduction within a socio-economic transformation will result in – in our opinion – justifiable limits to consumption (e.g., reducing the share of ruminant meat) and in many cases in an improved fulfilment of human needs (as reducing the use of private cars will lead to fewer accidents, less noise and cleaner air)
- **general conceivability**
  We explored whether there are best-practice examples in other regions or from the past that make a change conceivable. Additionally, we searched for political movements or cultural shifts that increase conceivability.[50]
- **emission reduction potential**
  For our climate scenario, we chose societal changes that lead to substantial emission reductions

46 Kothari, A. et al., 2019. Pluriverse: A Post-Development Dictionary.
47 Acosta, A., 2013. El Buen Vivir: Sumak Kawsay, una oportunidad para imaginar otro mundo.
48 https://en.wikipedia.org/wiki/Ubuntu_philosophy
49 For a good concept on human needs see Ekins, P. and Max-Neef, M., 2006. Real Life Economics.
50 In this, we follow the theory of change as outlined by Wright, E.O., 2020. Envisioning Real Utopias. Transforming societies, Wright states, relies on real alternatives that can be found within actually-existing societies, such as practical experiments, alternative forms of living, or political movements, which may then be adopted within broader political contexts.

- **good model representation of the parameter**
  A trend towards more carsharing may be presented in the model by an increased occupancy of cars. Some changes are much harder to implement in the model, however. Reducing the amount of smart phone usage, for example, would require a number of assumptions since smart phones are not an explicit item of the model. Whenever the model did not include some changes we wanted to incorporate in an explicit manner, we tried to approximate those changes by explaining them and altering some parameters. For example, we assumed a shift towards organic farming. Since organic farming is not a parameter, we approximated this shift by not increasing agricultural productivity and increasing pasture sizes.

Table 2 shows the resulting parameters and how we assumed they will change by 2050 in the STS. The changes are justified and described qualitatively on the following pages. For more quantitative information on the parameters see Annex 1.

Table 2: Consumption parameters and how they change in the STS up to 2050

Sector	Parameter	Changes up to 2050	
		Annex I countries	Non-Annex I countries
Transport	Road-based passenger transport	Transport demand falls to 1990 levels (i.e. by 17%) from 1990 to 2030. From 2030 to 2050, demand falls by another 20%	Linear convergence to Annex 1 levels by 2050
	Share of cars	Share of car transport reduced by 81% in urban areas and 52% in rural areas between 2015 and 2050	Share of car transport is reduced by 17% in urban areas and increases by 67% in rural areas.
	Occupancy	Car occupancy rises linearly by 38% to 2.5 persons/car between 2015 and 2050	Car occupancy stays constant
	Flights per person	The average number of flights per year falls to 1 by 2025 and one flight every three years in 2050, resulting in a reduction of 43% from 2017 to 2025 and 81% from 2017 to 2050	Increase in number of flights to 0.6 per person and year, an increase of 77% from 2017 to 2050
	Ground freight transport	Ground freight transport reduced by 62% (1990 levels)	Ground freight transport increa-ses by 20%
Housing	Living space	Living space per person is reduced by 25%.	Linear convergence to Annex I levels by 2050
	Number of appliances per person	Halving of appliances per per-son.	Appliances per person stay constant

Food	Food production	Calorie consumption per person reduced, figuratively, by 24%, achieved mainly through reducing food wastage and adoption of healthier diets, leading to lower food production	Calorie consumption stays constant
	Meat consumption	Meat consumption decreased by ~60% by 2030 and stays constant from then on	Meat consumption stays constant

5.2 Road-based passenger transport

Status Quo

In 2016, road-based transport (passenger and freight) is responsible for roughly 18% of global CO_2 emissions from fuel combustion.[51] From 1990 to 2015, average road-based passenger transport increased by 17%[52] in Annex I countries reaching 11,717 passenger kilometres (pkm)/person and year in urban areas and 25,674 pkm/person in rural areas. In Non-Annex I countries, road-based passenger transport increased by 377%, reaching 4,190 pkm/person in urban and 1,867 pkm/person in rural areas. Data also shows that motorization rates (vehicles per 1000 people) rose in all world regions from 1999 to 2016, with an increase from 790 to 832 in the Unites States and jumping from 10.2 to 141.2 in China.[53] Furthermore, road traffic was also responsible for 1.3 million death from accidents in 2018;[54] it is a major source of air and noise pollution, and most of its impacts are unevenly distributed.[55]

These problems cannot be solved through technical solutions alone. The material footprint of simply substituting a substantial part of the more than one billion cars worldwide by electric cars or hydrogen vehicles would be enormous. The environmental and health impacts of mining the materials needed for electric vehicle batteries, such as cobalt, lithium or nickel, are substantial and contribute to human rights

51 International Energy Agency, 2016: CO_2 emissions from fuel combustion by sector in 2017, in CO_2 Emissions from Fuel Combustion, IEA, 2019

52 Own calculations using OECD transport data (https://data.oecd.org/transport/passenger-transport.htm) and UNDP population values (https://population.un.org/wpp/), excludes the following Annex 1 countries due to data restrictions: Belarus, Cyprus, Ireland, Liechtenstein, Monaco Luxembourg, New Zealand, Northern Ireland, Austria, Canada, Czech Republic, Greece, Japan, Lithuania, Malta, Netherlands, Portugal, Slovak Republic, Slovenia, Ukraine

53 Comparison between Stacy, C.D., Diegel, S.W. and Boundy, R.G., 2011. «Transportation Energy Data Book: Edition 30» and Stacy et al., 2018. Transportation Energy Data Book: Edition 36.2

54 WHO, 2018. Global Status Report on Road Safety.

55 Gössling, S., 2016. Urban Transport Justice. Journal of Transport Geography, Vol. 54, 1-9.

violations.[56] In addition, renewable energies have to be regarded as a scarce good that has to be developed and used in line with nature protection criteria and respect for the rights of the people affected by those technologies. This is especially true for biofuels, which have proven to bring with them devastating environmental impacts such as large-scale deforestation, biodiversity loss, soil degradation, depletion of scarce water resources, a violation of human rights including the right to food, and land-grabbing.[57]

In contrast, societal changes to reduce motorized private transport offer a way to reduce GHG emissions that is much more sustainable for climate, biodiversity and human beings while at the same time improving quality of life for billions of people in many other aspects.

Road-based passenger transport in the STS

Today's transportation system is based on cars and individual transport. In the decades to come, we presume that there will be less need to drive as much or as far as is currently being driven. Empirical evidence has shown that car traffic can be reduced. Cairns et al.[58] found that, within approximately ten years, non-coercive measures could reduce national traffic levels by about 11% in the UK. Goodwin et al.[59] examined the phenomenon of traffic «evaporating» when road capacity is reduced. They concluded that «measures which reduce or reallocate road capacity, when well-designed and favoured by strong reasons of policy», usually lead to an overall reduction of car traffic that is not negated by more car traffic elsewhere. There are also promising examples and ongoing societal experiments:

- **Copenhagen** started building an extensive and well-designed system of cycle tracks 25 years ago with the effect that 62% of its inhabitants commute by bicycle to work, university or school.[60]

56 See e.g., UNCTAD, 2020. Commodities at a glance. Special Issue on strategic battery raw materials; Amnesty International, 2016. This is what we die for. Human rights abuses in the Democratic Republic of the Congo power the global trade in cobalt; Misereor, 2018. Rohstoffe für die Energiewende. Menschenrechtliche und ökologische Verantwortung in einem Zukunftsmarkt; Friends of the Earth, 2013. Lithium. Factsheet, https://www.foeeurope.org/sites/default/files/publications/13_factsheet-lithium-gb.pdf; Brot für die Welt, 2018. Das weiße Gold – Umwelt- und Sozialkonflikte um den Zukunftsrohstoff Lithium.

57 Gonzales, C.G. et al., 2018. An Environmental Justice Critique of Biofuels. In: Energy Justice: US and International Perspectives (Raya Salter, Carmen G. Gonzalez, and Elizabeth Ann Kronk Warner, eds.); See also publications of https://www.biofuelwatch.org.uk

58 Cairns, S. et al., 2008. Smarter Choices: Assessing the Potential to Achieve Traffic Reduction Using ‹Soft Measures›. Transport Reviews, 28(5), 593-618.

59 Goodwin, P. et al., 1998. Evidence on the effects of road capacity reduction on traffic levels.

60 «Copenhagen Bicycle Account» (in Danish). City of Copenhagen. July 2019. https://web.archive.org/web/20190707123514/https://www.kk.dk/indhold/62-af-koebenhavnerne-cykler-til-arbejde-og-uddannelse

- **London** introduced a Congestion Charge Zone in 2003 for most motor vehicles, leading to a large drop in traffic flows.[61]
- **Vienna** has an excellent public transport system, including metro, tram and bus services, that is partly financed by parking fees.[62]
- **Tallinn** has offered since 2013 free public transport for registered residents (tourists have to pay), allowing residents to use buses and trams independent of their income.[63]

Reducing the need for traffic also includes rethinking settlement structures. In contrast to today's urban sprawl, future settlement structures will feature local centres providing (mostly locally sourced) shops, public buildings such as schools and libraries and recreational areas such as parks, cinemas and theatres. Many of these local centres will be car free. Streets, crossroads and squares will be transformed into bicycle lanes, parks, playgrounds, sports fields – depending on what needs the inhabitants define. People will usually hike, bike or use a good, inexpensive public transport system to get around.

In the future, more and more people will no longer see a need to own a private car, hiring instead a car for the relatively rare occasions they need one. People will have become much more familiar with procedures and devices for organising shared car trips in both cities and the countryside. For example, since 2018, Helsinki has offered the smartphone App Whim, which allows all different means of transport to be used – from bicycle to metro to taxi. Use is paid per ride or as a flat rate. All those promising examples and ongoing experiments show that the need for liberty of movement and for an affordable way to commute to work, meet family and friends, or to do trips will be fulfilled. But mass mobility will be organised more sustainably and socially justly.

Even on a national level, examples can be found of nations that have a low transportation demand while already being an affluent society – in Japan the average person travelled only 7300km/year in 1987 (compared to, e.g., the Netherlands with more than 14,000km/year in 1995), when the country was already known for its population living a modern life style.[64]

Model assumptions

Annex I countries

- From 2020 to 2030, we assume a reduction of road-based passenger transport per person back to the levels of 1990 on a linear path from 2020 until 2030, i.e. a

61 Transport for London, 2019. Travel in London, Report 12. http://content.tfl.gov.uk/travel-in-london-report-12.pdf

62 Buehler, R. et al., 2016. Vienna's Path to Sustainable Transport. International Journal of Sustainable Transportation, 11(4), 257-2711.

63 Cats, O. et al., 2016. The prospects of fare-free public transport: evidence from Tallinn. Transportation 44, 1083-1104.

64 Schafer, A., 2000. Regularities in Travel Demand: An International Perspective Journal of Transportation and Statistics, 3(3), 1-31.

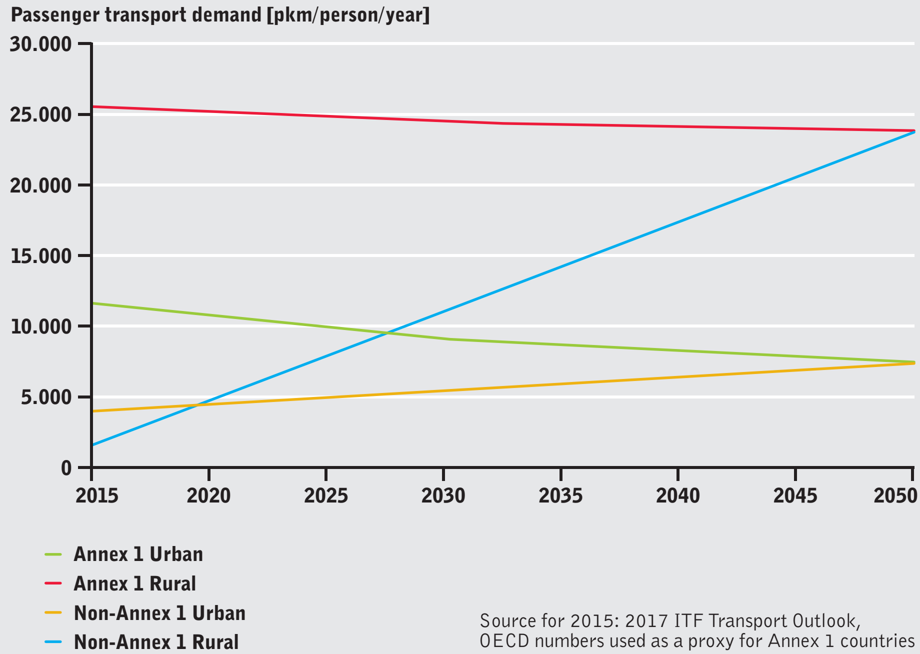
17% reduction. From then on, we assume a further decrease of 20% until 2050. We assume that 70% of the reduction burden is carried by a reduction in pkm/person in urban areas since here a reduction of transport is more easily achievable. The remaining 30% of reduction is achieved by reducing rural pkm/person.

- Due to shorter travel distances and better public transport, we assume a shift away from cars towards hiking, biking, buses and trains:
  - For urban areas, the share of car transport will fall from 64% in 2015 to 12% in 2050.
  - For rural areas, that share will drop from 84% to 40%.
  - For urban areas, we assume more ambitious changes in modal split since it is easier to shift away from car travel. We assume that the modal shift changes from 2020 on and linearly moves towards an average of the «best« 50 European cities (see Annex 1, Table 8). The target is reached for all urban populations by 2040. From 2040 to 2050, the shares of car transport will halve again to represent a shift towards car-free cities in some places. See Annex 1, Table 9 for the resulting modal split.
- Due to disincentives for car ownership, costly parking spaces and a trend toward car sharing, we assume a linear increase in car occupancy from 1.6 in urban areas and 1.8 in rural areas in 2015 to 2.5 people per car in both urban and rural areas.
- We also assume a 20% increase of passengers in buses and trains. For buses, we assume an increase from 27 passengers per bus in 2015 to 32 passengers per bus in 2050. For trains, we assume an increase from 384 passengers per train in 2015 to 461 passengers per train in 2050 (see Annex 1, Table 10).

Non-Annex I countries

- For road-based passenger transport, we assume a linear convergence to Annex I country levels by 2050 in both urban and rural areas. This convergence means an increase from 4,190 pkm/person and year to 7,526 pkm/person in cities and from 1,867 pkm/person to 23,878 pkm/person (!) in the countryside.
- With regards to car transport, its share will decline by 17% in urban areas and increase by 67% in rural areas.
- We assume occupancy to stay constant from 2015 on (see Annex 1, Table 10). That is, we assume a car occupancy of 1.9 passengers per car in 2050 in urban areas and of 2.2 passengers/car in rural areas. We assume an average bus occupancy of 32 passengers/ bus on average in 2050 and an average train occupancy of 461 passengers/train in 2050.

Figure 2: Passenger transport demand in Annex I and Non-Annex I countries



Source for 2015: 2017 ITF Transport Outlook, OECD numbers used as a proxy for Annex 1 countries

Policies and measures

The societal changes needed within the private transport sector can be generated by a wide array of political measures and policies:

- Short-term instruments/measures: improvements of cycling infrastructure, cheaper public transport, more pedestrian zones, disincentives for car ownership and travel such as fewer and more costly parking spaces, increased taxation of ownership and fuel, access restriction and road pricing.
- Mid-term measures: expansion of public transport systems, subsidies for local businesses, subsidisation of car-sharing services, introduction of co-working spaces in rural areas, synchronisation of day structures in rural areas to improve occupancies, curtailing of car production, car-free cities and village centres.
- Long-term measures: changes in city and settlement structures, conversion of the car industry

5.3 Passenger Aviation

Status Quo

Aviation is the most climate damaging form of transport because the non-CO_2 climate impacts of aviation are estimated to be anywhere between as large as or even three times larger than the direct impacts of CO_2.[65] The CO_2 emissions of the sector are rapidly growing and were responsible for 2.4% of global emissions in 2018 from fuel use (disregarding non-CO_2 climate impacts).[66] From 2005 to 2018, emissions from commercial aviation increased by 32%[67] – showing that any efficiency improvements achieved so far lag far behind the growing number of air passengers. The United Nations' International Civil Aviation Organisation (ICAO) expects emissions to triple by 2050 under a business-as-usual scenario. Currently 1,200 new airport infrastructures are being planned.

The current strategy of the aviation industry focuses on biofuels and carbon-offsetting – promising carbon neutral growth from 2020 on.[68] However, new technologies that could substitute fossil fuels with their high energy density without devastating impacts to environment and human beings are nowhere in sight.[69] Offset mechanisms and biofuels must be regarded as false solutions with impacts on biodiversity, conflicts about land and food security as well as the rights of the communities affected by offsetting projects or large-scale biofuel production sites. As climate-friendly fuel cannot be supplied at the scale the aviation industry needs without harming the environment and people, the only way to reduce emissions is to stop growth and reduce travel.

Aviation in the STS

Due to its relatively small climate impact, we omit freight transport by air and focus on passenger transport in our scenario. Currently, flying is the default mode for international travel in the Global North.[70] Only the very beginning of a societal debate about

65 IPCC, 1999. Aviation and the Global Atmosphere: A Special Report of the Intergovernmental Panel on Climate Change

66 Graver, B. et al., 2019. CO_2 emissions from commercial aviation, The International Council on Clean Transportation.

67 International Council on Clean Transportation, 2019. https://theicct.org/sites/default/files/publications/ICCT_CO_2-commercl-aviation-2018_20190918.pdf

68 See for example https://www.icao.int/environmental-protection/Pages/default.aspx

69 Biofuelwatch, 2017. Aviation biofuels: How ICAO and industry plans for sustainable alternative aviation fuels could lead to planes flying on palmoil, http://www.biofuelwatch.org.uk/wp-content/uploads/Aviation-biofuels-report.pdf; Biofuelwatch, 2019; CORSIA: A False Solution to the Very Real Threat of Emissions from Aviation, https://www.biofuelwatch.org.uk/2019/corsia-briefing/

70 Scott, D. et al., 2012. Tourism and Climate Change: Impacts, Adaptation and Mitigation (p. 109), citing Worldwatch Inst., 2008. Vital Signs 2006-2007 (http://www.worldwatch.org/node/4346). «Yet only 5 percent of the world's population has ever flown.» (p. 68) This estimate is old, but the most recent, so we use the – rather conservative – figure of 10% of the world's population.

our unlimited right to fly is audible while it becomes increasingly obvious that the growing aviation sector causes more GHG emissions than can be afforded. From a global justice perspective, our scenario can be read as a way to reserve most flights for people who have to migrate due to climate change, destroyed livelihoods, poverty and other detrimental impacts of the economic system established by the Global North, as well as for people whose families have to live in different countries for historical or other reasons.

For the future, we assume a cultural shift with flying once again seen as something extraordinary that is done every couple of years. Short, medium and also longer distances will mostly be travelled by using long-range trains and buses and modern ferries that are affordable for everyone and allow for comfortable travelling with reliable and fast connections. There are some promising trends in Europe that could boost the role of trains on the continent:

- In 2019, **Sweden** announced it would financially support bringing into service overnight trains to central Europe to provide a practical alternative to short-haul flights. Those would, for example, allow passengers to leave Sweden after dinner and arrive in Paris at 10 am the next morning, or Munich and London around lunch.[71]
- **Austria** already operates nearly 30 night-jet train lines, partly together with partners from other European countries; the country has started to buy up discarded night trains.[72]
- Since the **German railway company** Deutsche Bahn introduced a much faster train connection for the most frequented air connection in Germany,[73] Berlin and Munich – 4.5 hours instead of 6 – many more passengers, among those many business travellers, have changed from air travel to the railway connection. In 2018, 4.9 million passengers used the connection – a doubling compared to 2017.[74]
- **Argentina** has an excellent network of long-distance bus connection that allow for fast and comfortable travel. Most Argentines get around this way.[75]
- Ideas about long distance travel are being reshaped by **companies such as the German travel agency Travelling**, which specialize in climate-friendly travelling and offer exclusively long-distance train trips, e.g., from Germany to Hanoi, and the **Sail Cargo alliance**, an alliance of sailing cargo vessels that also carry passengers.

71 The Independent, 17.01.2020. https://www.independent.co.uk/travel/news-and-advice/sweden-london-train-sleeper-malmo-amsterdam-cologne-munich-rail-a9288206.html

72 Tagesspiegel, 25.01.2020 https://www.tagesspiegel.de/politik/die-rueckkehr-des-nachtzugs-warum-die-klimadebatte-schlafwagen-wieder-in-mode-bringt/25471670.html

73 Arbeitsgemeinschaft Deutscher Verkehrsflughäfen (Flughafenverband ADV) http://www.adv.aero/fachbereiche/verkehr-und-kapazitaeten/airport-travel-survey-repraesentative-fluggastbefragung-der-adv/

74 Deutsche Bahnk: Wettbewerbskennzahlen 2018_19, p.17, https://www.deutschebahn.com/resource/blob/4593160/52024c17f17fd809cd4c9c9a58de1954/Wettbewerbskennzahlen-2018_19-data.pdf

75 Blas, F. et al., 2016. Bus Rapid Transit Project: La Matanza, Buenos Aires, Argentina.

- **Ghent University in Belgium** adopted a «Sustainable Travel Policy» according to which trips by university members to cities no farther than six hours by train will not be reimbursed if flown.[76]

We assume that these trends will be pushed by stronger restrictions on aviation infrastructures due to climate change. As a first step, bans on night flights could reduce the number of flights. As a much stronger instrument, our scenario assumes moratoriums on the expansion and construction of new airports. In 2017, an administrative court blocked construction of a third runway at **Vienna Airport**, referring, among other things, to the Austrian commitment to the Paris Agreement, and thereby preventing the creation of an additional 1.2 million tonnes of CO_2 each year.[77], [78]After an appeal by the airport company to the Higher Constitutional Court and the Federal Administrative Court, a third runway was permitted albeit with the requirement that the airport's on-ground operation must become carbon-neutral.

Restrictions on aviation infrastructure would also have further positive effects: With fewer flights and fewer and smaller airports, people living nearby would suffer less from air pollution and noise, farmland could be saved and biodiversity be protected.

The limitation of personal freedom that some might connect with fewer flights might be alleviated by more general changes we assume for societies as a whole, such as a decrease in wage labour time and a deceleration of life in general (see Section 7), giving people more leisure time for hobbies, friends or smaller trips within their region. Some first companies such as the German cooperative company Weiberwirtschaft and https://www.climateperks.com/ allow for extra days off if their workers travel without flying.[79]

Model assumptions

Annex I countries

Figure 3 shows the number of flights per person and year in the past and how we see this figure evolving in Annex I and Non-Annex I countries. Our scenario foresees a strong decline in the number of flights per person from 1.8 flights per year in 2020 to 1 flight every third year in 2050 (that is 0.33 flights/person/year). For the model run, we take this reduction in the number of flights to calculate the decrease in the average distance travelled per person. This figure declines from about 3150 km in 2020 to 580 km in 2050 (see Table 11).

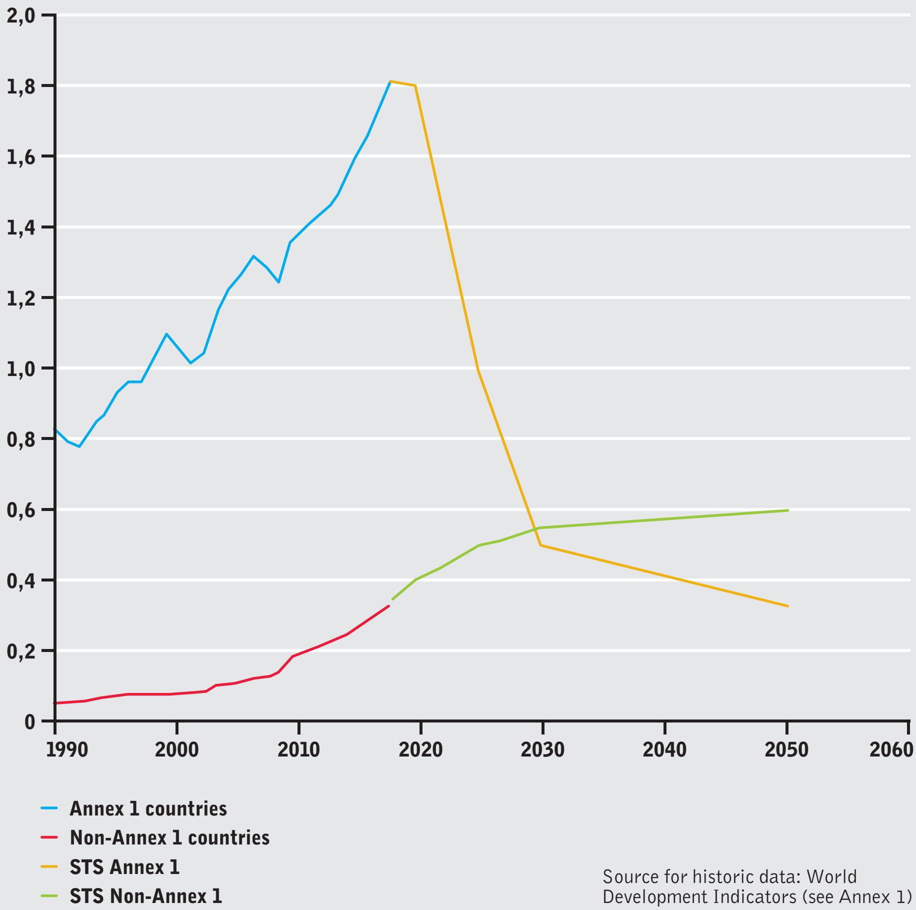
76 Sustainable Travel Policy Ghent University, https://www.ugent.be/en/ghentuniv/principles/sustainability/travelpolicy

77 Reuters, 2017. Vienna Airport Appeals against Ban on Expansion. https://www.reuters.com/article/us-viennaairport-runway/vienna-airport-appeals-against-ban-on-expansion-idUSKBN16U0T4

78 https://systemchange-not-climatechange.at/de/auswirkungen-3-piste/

79 WeiberWirtschaft eG, https://weiberwirtschaft.de/news/artikel/weiberwirtschaft-als-arbeitgeberin-foerdert-wirksamen-klimaschutz/

Figure 3: Average number of flights per person and year



Source for historic data: World Development Indicators (see Annex 1)

Non-Annex I countries

For Non-Annex I countries, we assume a steady increase from 0.35 to 0.6 flights/person/year in 2050, which translates into an increase of 711 to 1,065 km/person/year (see Table 11)

Policies and measures

We believe that societal change in the aviation sector can be generated by a number of political measures and policies. We list some of them here while underlining that the answer to the question of which measures and policy instruments will be implemented should be the result of inclusive democratic processes:

- bans on short-distance flights
- education on the environmental impact of flying
- reduction of working hours/increase in holidays, so that more time can be spent on trains and buses
- increasing ticket prices through taxation, levies and abolishing subsidies in the aviation sector
- increasing attractiveness of long-range train and bus rides by reducing prices, increasing comfort, reliability and interconnectedness including (re)opening of night trains and a better coordination of international train schedules and booking systems.
- introduction of quotas for flights per person
- moratoria on new infrastructure and scaling down of airports
- stricter environment and health policies in relation to noise and air pollution (e.g., implementation of the WHO guideline levels for average noise exposure due to aircraft noise)
- companies allowing employees to take the time they need to travel by train or bus and paying any extra costs
- ending public subsidies such as no fuel tax and little or no VAT.

5.4 Ground freight transport

Status Quo

Global ground freight transport including that by road and rail[80] totalled approximately 24103 Gigaton (Gt)-kilometres in 2014.[81] That is, global ground-based freight transport increased by almost 60% between 1990 (15098 Gt-kilometres[82]) and 2014, with current projections foreseeing a further tripling between 2015 and 2050.[83] In 2014, 18% of ground freight transport was international in both Annex I and Non-Annex I countries while 82% was domestic freight.[84] It is unclear whether this increase in trade has actually supported well-being as it was mainly driven by companies' attempts to externalise costs by situating production in the countries with the lowest wages and social and environmental standards.[85]

80 Furthermore, coastal shipping, i.e. transport in coastal areas, as opposed to maritime or inland waterway transport, is counted as ground or land freight according to OECD-statistics.

81 For the year 2014, we take the OECD and Russian amount of ground freight as a proxy for the freight transport demand in Annex 1 countries and that of China and India combined as representative of Non-Annex 1 countries.

82 Own calculations based on the OECD transport statistics, https://data.oecd.org/transport/freight-transport.htm

83 ITF, 2019, ITF Transport Outlook 2019, https://doi.org/10.1787/transp_outlook-en-2019-en.

84 The shares of domestic and international transport are taken from the Global Calculator and applied to both sets of countries.

85 Rodrik, D., 2018. Straight Talk on Trade: Ideas for a Sane World Economy.

In light of these trends and business models, we are sceptical that the mainly technology-focused strategies currently being discussed to achieve a climate-neutral ground freight transport will be sufficient. Though shifting ground freight transport from road to rail is an important strategy in making transport more sustainable, it will not be sufficient – in light of the projected tripling of global ground-based freight transport by 2050. The same is true for switching from traditional trucks to electric trucks. Though electric transporters may be regarded as a smart solution for transport within cities, a massive electrification of trucks would have the negative consequences already discussed in Section 5.2.

Ground freight transport in the STS

While still allowing for global trade and – more importantly – cultural exchange between world regions, we imagine much more localized economies. The external costs of ground freight transport will be internalized, leading to much less transport and especially limiting its use for the purpose of reducing production and processing costs.

We also imagine economies that are more extensively built on **cooperative action, sharing, swapping and donating products** and helping people to help themselves. This basis will contribute not only to reducing the number of products needed; it will also bring people into contact, strengthening social cohesion and helping low-income groups to partake in societal welfare. Feeling oneself to be part of a lively community again allows empowerment, individual and collective responsibility, self-efficacy – the contrary of feeling powerless in regards to big national or multinational enterprises.

Finally, we imagine a world in which products have a longer life span and can easily be adapted and repaired.

Some measures and policies to these ends are already being discussed or implemented:

- the **EU** is planning to deploy a carbon tax on goods from other countries that are manufactured unsustainably as **an anti-climate-dumping tool**.
- **Local complementary currencies, such as those in Japan, Canada, the United States or Spain**, have contributed to localizing trade and spurring local or regional economies.
- **In 2015, France** passed a **law that prohibits the intentional shortening of the lifespan of a product** when the aim is for consumers to replace it. Penalties include fines of up to 5% of annual turnover.
- **Repair cafés** offer a place people can go to get help when repairing their computers, bicycles, clothing, furniture or electrical appliances.
- **Fairtransport from the Netherlands** is a modern, emission free, shipping company sailing between Europe, the Islands in the Atlantic, the Caribbean and America, carrying products and passengers.

Model assumptions

Annex I countries

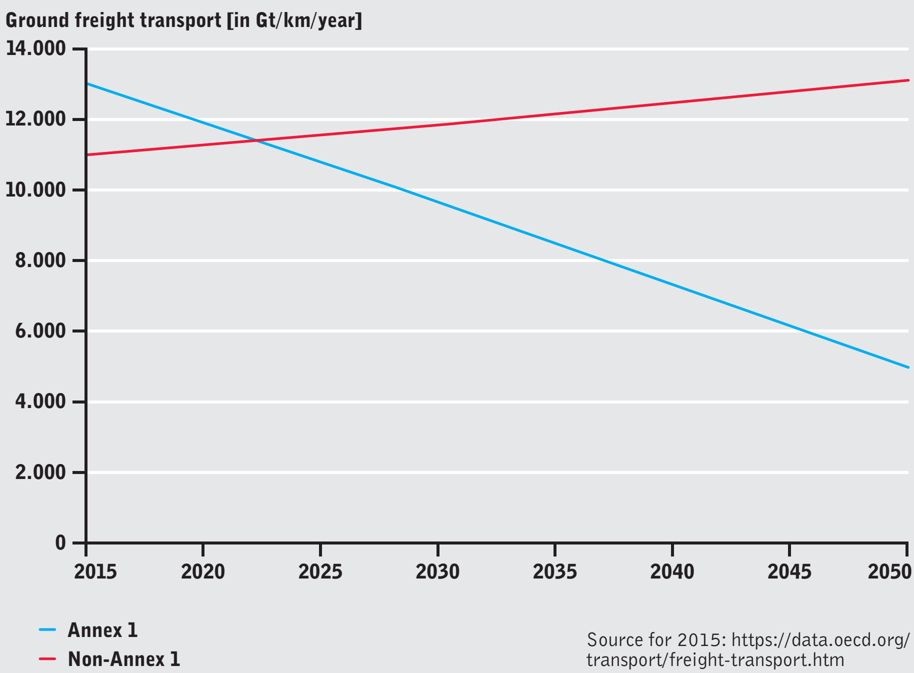
Figure 4 shows the assumed development of ground freight transport in Annex I and Non-Annex I countries.

- We assume a reduction of ground freight transport by 62% from 13,258 Gt/km/year in 2014 to 5,038 Gt/km/year in 2050 on, or in other words – a scaling back of ground freight transport levels to those of 1990 (see Annex I Table 12).
- The share of international travel of total freight is reduced from 18% in 2014 to 9% in 2050, as we want to represent a re-localization of trade in our scenario.

Non-Annex I countries

- We assume an increase of ground freight transport by 20%, up from 10,946 Gt/km/year in 2014 to 13,135 Gt/km/year in 2050.
- The share of international travel remains constant.

Figure 4: Development of ground freight transport in the STS



Source for 2015: https://data.oecd.org/transport/freight-transport.htm

Policies and measures

We believe that a reduction of ground freight transport can be achieved by a number of political measures, some of which are listed below:

- General instruments
  - appropriate taxation of fossil fuels
  - reducing unjust trade relations, e.g., trade of processed goods instead of raw materials from the Global South to the Global North.
  - border tax adjustments
  - introduction and enforcement of stronger labour and environmental standards
  - ban on advertising
- Regionalisation
  - subsidisation of local circular economies (regional shops, municipally owned business, local supply, community-supported agriculture, direct marketing)
  - support for Local Exchange Trading Systems and infrastructures for a sharing economy and second-hand shops
  - support for cooperative businesses
  - privilege of regional (and fair and ecologically produced) products within public procurement system
  - local complementary currencies
  - community supported economy/industry (e.g. community supported agriculture), citizen bonds (German: Bürgeranleihen), regional value public stock companies (German: Bürgeraktiengesellschaften, Regionalwert AGs[86]), local crowdfunding initiatives for local businesses
  - buy-local-initiatives
- Longer life span of products
  - increased mandatory warranty for products
  - legislation requiring that manufacturers declare intended product lifespans and inform consumers how long spare parts for a given product will be produced
  - a labelling system that indicates the durability of a product to disincentivise the diminishing quality of products due to planned obsolescence
  - legislation for «right-to-repair» electronics allowing consumers to repair and modify their consumer electronic devices
  - product standards for repairability of devices
  - subsidisation for repair infrastructure (repair shops, repair cafés)

86 Volz, P., 2012. The Regionalwert: Creating sustainable regional structures through citizen participation, https://www.agronauten.net/wp-content/uploads/2018/08/The-Regionalwert-Creating-sustainable-regional-structures-through-citizen-participation.pdf

5.5 Housing

Status Quo

As stated in Eom et al,[87] the amount of floor space per person correlates with income and has thus continually grown in industrialised countries. In Germany for example, this growth has led to a rise of floor space per person from 34.8 m^2 per person in 1990 to 46.7 m^2 in 2018.[88] This increase is the result of bigger and more single households and an increase in the amount of m^2 occupied by an aging population, who often stay at home once the children have moved out.[89] While we accept these choices when made purposely, we believe that solitude is often not a choice but the consequence of long working hours and a lack of communal living space. Similarly, while many elderly have become attached to their homes, there is no reason why they could not be shared with others, offering the possibility for a more social lifestyle.

From a climate-mitigation perspective, the trends described are problematic since more living space equals more space that has to be cooled during summer and heated during winter. Current technical solutions to the resulting increased energy consumption are better insulation, more efficient heating systems and the use of solar heat. While all these options are important, we believe that a purely technical focus will not suffice since those options a) neglect the energy demand of implementing the solutions (e.g., the energy needed to produce certain insulation material) and b) often lead to other environmental problems. An example of the latter is the use of «substances of very high concern», such as flame retardant in insulation material, and c) are often at least partially offset by rebound effects.

The trend towards less communal housing and more single households is also of concern since usually single households are similarly equipped with electric appliances such as washing machines, stoves, dish washers and fridges. While some of these will be used less, their production alone leads to increased energy consumption.

Housing in the STS

The way people want to live depends to a great extent on culture, individual preferences and people's life phase. Therefore, in our scenario, all modes of living are still available – single households, family houses, shared flats, etc. There is, however, a trend towards community that goes beyond the nuclear family, resulting in a need for bigger apartments, (inter-generational) housing projects, eco-villages etc. This trend will still allow for individual private space while recreational rooms (such as sports rooms, repair studios, and possibly living rooms and kitchens) as well as appliances

87 Eom, J. et al., 2012. China›s Building Energy Use: A Long-Term Perspective based on a Detailed Assessment. Pacific Northwest National Lab.

88 Deutschland in Zahlen citing Statistisches Bundesamt, https://www.deutschlandinzahlen.de/tab/deutschland/infrastruktur/gebaeude-und-wohnen/wohnflaeche-je-einwohner

89 Federal Environment Agency Germany, https://www.umweltbundesamt.de/daten/private-haushalte-konsum/wohnen/wohnflaeche#zahl-der-wohnungen-gestiegen (such as washing machines and tumble dryers, and possibly dishwasher, refrigerators and TVs) are largely shared. These changes have two effects with regards to reducing GHG emissions: First, the floor area per person is reduced, resulting in a reduced heating demand. Second, the number of appliances decreases significantly. For this decrease not to be offset by shorter product lifetimes, durability is increased in the STS. As a beneficial side effect, these new living arrangements can serve to increase spaces of interaction and community building.

In a sense, this trend is already underway, albeit only in small parts of the population. Some inspiring examples for sustainable communal housing are:

- Cluster apartments are a new concept combining the benefits of shared living spaces and small apartments. They often have the additional goal of creating a living space where people with different backgrounds get to know each other, dispersing preconceptions and forming special friendships.[90]
- Senior cooperative housing communities, e.g. know in the US,[91] are corporations where seniors collectively own their building with other residents. They are organised as non-profits.
- All over the world, people have founded eco-villages to explore new (and sometimes very old) ways of living together sustainably and collaboratively.[92]
- The apartment-house syndicate provides advice and financial support to self-organised house projects.[93]
- In Germany students are invited by student unions to live together seniors. One example is the campaign «Living for help»[94]

In our scenario, we do not only rely on societal change resulting in a decrease in living area: With regards to the building stock, we assume ecological insulation and buildings to become the norm (see Table 18). We further assume that many buildings will be renovated in a way that allows for more communal living,

Model assumptions

Annex I countries

Figure 5 shows the development of floor space per person in Annex I and Non-Annex I countries and rural and urban areas.

According to the International Energy Agency (IEA), the average OECD household is comprised of 2.6 people. We assume a doubling of people per household from 2020 up to 2050, accompanied by an increase in house size by 50%, thus decreasing

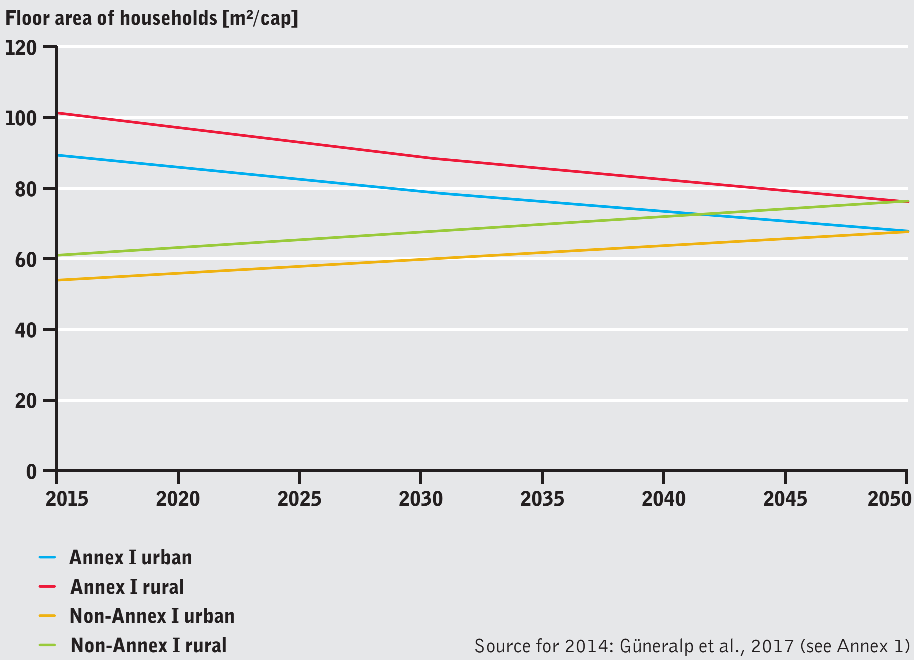
90 See for example https://www.kalkbreite.net/en/kalkbreite/habitation-kalkbreite/clusterapartments/
91 See for example https://www.seniorliving.org/cooperative-housing/
92 See https://ecovillage.org/ for a good overview.
93 https://www.syndikat.org/en/
94 «Wohnen für Hilfe» (Living for help) is a project run by the student union Schleswig-Holstein https://www.studentenwerk.sh/de/wohnen/wohnen-fuer-hilfe/projektidee/index.html (last visited: 10 October 2020)

individual living space by 25%. We leave the number of appliances per household constant. Since we assume a doubling of people per household, the number of appliances per person is halved. At the same time, we double both appliance usage (except for refrigerators, which run 24 hours anyway and no full doubling for televisions since they can be shared) and appliance durability. The resulting effect is a reduction in appliance production.

Non-Annex I countries

For these countries, we increase household size by 20% up to 2050 and do not change the number of people per household after that. This results in a floors space per person similar to that in Annex I countries in 2050. We do not change the number of appliances per household.

Figure 5: Development of floor space per capita in the STS



Source for 2014: Güneralp et al., 2017 (see Annex 1)

Policies and measures

We imagine the increase in people per household as a voluntary cultural shift that draws from already existing communal living forms in the Global North and Global South. While we experience that many people in the Global North feel relatively isolated and would appreciate more community, we understand that this change will not be for everyone. Thus, we imagine mostly «pull» measures on an individual level. At the same time, «push» policies are needed for social classes that feel entitled to large living spaces just because they can afford them and capital investors that build large, expensive apartments, often preferring to leave apartments empty rather than lowering the rent. Some concrete measures are

- city and community award practices that favour affordable and sustainable housing practices
- financial support/tax advantages for communal (public) housing projects
- easy and preferential access to communal real estate for communal (public) housing projects
- high fees for misappropriated living space
- socialisation of living spaces through expropriation when market signals fail to lead to affordable and sustainable apartment sizes
- clearing houses and information centres for people who are searching for communal living opportunities
- educational programmes about already existing projects and alternatives
- increased minimum appliances warranty times.

5.6 Food Sector: Sustainable diets and ruminant meat

Status Quo

Global agriculture is another substantial source of the world's annual GHG emissions. If emissions from activities across the entire production and consumption cycle – including deforestation through the expansion of agricultural cropland, chemical fertilisers, loss of carbon from soils, transport, processing and packaging, freezing, heating and food waste – are factored in, our global industrial food system accounts for 21-37% of GHG emissions according to the IPCC,[95] or even for up to 44-57% according to calculations by the international NGO Grain.[96]

Global peasant and agro-ecology movements claim that peasant agro-ecology – a food system based on food sovereignty, small-scale farming and agro-ecology – could not only drastically reduce emissions from agriculture but in fact help build carbon storage in soils and agricultural ecosystems. Unfortunately, the Global Calculator did not allow us to model such an encompassing transformation away from the industrial food system. In fact, none of the internationally dominant climate models is able to visualize such an agricultural transition. The inability to account for this transition leads to an over-reliance on technological change and efficiency increases (see the

95 IPCC, 2019. Summary for Policymakers. In: Climate Change and Land: An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [Shukla, P.R. et al. (eds.)], https://www.ipcc.ch/srccl/chapter/summary-for-policymakers/

96 Grain, 2016. The great climate robbery. https://www.grain.org/article/entries/5354-the-great-climate-robbery

critique of agricultural intensification and intensification below) rather than transformations in the way we produce, distribute and consume food and how we treat the land, the communities and the animals.

We therefore decided to focus on changing a select number of aspects of the current food system that would be relatively easy to implement and are in line with WHO health and nutrition guidelines:[97] reduction in food waste, healthier diets and reduction in ruminant meat production and consumption.

Today, up to one third of the food produced in the world for human consumption every year is never eaten; it gets lost or is wasted.[98] It is thrown away because it could not be sold before expiration date, its shape and form did not meet consumer expectations, too much of it was put on sale counters, consumers bought more than they could eat, it was not stored properly or restaurants threw away what was not eaten. A smaller part of it is wasted due to constraints in harvesting techniques, storage and cooling facilities. While much has to be done to stop hunger and starvation,[99] and access to and allocation of food plays a significant role in this, much of the current food wastage could be avoided.

When it comes to diets, unhealthy overconsumption is a widespread phenomenon in the Global North. The average person in Annex I countries consumes 2,748 kilocalories (kcal) per day – with WHO guidelines recommending 2,100 kcal per person per day.[100] Overconsumption is particularly prevalent, including consumption of meat and dairy products, in the Global North. It is also excessively unjust: It is also excessively unjust, for example, with people in high-income countries in the Global North eating up to 120 kg of meat every year while, in other parts of the world, this figure drops to 10 kg (figures from 2017).[101] Of course, within countries and populations, there are also great disparities that are not reflected by the averaged figures given here.

Overconsumption and in particular meat- and dairy-heavy diets are important drivers of GHG emissions in agriculture. Trends show an increase in meat consumption over the past decades in most parts of the world, albeit with the global disparities and inequalities mentioned above. Global meat production is projected to rise further,[102] with GHG emissions from it projected to rise accordingly. Ruminant meat

---

97 See http://tool.globalcalculator.org/gc-lever-description-v23.html?id=33/en and WHO, 2004. Food and nutrition needs in emergencies.

98 Food and Agriculture Organisation of the United Nations (FAO), http://www.fao.org/save-food/resources/keyfindings/en/

99 Stopping hunger and starvation is not only about the reallocation of food, of course, as the world's hunger is rooted in conflicts about land and expulsion from land, poverty and structural inequality in societies including gender inequality, unequal trade relations, bad governance and conflicts, natural disasters including climate crisis and resource waste.

100 See http://tool.globalcalculator.org/gc-lever-description-v23.html?id=33/en and WHO, 2004. Food and nutrition needs in emergencies.

101 https://ourworldindata.org/meat-production#which-countries-eat-the-most-meat

102 GRAIN/Institute for Agriculture and Trade Policy (IATP), 2018. Emission impossible: How big meat and dairy are heating up the planet, p. 4. https://www.iatp.org/sites/default/files/2018-08/Emissions%20impossible%20EN%2012.pdf production – such as that of beef and lamb – has the greatest climate footprint of all meat sources.[103]

The technological approach to mitigation in agriculture is intensification. Intensification means producing more per unit of input. In the case of meat production, this approach aims at reducing the emissions per kilo of meat, rather than the overall amount of meat that is being produced globally. We proceed from the assumption that forcing intensification in factory farming is problematic for a number of reasons, including animal welfare, ecological and biodiversity impacts, working and health conditions.[104] Rather than continuing to produce more and more meat more efficiently and at lower cost, a climate-just transformation in agriculture must include less but better meat and dairy.

The food sector in the STS

In our scenario, we assume that food consumption in the Global North is reduced by 23.5% by 2050. This shift is the result of reducing daily caloric intake to 2,100 kcal per person per day, achieved through healthier diets in line with WHO dietary guidelines. Overall, lower calorie intake also helps to reduce food waste at the level of consumption, leading to additional emissions savings.

Additionally, we assume that meat consumption is significantly reduced as meat production, especially that of ruminant meat, is a major source of GHG emissions. That is why we assume not only a significant reduction in meat consumption from 344 to 135 kcal per person per day but also a reduction in the share of ruminant meat. We consider these changes justified and feasible for a number of reasons:

- eating less (ruminant) meat not only lowers emissions but also improves health
- we see that large parts of the world population live on a diet that is less meat-based. Such healthy diets are, for example, to be found in Guyana, Turkey and India, according to a report in The Lancet, one of the world's oldest and most well-respected peer-reviewed medical journals.[105]
- even in regions with high meat consumption, we see hopeful developments such as vegetarianism and veganism, which can be expected to grow as plant-based substitute products for meat are increasingly available and improving.

We expect a reduction in meat consumption to come about as a cultural change facilitated through measures that lead to producing less but better meat while also reducing prices for less-resource-intensive, organic diets. Thus, we assume a larger change in producing and consuming food, toward organic and sustainable agriculture, and a

103 Heinrich Boell Foundation, 2014. Meat Atlas, https://www.boell.de/en/meat-atlas
104 Action Aid, 2019, Principles for a Just Transition in Agriculture, https://actionaid.org/publications/2019/principles-just-transition-agriculture
105 Imamura, F. et al., 2015. Dietary quality among men and women in 187 countries in 1990 and 2010: a systematic assessment. The Lancet Global Health, Vol. 3, Issue 3, E132-E142.

more conscious preparation and consumption. This change is eased by reduced working hours and a deceleration in everyday life (see Section 7).

When less food is wasted and less meat is consumed in the Global North, less land will be needed to grow food and feed for livestock, or food can be grown in more sustainable, extensive agricultural systems. The result will be a larger share of sustainable agriculture and large shares of agricultural cropland on which natural, biodiverse forest and grassland ecosystems can regrow and be carefully restored. Both carry a significant potential for natural carbon sequestration, as do integrated agricultural practices such as agro-ecology and agro-forestry, which are also difficult for climate models to visualize. The issue of carbon sequestration will be picked up again in the Section 5.7.

Model Assumptions

Annex I countries

- We assume a reduction of food consumption by 23.5% resulting from a reduction of caloric intake per person in accordance with WHO guidelines from 2,748 kcal/day (2014) to 2,100 kcal/day (2050).
- We assume meat consumption is significantly reduced from 344 kcal in 2013 to 135 kcal per person/day in 2030 and constant from then on.
- As producing ruminant meat is particularly GHG emissions intensive, we assume a reduction of beef calories in total meat calories from around 21% in 2013 to 10% in 2050.

Non-Annex I countries

- For 2030 and 2050, we assume no change of caloric intake per person compared to 2014. In 2014, the average daily caloric consumption was calculated to be at around 2,276 kcal/person/day.[106]
- For 2030 and 2050, we assume no change in meat consumption compared to 2013 when the average daily meat consumption in Non-Annex I countries stood at around 173 kcal/person/day.
- In 2013, ruminant meat accounted for a share of around 14% in the total meat calories consumed by populations in Africa, South America and Asia. For our model, this share was kept constant through 2030 and 2050.

106 Note that this is a figure averaged across the materially poorest countries and so-called developing countries and accordingly does not reflect the great disparities and inequalities in provision of and access to nutritious and healthy food in sufficient quantity and quality in and between those countries, as well as between the Global South and the Global North. The fact that 690 million people suffer from hunger and malnutrition (https://www.un.org/sustainabledevelopment/hunger/) while sufficient food is being produced implies the urgent need for political measures to address the structural inequalities in the global food system.

World: Transition away from industrial agriculture

- We do not assume an increase in agricultural productivity.
- We assume an end of confined systems (sheep, goat, cows, bovine, poultry)
- We envision a generalised decrease of crop and meat waste on the production side. For crop waste, we assume that wastage is reduced from 24% to 10%, and for meat from 19% to 5% (changes from 2011 to 2050).

Policies and measures

We imagine the changes in diet to be supported by the following policies and measures:

- less stringent trade standards with regard to the appearance and shape of fruit and vegetable
- integration of food waste in food hygiene compliance schemes
- improved education on food/meat production and its impacts and on vegetarian and vegan diets
- abolishment of subsidies for meat production and industrial farming
- internalisation of all external costs of meat production
- reduced share of meat-based dishes in public institutions
- option to choose vegetarian or vegan food in canteens and cafeterias.

5.7 Land use changes and CO_2 sequestration

Dietary shifts in Annex I countries towards healthier diets and lower meat consumption, especially ruminant meat, would lead to large areas of agricultural land no longer being needed for animal feed production such as soy and maize. This land, or part of this land, could be restored to natural ecosystems. Through regrowth of natural ecosystems such as forests and grasslands, CO_2 can be drawn from the atmosphere and stored in soils and plant matter – called CO_2 sequestration.

However, calculating exactly how much CO_2 could be stored through returning land to the state of natural ecosystems rather than agro-industrial exploitation is far more complex than could be accomplished with the Global Calculator (or any other global models). It would require identifying the precise hectares and, more importantly, the locations of agricultural land that would be «freed up« from intensive agricultural use and comparing the results with an ecosystem biome map to identify which type of ecosystem a given area could be restored back to. It would also simultaneously involve working with local communities and Indigenous peoples as well as taking into account biome changes due to climatic changes. All of these factors are important if the aim is an ecological restoration of natural ecosystems rather than afforestation in areas that are not traditionally forest areas.

The Global Calculator, however, does not feature this level of detail and complexity and simply assumes a switch back to natural grasslands and forests, regardless of biome conditions. For the STS, we decided to keep the level of CO_2 sequestration deliberately at the lower end of what is potentially possible. We assumed a 20/80 split between natural grasslands – which have lower CO_2 sequestration rates – and forest recovery.

We prefer to treat those natural ecosystem carbon removals as a safety net rather than overly depend on them for pathways towards 1.5°C for a number of reasons:

- as described above, the constraints of the model would inevitably lead to inaccuracy, in particular when assuming large quantities of CO_2 removed from the atmosphere through ecosystem restoration
- treating the removals as separate, additional mitigation potentials rather than «netting them out« with fossil and industrial emissions prevents them from being used as offsets or as an excuse for slow and insufficient emission reductions
- there are (legitimate) concerns around the stability and permanence of CO_2 stored in natural ecosystems. We can confidently assume that permanence and stability are higher in natural, biodiverse ecosystems than in monoculture «carbon farming« tree plantations, but the sequestration potential of the world's ecosystems may also change due to climatic changes.

However, we do think the actual potential of CO_2 sequestration in the land sector through rights-based and ecosystem-based approaches is higher than what we – for the reasons laid out above – assume for the STS.

The potential of such approaches, and ways to go about them, is fleshed out in more detail in Annex 2.

Box 6: Feedback of climate impacts

The Global Calculator does not account for the feedback of climate impacts. This lack of feedback means that, for example, negative or positive effects of temperature change until 2050 on agriculture production are not modelled. Although this drawback is a disadvantage from the perspective of representing reality, there are reasons to assume that it does not produce significant effects in the results. One important reason is that most of the climate-related damages in the economy are expected for levels of warming beyond 2°C and therefore unlikely to materialize before 2050, when temperatures rise much less.[107] Given the above, and the fact that our scenario is envisioned as a deep reductions pathway, we can be relatively sure that in our scenario, by 2050, temperatures will not have increased to levels that would substantially lead to a disproportionate rise in climate impacts. The lack of climate feedback also implies that climate-induced changes in the area covered by ice or deserts will not be represented in the Global Calculator.

5.8 Technology, agriculture and land use parameters

Although the scenario focuses on analysing the effect of more societal change and is born out of a mindset sceptical of techno-solutionism, we agree that technological improvements, changes in efficiency and innovation in combination with lifestyle changes are needed to reduce emissions effectively. Our assumptions regarding technical changes are described below.

In contrast to lifestyle parameters, for which we choose different parameters for Annex I and Non-Annex I countries, we do not distinguish between these two groups for the following parameters. For a justification of these choices and a description of the drawbacks see Box 3.

All assumptions can be found in Table 18 in Annex 1. An overview of the key assumptions is provided in Table 3 below.

107 For example, using process-based models of agriculture Li, T. et al (2015, Uncertainties in predicting rice yield by current crop models under a wide range of climatic conditions. Global Change Biology, Vol. 21, Issue 3, 1328-1341) report an average yield loss of 5.3% per °C for rice yield for a 3°C warming, which increases to 8.3% per °C for 6°C warming. A statistical study of yields in the U.S. reports an average 8.2% per °C loss for maize and 5.7% for soybean up to 3°C, which increases to an average of 10.4% per °C loss for maize and 10.6% for soy bean between 3–6°C of warming (Schlenker, W. and Roberts, M.J., 2009. Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change. PNAS, 106 (37), 15594-15598).

Table 3: Summary of technological changes in the STS

Population growth and distribution	In our scenario, the population of Annex 1 countries rises only slightly from 1.31 billion in 2018 to 1.35 billion in 2050. The share of urban population rises from 79.1 to 86.6%. The population of Non-Annex I countries increases from 6.31 to 7.2 billion in the same time frame, with the share of urban population rising from 51.7 to 65.6%.108
Transport	We assume ambitious increases in transport efficiency and a shift towards hybrid and electric/hydrogen vehicles.
Buildings and appliances	We assume ambitious improvements in building insulation and shifts toward low carbon heating technologies. We also assume ambitious increases in appliance efficiency.
Manufacturing	We assume ambitious increases in recycling and efficiency improvements in the manufacturing sector. These increases include the production of iron, steel and aluminium, chemicals, paper and cement.
Power generation	For biomass, we assume a moderate increase in energy crop yield with a shift from liquid to solid biomass use. For fossil fuels, we assume a shift towards 100% natural gas in 2050. For nuclear power, we assume no further plant construction so that nuclear power is phased out by the time current plants reach the end of their lifetime. For renewables, we assume ambitious development of wind, solar, marine, hydroelectric and geothermal power generation as well as increases in electricity storage capacity.
CCS	We assume no use of CCS.
Land and food	We assume a shift away from industrial agriculture with its negative consequences (as soil degradation, overuse of water, biodiversity loss, nitrate contamination of ground water) toward sustainable and organic farming practices. In line with the argument that hunger and starvation must be abolished by finding solutions for conflicts about land, poverty and structural inequality, unequal trade relations, bad governance, and natural disasters, we are convinced industrialised agriculture with its many negative side-effects is not the solution to end hunger in the world. Thus, we assume no increases in agricultural productivity (as this would mainly be based on industrialised agriculture with its negative side-effects), an end of confined systems and an ambitious decrease in waste of agricultural products.

108 The figures stem from the «Medium Variant» population scenario in the UNDP World Population Prospects 2019 report and the United Nations Revision of the World Urbanization Prospects 2018

6 Scenario results

The most important result of running the Global Calculator on the basis of the parameters sketched above is the following:

> **The Societal Transformation Scenario (STS) depicts a CO_2 emission pathway that allows for the temperature increase to remain below 1.5°C without the need for nuclear power, carbon capture or other geoengineering options.**

In the following we describe how, in the STS,

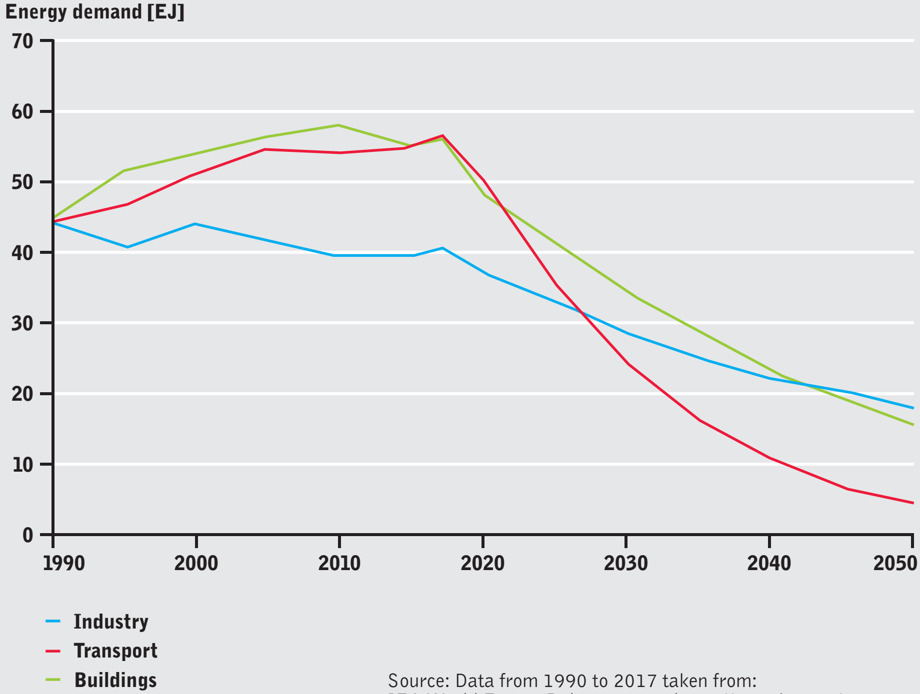
- final energy demand is reduced through efficiency and sufficiency
- the CO_2 intensity of the energy system is reduced through a shift away from fossil fuels
- land use changes due to dietary changes result in natural carbon sequestration

Final energy demand

Figure 6 shows the final energy demand of Annex I countries when the STS is followed. Due to both decreases in demand and increases in efficiency, the final energy demand drops significantly from 2020 on. This drop is particularly noticeable in the transport and building sectors while the decrease in the industry sector is linear, less pronounced but still significant. The linear decrease can be explained by industry's need to supply a large amount of materials for the energy transition, e.g., wind power plants, electric vehicles. On the other hand, given that the overall demand is reduced, there is less need for cement for new buildings or fossil fuel infrastructure for e.g., gas plants. In the Global Calculator, the industrial sector responds to the demand generated, meaning that the manufacturing capacities are adjusted accordingly.

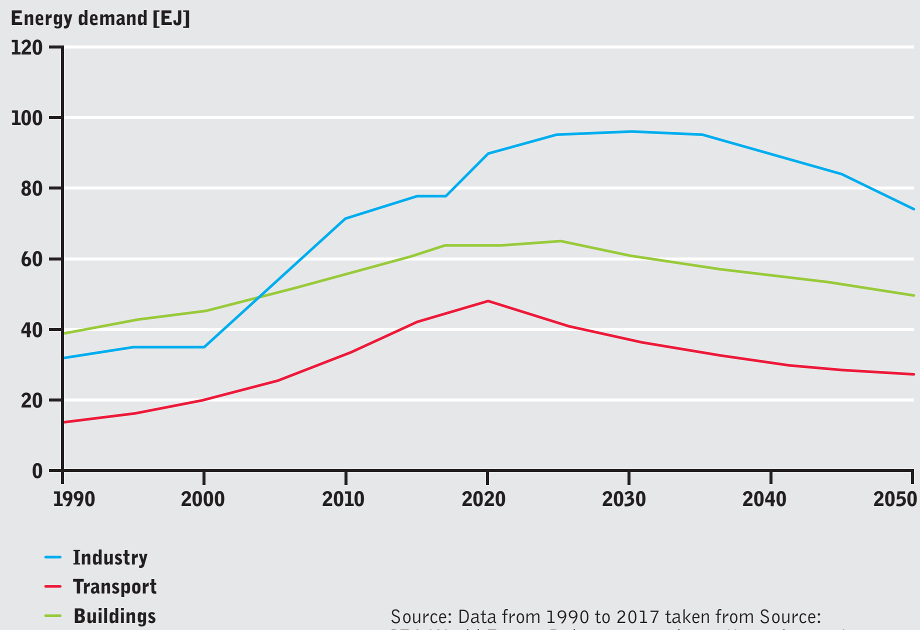
In line with our reasoning that it is foremost the responsibility of industrialized countries to reduce consumption, the reduction in final energy demand is much lower for Non-Annex I countries (see Figure 7). The drop in demand stems mostly from efficiency improvements while consumption parameters are assumed to increase slightly or, in some cases, to remain constant.

Figure 6: Final energy demand in Annex 1 countries



Source: Data from 1990 to 2017 taken from:
IEA World Energy Balances 2019 https://www.iea.org/subscribe-to-data-services/world-energy-balances-and-statistics.
Own calculations from 2020 onward.

Figure 7: Final energy demand in Non-Annex 1 countries

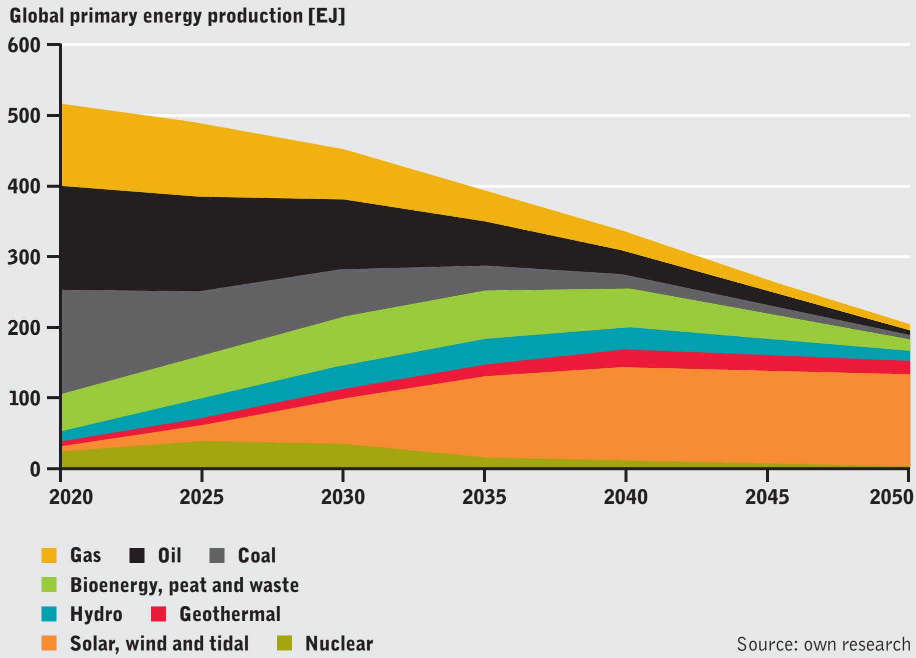


Source: Data from 1990 to 2017 taken from Source:
IEA World Energy Balances 2019 https://www.iea.org/subscribe-to-data-services/world-energy-balances-and-statistics.
Own calculations from 2020 onward.

Primary energy demand

Due to the falling final energy demand, primary energy production also falls with sharp declines in fossil fuel use, a phase-out of nuclear energy and a strong expansion of renewables (see Figure 8). While still in use in some niche areas, fossil fuel use is negligible in 2050, with the different carbon-based fuels accounting for less than 10% of primary energy production.

Figure 8: Global primary energy production [EJ], model results



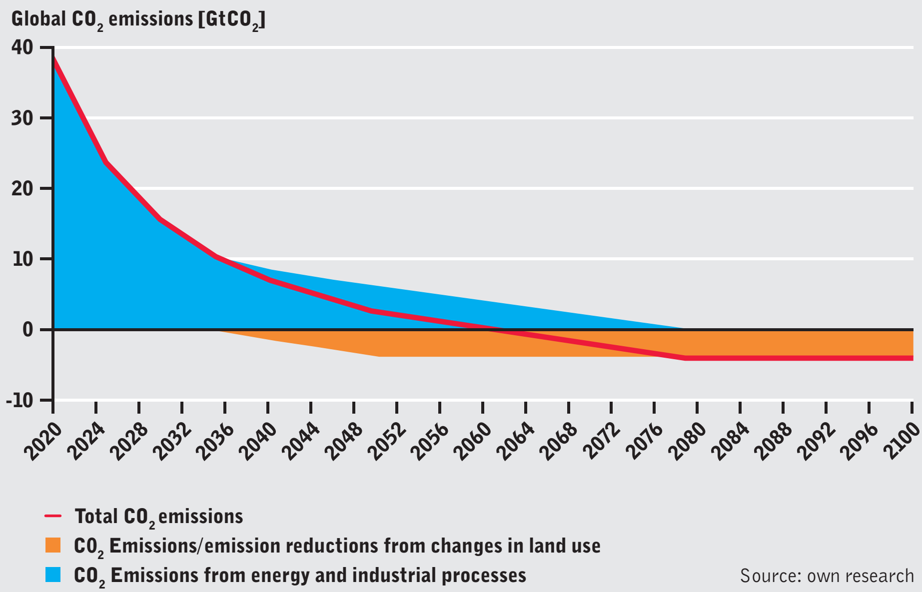
Source: own research

Greenhouse gas emissions

According to the model results, GHG emissions fall by roughly 50% between 2020 and 2030 and continue to decrease to about 28% of 2020 emissions by 2050 (see Figure 9). From then on, we assume a linear reduction in line with the average decline from 2040 to 2050. Due to a dietary shift towards healthier diets, lower meat consumption and less food wastage, large agricultural areas can be carefully restored into natural ecosystems or managed more sustainably, in the process serving as CO_2 sinks (Section 5.7). By 2050 we assume those sinks to sequester almost 4 Gt CO_2 per year. From 2050 on, we assume carbon sequestration rates to stay constant at that level, which we take as a realistic and plausible assumption for carbon sequestration potentials over the

course of the century. Our scenario yields a cumulative total of 232 Gt CO_2 sequestered through ecosystem-based approaches.[109]
CO_2 emissions show a similar pathway and cumulative emissions stay well below the threshold of a 2/3 chance to stay below 1.5°C, as shown in Table 4.

Figure 9: Global CO_2 emissions



Source: own research

Table 4: Cumulative emissions [in Gt CO_2] and remaining carbon budgets to stay within 1.5°C warming[110]

	Remaining carbon budget for 33% chance to stay within 1.5°C	Cumulative emissions in 2100 w/o carbon sequestration of land use sector	Remaining carbon budget for 50% chance to stay within 1.5°C	Remaining carbon budget for 67% chance to stay within 1.5°C	Cumulative emissions by 2100 with carbon sequestration
1.5°C	773	551	513	353	320

Note: Since our scenario starts in 2020, we subtracted the global emissions of 2018 and 2019 = 33.3 Gt CO_2.[111]

109 There is much uncertainty and scientific debate on the annual and total sequestration potential. We decided to use 4 Gt of CO_2 as the maximum amount for annual sequestration as a conservative interpretation of the potentials featured in «Missing Pathways to 1.5°C – The role of the land sector in ambitious climate action», Dooley, K. and Stabinsky, D., 2018. See also Section 5.7 and Annex 2 of this study.

110 Carbon budgets according to Rogelj et al., 2018. Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development. In: Global Warming of 1.5°C. An IPCC Special Report.

111 Source: International Energy Agency, 2019. https://www.iea.org/articles/global-co2-emissions-in-2019

Reaching zero net emissions

From a natural scientific view point, the most relevant aspect of ambitious mitigation scenarios is large and fast emission reduction in the next decades. From then on, net emissions will need to be close to or even below zero. When exactly zero net emissions are reached is of much less importance than the emission path of the near future.

In the political and public debate, however, the year in which net emissions become zero has become an important figure. In our scenario, net GHG and CO_2 emission reach zero around 2084 and 2062, respectively. One reason for this late date is that the model does not produce negative emissions from land use separated by Annex I/Non-Annex I countries and thus we do not know when emissions will reach net-zero in Annex I countries. A second reason is that, for some production technologies, the model has no non-fossil substitution implemented although substitutions might become available. For example, possibly producing primary steel using hydrogen is not accounted for and hence coking coal is still depended on. Taking these shortcomings into account and considering that a) total GHG emissions for Annex I countries are less than 1.8 Gt in 2050 (excluding emissions from land use, land use change and forestry) and b) defining a date for net-zero emissions is important for the dynamics of political processes, we believe that reaching net-zero emissions by 2050 or even earlier is an attainable and justifiable target for industrialised countries.

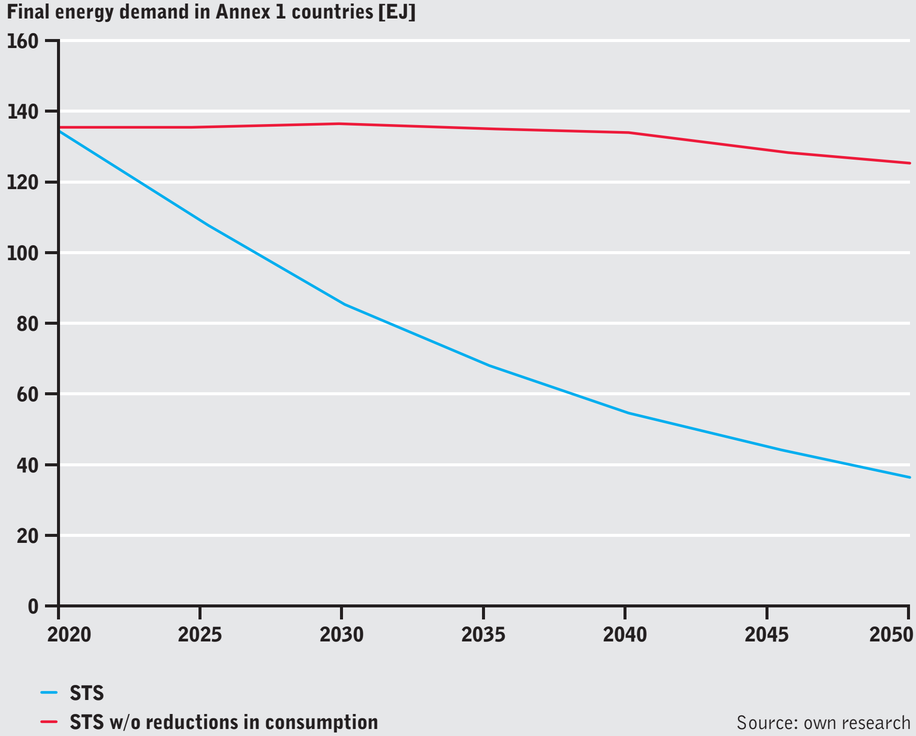
Impact of reductions in consumption

Figure 10 and Figure 11 show the impact of the assumed reduction in consumption in the STS. The red lines show final energy demand and global emissions for a scenario with the same assumptions as the STS with regards to energy mix, efficiency improvements, demography, etc., but without the strong decline in consumption. For this scenario run, we assumed all consumption trends to remain at the lowest level of ambition of the Global Calculator, representing a world in which current trends in consumption continue.

As shown in Figure 10, final energy demand in Annex I countries remains almost constant until 2035 under those conditions. It is only after 2035 that improvements in efficiency finally outweigh increases in consumption.

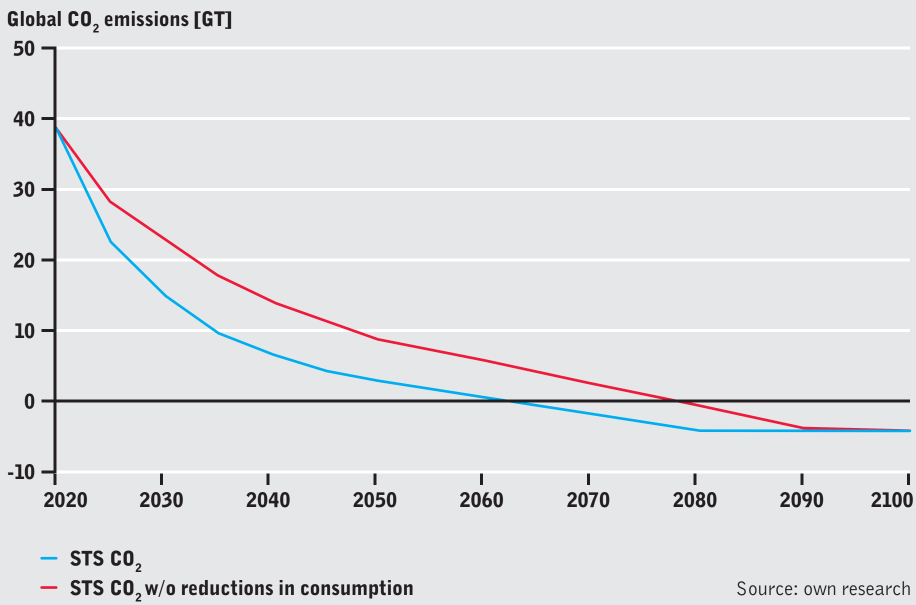
Regarding global emissions, the difference between the two scenarios is most pronounced between 2020 and 2050 (see Figure 11) and becomes less towards 2100, when renewable energy production substitutes more and more fossil fuels. Due to the higher emissions pathway, cumulative emissions amount to 696 Gt CO_2 in the scenario run without consumption reductions, thereby granting less than a 50% chance to stay below 1.5°C of global warming.

Figure 10: Comparison of final energy demand in Annex I countries with and without reductions in consumption



Source: own research

Figure 11: Comparison of global CO_2 emissions with and without reductions in consumption



Source: own research

Box 7: Comparison to the Low Energy Demand scenario

Similar to the STS, the Low Energy Demand (LED) scenario[112] that was featured prominently in the latest IPCC report on 1.5°C of global warming (SR1.5) strives to reduce emissions by reducing energy demand (see Section 2). Since there are some similarities between the LED and the STS, a comparison between the two is insightful (see Table 5).[113]

In comparison to the STS, final energy demand in the LED scenario is higher for Annex I countries (2030 and 2050) and lower for Non-Annex I countries in 2030/almost the same in 2050. For Annex I countries (in the LED: countries of the Global North), this difference is expected since it was our goal to reduce energy demand in the Global North to make space for self-determined development in the Global South. The higher energy demand in Non-Annex I countries (in the LED: countries of the Global South) in the STS in 2030 indicates that our assumed path of gradual alignment of global consumption is more generous than the path assumed in the LED.

While in the STS, total global final energy demand is slightly lower in 2030, primary energy production is higher, suggesting a different energy mix (e.g., coal power has a lower ratio of final energy production/primary energy carrier than gas). The opposite is true for 2050, where the lower total final energy demand of the STS is met more efficiently than in the LED scenario, resulting in a much lower primary energy demand.

The share of nuclear energy increases in the LED scenario up to 8.9% in 2050 while nuclear energy is phased out in the STS. The share of fossil fuels drops in both scenarios while renewable energy production from solar and wind increases. While a fast extension of renewable capacities is key to reducing emissions in both scenarios, the STS eventually allows for a slightly lower total renewable capacity to be installed.

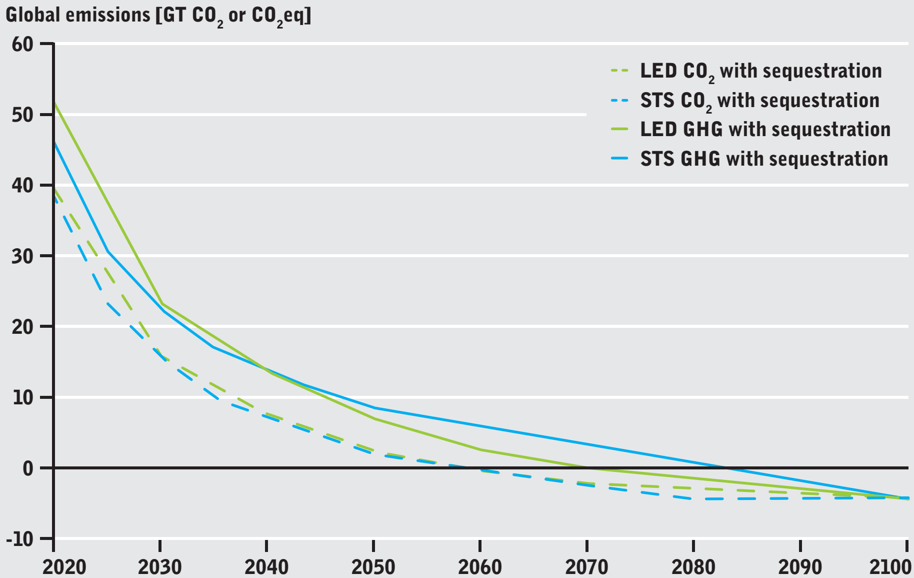
The cumulative CO_2 emissions from 2020 to 2100 are higher in the LED scenario, a difference that can be almost completely explained by a higher amount of carbon sequestration in the STS. All in all, the emission pathways are strikingly similar, as can be seen in Figure 12.

In summary, it can be said that the main difference between the scenarios is that the LED scenario employs a significant amount of nuclear power while the STS features sufficiency measures and about 25% more carbon sequestration.

112 Grubler, A. et al., 2018. A low energy demand scenario for meeting the 1.5 °C target and sustainable development goals without negative emission technologies, Nature Energy, Vol. 3, 515-527.

113 First, both scenarios aim at reducing energy demand, with the LED scenario focusing on energy efficiency while we include reductions in consumption as well. Second, both scenarios split the demand side between two regions and calculate demand outside of an IAM.

Figure 12: Global GHG emissions/CO_2 emissions in the LED and STS



Source: Low Energy Demand (LED) Database (Version 1.0.5), https://db1.ene.iiasa.ac.at/LEDDB and own calculations

Table 5: Comparison of the STS and the LED scenario[114]

	STS		LED	
	2030	2050	2030	2050
Final Energy demand Annex I/Global North [EJ]	86	36	125	82
Final energy demand Non-Annex I/Global South [EJ]	193	150	175	153
Primary energy production total [EJ]	447	201	378	289
Share of nuclear energy	7.0%	0.0%	4.3%	8.9%
Share of fossil fuels	52.0%	9.0%	57.4%	16.0%
Energy production from solar and wind [Ej]	65	131	72	139
Cumulative CO_2 emissions from 2020 to 2100 [Gt CO_2]	320		391	
Total sequestered CO_2 [Gt CO_2]	232		169	

114 Data for the STS is taken from the model run, LED scenario data was taken from the LED scenario database at https://db1.ene.iiasa.ac.at/LEDDB/dsd?Action=htmlpage&page=40#.

7 The Societal Transformation Scenario – sketches of a different tomorrow

So far, we have described the STS in terms of philosophy, parametrisation and emission reductions. In this section, we provide a more holistic sketch of the societal transformation we envisage. These details should make clear that the STS is not primarily about producing and consuming less; it is about organising society differently. What we envisage is a collectively undertaken and well-pondered process. The STS is based upon the conviction that the current underlying values and paradigms of political and economic decision-making need to be re-thought for both ecological and social reasons.[115] Instead of focusing on material welfare – fostering economic growth, competition and profit-making – **we focus on fulfilling concrete human needs and serving common welfare – fostering cooperation, care, solidarity and sustainability in order to achieve a good life for all.**[116]

By a «good life», we understand a life of dignity and self-determination allowing the fulfilment of essential needs including basic, necessary and sustainable material welfare and travel as well as social protection. The STS assumes that different sectors of production and consumption will be reduced as the result of democratic deliberation – because they are unsustainable and/or do not primarily aim at fulfilling human needs.

For the STS, we assume a society that finds ways and instruments to prosper without an ever-increasing level of consumption and production, to prosper beyond growth, with redistribution of wealth and work as a fundamental building block. This assumption is not naïve; it is backed by the findings of a still small but lively practical and scientific debate,[117] by thousands of real-life alternatives and practices throughout the world and by manifold traditions in organising human life to the well-being of each member of the community.

---

115 There are many reasons for criticizing the focus of modern society on economic growth as the key political paradigm. The STS is based on ecological critique. Other strands of critique are social-economic critique, cultural critique, critique of capitalism, feminist critique, critique based on industrialism, south-north critique. See Schmelzer, M.; Vetter, A., 2019. Degrowth/Postwachstum zur Einführung.

116 This chapter has been inspired by the following sources: Burkhart, C. et al., 2020. Degrowth in movement(s); Schmelzer and Vetter, ibid.

117 See for example Kallis, G., 2018. Degrowth; Kallis, G. et al., 2018. Research on Degrowth; Victor, 2019. Managing Without Growth: Slower by Design, Not Disaster; Jackson, T., 2016. Prosperity without growth: Economics for a finite planet.

In the following, we give a rough outline of some of the broader changes we assume to be part of the STS. Many of those changes are being intensively discussed by scientists and practitioners. Though fragmentary and tentative, they are promising elements of a much more sustainable and just society that is able to cope with declining growth rates without decreasing quality of life and social stability. For this transformation, science and research are just as important as practical projects that experiment with alternative ways of living. Many of the changes we assume in our scenario are underway – new lifestyles and modes of production and consumption are already being tried, tested and established, some even have a long history.[118] Please note that the following description is neither exhaustive nor definitive – many different futures are conceivable.

For the STS, **we assume taxation gradually shifts away from labour to resources and ecologically damaging behaviour.**[119] The STS assumes this to be part of a comprehensive tax reform that not only puts a high price on CO_2 as well as on the use of other resources but also aims to decrease inequality. Progressive tax systems, wealth taxes and high inheritance taxes are political instruments that finance essential services and social security independently of economic growth. At the same time, any subsidies and public investments that are harmful to the environment are discontinued.

Furthermore, we assume that **social services** are designed so that they are **growth-independent.**[120] This design combines with instruments guaranteeing that partaking in social, cultural and democratic life is not/is much less dependent on having a job and earning one's living on the «job market». We assume that job loss is not connected to losing one's social status or livelihood, including access to essential goods such as housing, electricity, health care, education and leisure time activities e.g., sports, museums, cinemas and concert halls. Basic human needs are provided for. Many basic goods are no longer traded on markets; their production and distribution are arranged through democratic processes. Our STS assumes a strong social infrastructure. People do not need to suffer from existential fear when losing their job because it is no longer connected to their ability to fulfil essential needs and/or to taking part in social, cultural and democratic life.

One concrete measure being discussed for reaching this scenario is the **reduction of working hours** (e.g., to 20 to 30 hours/week) without salary loss for the lower income groups.[121] Combined with a **basic income and maximum wage** (e.g., two to five times the basic income), this reduction not only facilitates better allocation of the societal workload – both paid and non-paid – in a non-growing economy,[122] it would

118 Paulson, S., 2017. Degrowth: culture, power and change. Journal of Political Ecology, Vol. 24, No. 1.
119 Daly, H.E. and Farley, J., 2011. Ecological Economics: Principles and Applications; Jackson, T., 2017. Prosperity Without Growth – Foundations for the Economy of Tomorrow.
120 Seidl, I. and Zahrnt, A., 2019. Tätigsein in der Postwachstumsgesellschaft.
121 Kallis, G., 2018. Degrowth; Liebig, S. et al., 2017. Bedingungen und Optionen der Arbeitspolitik für die Postwachstumsgesellschaft. In: Adler, F., Schachtschneider, U. (eds.). Postwachstumspolitiken: Wege zur wachstumsunabhängigen Gesellschaft.
122 Jackson, T., 2017. Prosperity Without Growth: Foundations for the Economy of Tomorrow.

also contribute to developing a much broader perspective on wage labour and its relation to care work. This is important because care work is the precondition for any production and processing of goods. It encompasses (unpaid) care work (caring for kids, elderly, ill people), honorary office, civic and political participation and education.[123] In this regard, work, influence and participation will be distributed much more evenly from a gender perspective.

The reduction in working hours goes hand in hand with a **general deceleration of life and «time welfare»**. This combination not only gives room for leisure time and a better «work-life-balance». Working less on the job market also leaves the necessary room for self-determined activities and political engagement and improves the quality of human relationships.[124]

As for companies and businesses, our STS assumes a **democratization of economic decision-making, a broader variety of company forms and much less hierarchy.**[125] The economy of the future will be run by cooperatives, community-supported businesses, from small local and regional firms and other forms of collectively administered common properties (such as houses and companies). Production is focused on creating long-lasting goods that are sustainably produced. Attention is paid to healthy and non-exploitive working environments. In the STS, the political framework favours companies that focus not on profit-making but on serving the common welfare, including the well-being of workers and safeguarding the environment.[126] This framework might include changes in law, allowing e.g., easier founding of cooperatives, lower taxes for sustainable companies, privileged access to attractive loans, state subsidies and improved access to public procurement. In return, profit-orientated companies and enterprises would be taxed much higher, and get neither state subsidies nor access to public procurement. Production and consumption will be organised around commons,[127] solidarity economy[128] and a circular economy.[129]

An entirely **different regulative framework** will be the background for the process of dismantling unsustainable industries such as the car sector, aviation or industrial livestock farming. It will be by collective processes that, for example a car manufacturing company might decide to produce buses, a farm might decide to

---

123 Tronto, J.C., 2013. Caring Democracy. Markets, equality and Justice; Winker, G., 2015. Care Revolution: Schritte in eine solidarische Gesellschaft; Seidl, I. and Zahrnt, A., 2019. Tätigsein in der Postwachstumsgesellschaft.

124 Seidl, I. and Zahrnt, A., ibid.; Rosa, H., 2019. Resonance: A Sociology of Our Relationship to the World.

125 Solón Pablo, P., 2018. Systemwandel. Alternativen zum globalen Kapitalismus; Akuno, K. and Nangwaya, A., 2017. Jackson Rising: The Struggle for Economic Democracy and Black Self-Determination in Jackson. Daraja Press. Maheshvarananda, D., 2012. After Capitalism: Economic Democracy in Action. Innerworld Press; Kothari, A., 2019. Pluriverse. A Post-Development Dictionary.

126 Kallis, G., 2018. Degrowth.

127 Bollier, D. and Helfrich, S., 2019. Free, Fair, and Alive: The Insurgent Power of the Commons.

128 Nardi, J., 2015. Solidarity Economy in Europe: an emerging movement with a common vision.

129 Genovese, A. and Pansera, M., 2019. The Circular Economy at a Crossroad: Technocratic Eco-Modernism or Convivial Technology for Social Revolution?

switch to ecological farming, a mobile phone company might concentrate on building long-lasting, upgradeable devices. This process involves converting production processes and also abandoning whole industrial sectors. With social security not being based on wage labour and a much broader variety of economic activities and players, such a process leaves much more room for creativity and self-determination of the individual.

Box 8: Impacts of the STS on the Sustainable Development Goals (SGDs)[130]

Since the STS depicts a socio-ecological transformation, based on a reduction of consumption in Annex I countries with the goal of a good life for all, it is not surprising that its impacts on the SDGs are almost all positive.[131] For example, the changes in the mobility sector – less traffic, less car use, reducing health risks, especially for the urban population – will have a positive effect on human health and well-being (SDG 3) and will make cities and communities more sustainable (SDG 11). Also, the assumed reduction of working hours will have a positive effect on human health and well-being (SDG 3). The assumed reduction of meat consumption allows industrial agriculture to be wound down. In combination with further measures such as equitable trade rules, this reduction can help to alleviate hunger by freeing up land for the production of food for domestic markets (SDG 2) and improve the availability of clean water and sanitation (SDG 6). Lower meat production also reduces pressure on ecosystems and biodiversity (SDG 15). Lower production and consumption in general allow natural resources to be preserved and reduce the use and release of chemicals and waste generation, contributing to more responsible consumption and production (SDG 12). This contribution may also have a positive effect on life below water (SDG 14) and on land (SDG 15).

Notably, this transformation is not envisaged as the result of some master plan that is implemented top-down; it is developed bottom-up. An increase in codetermination and redistribution of power are prerequisites so that everyone can be part of the decisions that affect him or her, be it in his or her company, neighbourhood, community,

130 The low complexity of the Global Calculator does not allow for a quantitative analysis of the impact of the STS on SDGs.

131 The only SDG that the STS impacts negatively is SDG 8 «Decent Work and Economic Growth». While we believe that the STS can result in better working conditions e.g., through a reduction of reducing working hours, we do not consider full employment in wage labour or economic growth as meaningful goals. Instead, they are means to goals – like societal well-being and material security – that in our opinion can be achieved through better pathways, such as the ones outlined in the STS. Generally, the low complexity of the Global Calculator does not allow for a thorough quantitative analysis of the STS's impact on SDGs. The examples here serve to illustrate the argument.

Suggestions for a social-ecological transformation

Tax and financial system
- tax is shifted away from labour towards resources
- subsidies for harmful industries are discontinued
- progressive tax systems, a wealth tax and a high inheritance tax to strongly decrease inequality
- income and wealth are redistributed
- externalized costs are internalized

Work / Care
- putting care work at the centre
- reduction in wage labour; working hours are reduced to 25 to 30 hours a week
- more time for unpaid care work, quality in human relationships, education, civic and political participation, slowness
- production and processing of goods are subordinate to human welfare
- maximum wage

Habitation / Living
- communal housing projects
- communal living increases, single households decline, leading to more shared appliances
- eco-villages

Consumption
- swap shops
- give-away shops
- repair shops and service stations
- measures to limit advertisement in order to move beyond consumerism[132]
- vegetarianism, veganism
- libraries

Energy
- phasing out of destructive/fossil fuel industries
- decentralised and renewable energy sources exist as commons

Trade
- economies are much more localized, but remain open and connected
- trade regimes are based on the principle of fairness
- border adjustments are allowed/encouraged

Technology
- conviviality[133]
- digitalization with democratic oversight

132 For more suggestions see Victor, Peter A., 2019. Managing Without Growth: Slower by Design, Not Disaster; Jackson, Tim, 2016. Prosperity without growth: Economics for a finite planet; Pickett et al., 2009. The Spirit Level: Why More Equal Societies Almost Always Do Better, and Piketty, Thomas, 2014. Capital in the Twenty-First Century.

133 Adloff, F. and Heins, V., 2015. Konvivialismus. Eine Debatte; Les Convivialistes, 2014. Convivialist Manifesto. A declaration of interdependence; Illich, I., 1973. Tools for Conviviality.

Social welfare

- social welfare systems are independent of economic growth
- basic human needs are provided for; necessary basic goods (housing, food, health care, education, electricity) are no longer traded on markets; their production and distribution are arranged through democratic processes
- unconditional basic income —not only as money but also as a social infrastructure

Production / Economy

- economic decision-making and investments are democratised
- production is focused on creating long lasting, sustainably produced goods
- production is organized democratically through cooperatives and collectives
- attention is paid to a healthy and non-exploitive working environment
- commons, open source projects, maker spaces are created
- solidarity economy is developed
- circular economy is supported

Agriculture

- organic farming
- agro-forestry
- permaculture
- community-supported agriculture

Finance

- stronger regulation of the finance sector
- taxing financial transactions
- stopping speculation
- strong societal oversight in the field of private and public finance (change in credit praxis)
- certification system (for an adequate development of sustainable finances[134]
- monetary reform (diversity in local complementary currencies as exchange mechanisms)[135]

Nutrition

- consumption of meat greatly decreases, many households go back to the Sunday roast as the main meat dish
- some reduction of meat consumption is replaced by meat substitutes

Transport / Mobility

- daily life is slowed down, generally reducing the demand for motorized private transport
- settlement structures reduce transport demand (especially in cities) while maintaining mobility
- for shorter distances, cycling and walking is the norm (facilitated by car-free city and village centres), good cycling infrastructure
- longer distances are usually travelled by public transport or shared cars
- affordable/free public transport
- cargo bicycles, car sharing

---

134 Fernandez, Blanca, 2013. Fostering Sustainable Finances: The consideration of a Third Party Certification Program. Prospective Innovation at Ethical Banking and Finance. Leire San-Jose, Jose Luis Retolaza (eds.), 78-99.

135 Greenham, T. and Ryan-Collins, J., 2014. Rethinking the Role of Economy and the Financial Market. Journal of Civil Society, 9(2).

village, city, region, county or nation state. All spheres of life need to be re-politicised, especially the economic sphere, if alternatives are to be discussed, tested and evaluated.[136] If the climate crisis can only be prevented by reducing energy-intensive economic activity, that activity needs a framework of fundamental socio-economic transformation. There can be no ecological sustainability without social justice.

Box 9: On digitalisation

When talking about the future, technological trends, especially digitalisation, are the elephant in the room. This is somewhat telling – we are used to thinking about the future in a technical sense, not a societal one. Many proponents of digitalisation point out the ecological benefits that those trends might have e.g., a transport system centred around electric and driverless cars, fully occupied and running efficient, safe and without congestion. While we believe that some technology can be helpful in reducing emissions, such as video conferencing, we are generally sceptical about claims that see digitalisation as the solution for environmental problems. First and foremost, digitalisation is mostly seen as a new wave of technology that can be used to gain a competitive edge for countries and companies, a way to secure market shares. As such, it is a promise for continuous growth that is often pursued without considering social or environmental consequences. Secondly, without change, the digital future will be shaped by big companies with an incentive to produce more to sell more. For example, if big car companies are the driving force behind driverless cars, then they will attempt to sell as many cars as possible and not fewer but shared cars. Finally, data-driven-digitalisation itself relies on an IT-infrastructure whose energy and resource demand increases rapidly.[137] In conclusion, we see some chances for digitalisation but only if there is democratic oversight. Since we do not know what this digitalisation will look like, we did not assume any radical changes through digitalisation in our scenario.

136 Akuno, K. and Nangwaya, A., 2017. Jackson Rising: The Struggle for Economic Democracy and Black Self-Determination in Jackson. Maheshvarananda, D., 2012. After Capitalism: Economic Democracy in Action.

137 Andrae and Edler expect electricity consumption from communication technology to reach 21% of total global electricity consumption with access networks and data centers being the main drivers for increases. See Andrea, S.G. and Edler, T., 2015. On Global Electricity Usage of Communication Technology: Trends to 2030. Challenges, 6(1), 117-157.

Box 10: How realistic is the STS?

The changes we assume in our scenario might seem unrealistic with regards to their direction, speed and scale. After all, many trends are going in the other direction – driven by the Global North and, increasingly, by the so-called emerging economies, consumption has been increasing for decades. The current lifestyle is deeply rooted in many people's understanding of normality and a life worth living.

The catastrophe unfolding in front of our very eyes makes it all the more important to state that the changes we envisage are physically-technically feasible – while mitigation scenarios that bet on economy-optimal decoupling of emissions or reliance on large-scale «negative emissions» technologies have been critically assessed in terms of limitations and uncertainty.[138]

Concerning the STS, the notion of «unrealistic» primarily stems from assumptions about current societal constraints: a scaling down of emission-intensive parts of our economy

a) destroys established profitable business models,
b) axes current jobs, or
c) clashes with established lifestyle habits,
d) leads to a decline of economic growth rates.

However, given the threat we are facing – a changing global climate with disastrous consequences –, these assumptions must be regarded as challenges that can be overcome, not as arguments against a comprehensive societal transformation as such. The task of the scientific community – including the natural and social sciences – is to inform this debate by presenting a picture of the present and possible futures and helping to find solutions. For example, research in line with a comprehensive societal debate might (a) show that people might profit from changed lifestyle patterns in many regards,[139] (b) encourage restricting the political and economic influence of those who profit from current devastating business models, (c) help to rethink the role of jobs for allowing people to lead a decent life,[140] or (d) tell us in how far economies and societies can be organised that are not dependent on economic growth.[141] All these things are already being debated by

138 Smith, P. et al., 2016. Biophysical and economic limits to negative CO 2 emissions. Nature climate change, 6(1), 42-50.

139 Diener, E. and Seligman, M.E.P., 2004. Beyond Money: Toward an Economy of Well-Being. Psychological Science in the Public Interest, 5(1), 1–31.

140 Koepp, R. et al., 2015. Arbeit in der Postwachstumsgesellschaft. Diagnosen, Prognosen und Gegenentwürfe. Eine kommentierte Literaturübersicht. http://www.kolleg-postwachstum.de/sozwgmedia/dokumente/WorkingPaper/wp6_2015.pdf; Graeber, D., 2018. Bullshit jobs.

141 Lange, S. and Jackson, T., 2019. Speed up the research and realization of growth independence. Ökologisches Wirtschaften, 1, pp. 26-27.

scientists, social movements and some politicians. We are convinced that society can always be reshaped and that the question of what is deemed realistic or preferable greatly depends on societal debate.

In fact, in more and more pockets of societies, people are rethinking not only their own lifestyle but also the general societal agenda towards more production and consumption.[142] In many places, calls for climate justice join forces with struggles for equal rights, workers' rights, social justice, gender and women rights or rights to land. We believe that these movements, in cooperation with progressive politicians, workers, teachers, reporters, farmers, business leaders, government officials etc., can accomplish fast change while taking the time needed for democratic processes. It is the role of science to present possible pathways for these changes.

In the end, we also believe that there is no alternative since the politics of growth are an obstacle not only to reducing consumption and production but to change itself. They rely on and perpetuate an economic system driven by fossil fuels.

142 Examples are the big protests of civil society that have formed around climate summits but since then moved on to become a global movement. Examples are also all the movements of Indigenous People, fighting to preserve their land and way of living.

8 Conclusion

In this study, we set out to explore a different kind of GHG emission mitigation scenario. One that relies not solely on technical change but on a reduction of consumption and production in the Annex I countries. More exactly, a reduction of

- transport by car through an overall reduction of distance travelled, an increase in car occupancy and a change in the modal split
- transport by plane
- ground freight transport
- living space per person
- appliances per person
- food, and specifically meat, consumption.

We believe that these changes cannot come about through responsible consumerism alone but have to be part of a larger, democratically planned socio-economic transformation with the satisfaction of peoples' needs at the centre. We present sketches of how this transformation can come about in Section 7.

Taking into account a very different point of departure for Non-Annex I countries, we assumed an increase in material consumption, leading to levels in line with, or even above, consumption rates of Annex I countries in 2050.

While the focus was on analysing the effect of reducing consumption, the scenario does feature an ambitious technological change path as well. The difference to common mitigation scenarios is the low reliance on negative emission technologies and a phase out of nuclear power.

The climate-related impacts of the measures described above were calculated using the Global Calculator, a much simpler and therefore more transparent modelling tool than IAMs.

The results show that, by reducing consumption in Annex I countries, it is possible to stay within the global carbon budget corresponding to no more than 1.5°C global warming with only a limited amount of ecosystem-based carbon sequestration, no use of so-called «negative emissions» technologies and while phasing out nuclear power.

Hopefully, these findings will start a conversation on the feasibility and desirability of socio-economic-transformation-based scenarios in contrast to technology-focused scenarios. These conversations should be concerned less with the choice, risks and affordability of technologies and more with the question of how society wants to live together in the future. Accordingly, these discussions must be as inclusive as possible for us to not only limit climate change but increase human well-being and achieve a good life for all.

ANNEX 1 – ASSUMPTIONS IN THE MODEL

Reducing road-based passenger transport

Road-based passenger transport

For Annex I countries, we assume a reduction back to 1990 (i.e. a 17% reduction) levels of pkm/person on a linear path from 2020 until 2030 (see Table 7).[143] From then on, we assume a further decrease of 20% until

2050. We assume that 70% of the reduction burden is carried by a reduction in pkm/person in urban areas, where reducing transport is much easier (see below). The remaining 30% reduction is achieved by reducing rural pkm/person.

Table 7: Scenarios of urban and rural transport demand

Variable	Countries		2015	2030	2050
Passenger transport demand (pkm/person/year)	Annex I	Urban	11717	9293	7526
		Rural	25674	24635	23878
	Non -Annex I	Urban	4190	5620	7526
		Rural	1867	11300	23878

For Non-Annex I countries, we assume a catching-up to the transport demand of the Annex I countries by 2050.

Reduction in the share of cars (compared to other modes of transport)

Due to shorter distances and better public transport, we assume a shift away from cars towards hiking, cycling, buses and trains. For urban areas, the share of car transport falls from 64% in 2015 to 12% in 2050. For rural areas the share drops from 84% to 40%.

For the case of urban areas, we assume more ambitious changes in modal split since it is easier there to shift away from car travel. We assume that the modal shift changes from 2020 on and linearly moves towards an average of the 50 «most car-free« cities within Europe (see Table 8). The target is reached for all urban population by

143 Data is collected from the 2017 ITF Transport Outlook 20171 and uses OECD numbers as proxy for those in Annex 1 countries.

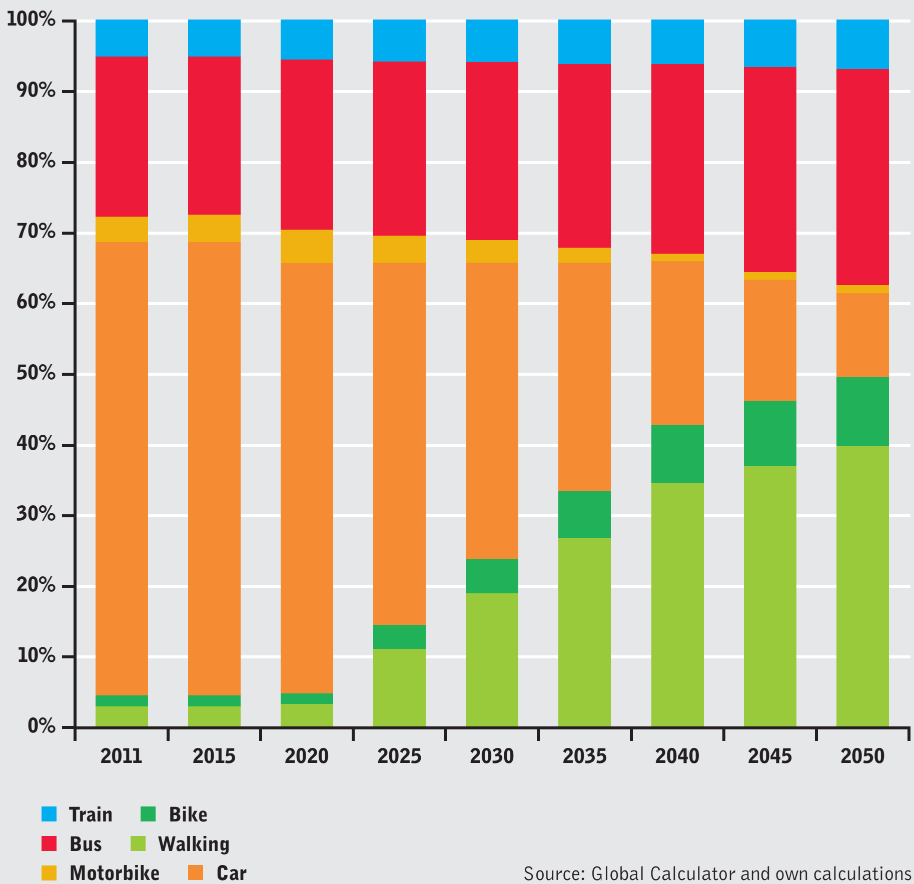
2040. From 2040 to 2050, the car transport share is halved again to represent a shift towards car-free cities in some places. Figure 13 shows the resulting modal split.[144]

Table 8: Average shares for different modes of transport of the 50 European cities with the least car traffic

	Walk	Bicycle	Public transport	Car
Average share	34.5%	8.34%	33.1%	24.08%

Own calculation, data source: http://www.epomm.eu/tems/result_cities.phtml?new=1

Figure 13: Modal share in urban areas for Annex I countries

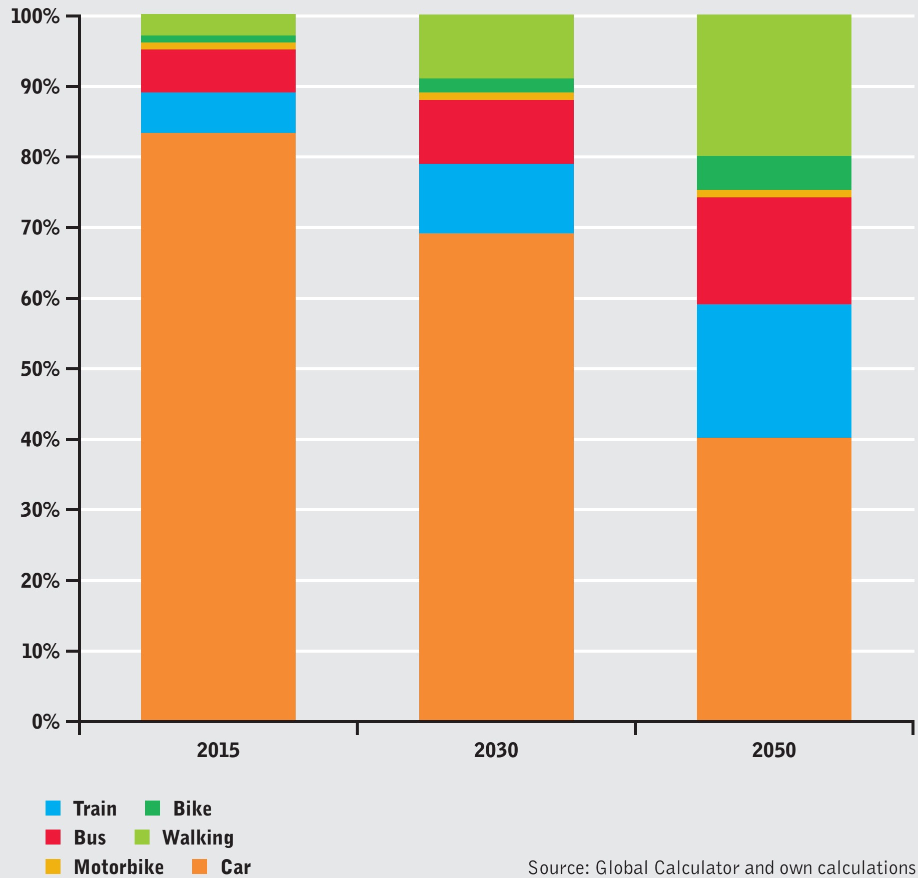


Source: Global Calculator and own calculations

144 The figure only shows the data for the population living in what is called «automobile cities» and «transit cities» in the model.

Due to bigger distances impeding a switch to bicycling/public transport, we assume a less pronounced shift away from car traffic in rural areas. Figure 14[145] shows the resulting modal split in rural areas. We expect an increase in bus traffic to 15%, in train traffic and in walking to 20% and in cycling to 6%. The ratio of motorbikes to cars is kept constant at 2015 levels.

Figure 14: Modal share in rural areas for Annex I countries



Source: Global Calculator and own calculations

Table 9 shows the resulting modal shares in Annex I and Non-Annex I countries for the 2015 situation and the proposed evolution according to our scenario. The average for Annex and Non-Annex I countries were extracted from ITF Transport Outlook 2017[146] for the cases of urban passenger car, rural passenger car and rural passenger train. For Annex I countries, shares of buses and trains are taken from the Statistical Pocketbook

145 The figure only shows the data for the population living in what is called «rural developed» in the model.

146 https://www.oecd-ilibrary.org/transport/itf-transport-outlook-2017_9789282108000-en

2017[147] statistics on transport for the European Union as an approximation. Shares of bicycles and walking are taken directly from the Global Calculator (GC), which features a distinction between urban and rural areas and developed and developing countries. Shares for urban areas in developed countries from the GC are taken for Annex I countries, the rural share in developed countries in GC are applied to the rural shares in Annex I countries. Rural shares in developing countries in the GC are applied to the rural shares in Non-Annex I countries.

Increasing car occupancy

Due to disincentives for car ownership, costly parking spaces and a trend toward car sharing, car occupancy increases from 1.6 (1.8 in rural areas) in 2015 to 2.5 people/car.

The 2015 occupancies are extracted from the GC for Annex I countries. For Non-Annex I countries, occupancies are set at 20% higher than those in Annex I countries. Data on occupancy rates of vehicles is hard to come by in a consistent manner across countries, with most numbers being reported for the particular case of passenger car. In countries of the Global South, we found rates of car occupancy as low as 1.4 for South Africa[148] and as high as 3.1 for India[149]. In Beijing (China), average vehicle occupancy per trip declined from 1.56 in 2000 to 1.26 persons in 2006, indicating an increase in drive-alone car use.[150] Given such heterogeneity, we leverage on data from the AIM (Asia-pacific Integrated Model)/Transport model in Mittal et al 2017.[151] We noted that the differences of car occupancies between the EU25 (proxy for Annex I countries) and regions of Brazil, China and Africa ranged between +5% and +32%. We take, therefore, the somehow intermediate value of +20% as representative of the higher vehicle occupancies in countries of the Global South. We also apply this factor to all vehicle types in the in the GC (e.g., occupancies of buses and trains in Non-Annex I countries are also 20% higher than those in Annex I countries) reflecting the lack of better data for a more informed assumption.

147 https://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2017_en

148 Merven, B. et al., 2012, Quantifying the Energy Needs of the Transport Sector for South Africa: A Bottom Up Model, University of Cape Town.

149 Singh, S., 2006. The demand for road-based passenger mobility in India: 1950-2030 and relevance for developing and developed countries. European Journal of Transport and Infrastructure Research, 6(3).

150 Darido, G., 2009. Urban Transport and CO_2 Emissions: Some Evidence from Chinese Cities (No. 18863). The World Bank.

151 Mittal, S. et al., 2017. Key factors influencing the global passenger transport dynamics using the AIM/transport model. Transportation Research Part D: Transport and Environment, 55, 373-388.

Table 9: Scenario of modal share

		2015	2030	2050
Annex I countries (in %)	Urban passenger car	64	42	12
	Urban passenger train	5	6	7
	Urban passenger bus	22	25	31
	Urban passenger motorbike	4	3	1
	Urban passenger bicycle	1	5	10
	Urban passenger walk	3	19	40
	Rural passenger car	84	69	40
	Rural passenger train	6	10	19
	Rural passenger bus	6	9	15
	Rural passenger motorbike	1	1	1
	Rural passenger bicycle	1	2	5
	Rural passenger walk	3	9	20
Non-Annex I countries (in %)	Urban passenger car	48	45	40
	Urban passenger train	15	16	19
	Urban passenger bus	13	14	15
	Urban passenger motorbike	5	5	1
	Urban passenger bicycle	6	6	6
	Urban passenger walk	12	15	20
	Rural passenger car	24	30	40
	Rural passenger train	20	20	20
	Rural passenger bus	13	13	15
	Rural passenger motorbike	14	11	5
	Rural passenger bicycle	23	20	14
	Rural passenger walk	6	6	6

Table 10: Assumptions for car occupancy

Variable			2015	2030	2050
Occupancies (people/carrier)	Annex I countries	Urban passenger motorbike	1.1	1.2	1.3
		Urban passenger car	1.6	1.9	2.5
		Urban passenger bus	27	29	32
		Urban passenger train	384	417	461
		Rural passenger car	1.8	2.1	2.5
		Rural passenger bus	27	29	32
		Rural passenger train	384	417	461
	Non- Annex I countries	Urban passenger motorbike	1.3	1.3	1.3
		Urban passenger car	1.9	1.9	1.9
		Urban passenger bus	32	32	32
		Urban passenger train	461	461	461
		Rural passenger car	2.2	2.2	2.2
		Rural passenger bus	32	32	32
		Rural passenger train	461	461	461

For our scenario, we assume a linear increase in car occupancy from 2020 to 2050 to 2.5 people/car in both urban and rural areas in Annex I countries. We also assume a 20% increase of passengers in trains and buses. For Non-Annex I countries, we assume occupancy to stay constant from 2015 on.

Passenger aviation

Table 11 shows the average number of flights per person from 1991 to 2018 in Annex I countries[152] and Non-Annex I countries.[153] As can be seen, aviation is unevenly distributed and has seen an increase in Annex I countries and in Non-Annex I countries. For our scenario, we assume a decline of air travel from 2020 on back to one flight per person in 2025 and 0.33 flights per person in 2050. For Non-Annex I countries, we assume a steady increase up to 0.6 flights in 2050. Since aviation is parameterised neither through km travelled nor through number of flights, we used the relative reductions described above to arrive at the following data for pkm:

Table 11: Assumptions for aviation

Variable	Countries	2017	2020	2025	2030	2050
Average number of flights per person	Annex I	1.74	1.8	1	0.5	0.33
	Non-Annex I	0.31	0.35	0.4	0.5	0.55
Average distance travelled by air/person (pkm/person/year)	Annex I	3277.56	3166.45	1759.14	879.57	580.52
	Non-Annex I	622.48	711.05	888.82	977.7	1066.58
Total distance (bil. km)	Annex I	4000.88	4148.05	2304.47	1152.24	760.48
	Non-Annex I	3698.54	4486.74	5608.43	6169.27	6730.11

152 Source: World Development Indicators (World Bank). Annex I excludes the following countries due to data restrictions: Denmark, Estonia, Croatia, Lithuania, Latvia, Norway, Slovak Republic, Slovenia, Sweden, Ukraine.

153 Source: World Development Indicators (World Bank). Due to data restrictions, Non-Annex I countries are represented by: Angola, United Arab Emirates, Argentina, Antigua and Barbuda, Burkina Faso, Bangladesh, Bahamas, The Bolivia, Brazil, Brunei, Darussalam, Bhutan, Botswana, Chile, China, Cameroon, Colombia, Cabo Verde, Costa Rica, Cuba, Algeria, Ecuador, Egypt Arab Rep. Ethiopia, Fiji, Indonesia, India, Iran Islamic Rep. Israel, Jordan, Kenya, Korea, Rep. Kuwait, Lao PDR, Lebanon, Libya, Sri Lanka, Morocco, Madagascar, Mexico, Myanmar, Mozambique, Mauritania, Mauritius, Malawi, Malaysia, Namibia, Nigeria, Pakistan, Panama, Peru, Philippines, Papua New Guinea, Korea Dem. People's Rep, Portugal, Paraguay, Qatar, Saudi Arabia, Sudan, Senegal, Singapore, Solomon Islands, El Salvador, Suriname, Seychelles, Syrian Arab Republic, Thailand, Tonga, Tunisia, Tanzania, Uganda, Venezuela, RB Vietnam, Vanuatu, Yemen, Rep. South Africa, Zimbabwe.

Ground freight transport

Total ground freight transport, including that by road and air rail, amounted to approx. 24,103 Gt-kilometres in 2014, a rise of approx. 59% compared to 1990 (15,098 Gt-kilometres, own calculations based on the OECD transport statistics).[154] For the year 2014, we combine the OECD and Russia figures for freight as a proxy for the ground freight transport demand in Annex I countries and combine those of China and India as representative of Non-Annex I countries.

For Annex I countries, we assume a return to 1990 levels by 2050, meaning a linear reduction by 62%. For Non-Annex I countries, we assume an increase of 20% up to 2050.

Table 12: Assumptions for ground freight transport [Gt/km/year]

	2014	2030	2050
Annex I countries	13258	9735	5038
Non-Annex I countries	10946	11884	13135

The shares of domestic and international transport are taken from the GC and applied to both sets of countries, see Table 13. As we want to represent a re-localization of trade in our scenario, we assume a halving of the share of international travel to 9% of total ground freight transport in Annex I countries. For Non-Annex I countries, we leave the shares constant.

Table 13: Assumptions for domestic vs international ground freight transport

Variable			2014	2030	2050
Share of freight transport (in %)	Annex I countries	Domestic	82	86	91
		International	18	14	9
	Non-Annex I countries	Domestic	82	82	82
		International	18	18	18

154 https://data.oecd.org/transport/freight-transport.htm

Housing

Floor area per person

According to the OECD Family Database, the average OECD household was comprised of 2.6 people in 2011.[155] We assume a doubling of people per household from 2020 up to 2050, accompanied by an increase in house size by 50%, thus decreasing individual living space by 25%. For Non-Annex I countries, we assume a linear convergence of floor space per person, to Annex I levels, by 2050.

For the model, that assumption is translated into a decline of floor area per household since this is the metric used in the model. The values of m2 per household are obtained from the global analysis by Güneralp et al., 2017.[156] For the urban values in Table 14, we assume values of residential floor area per person for countries with an average income above 30,000 US$/year to be representative of Annex I countries and floor area values typically found in countries with an average income below 5,000 US$/year to be representative of Non-Annex I countries.

Table 14: Assumptions for floor area per household

Variable			2014	2030	2050
Floor area of households (m2/person)	Annex I countries	Urban	89.9	78.7	67.4
		Rural	101.6	88.5	75.8
	Non-Annex I countries	Urban	53.2	59.5	67.4
		Rural	60.1	67.1	75.8

Number of appliances (units/household)

The model covers the following appliances: refrigerators, dishwashers, washing machines, tumble dryers, TVs. We suggest keeping the number of appliances/household steady. Since we assume a doubling of people per household, the number of appliances per person is halved.

At the same time, we double appliance usage (except refrigerators, which run 24 hours anyway and no full doubling for televisions since they can be shared) and double their durability. The resulting effect is a reduction in appliance production.

For Non-Annex I countries, we assume no change in the number of appliances per household.

155 OECD, 2011. Doing Better for Families, https://www.oecd.org/social/soc/doingbetterforfamilies.htm, p. 19.

156 Güneralp, B. et al., 2017. Global scenarios of urban density and its impacts on building energy use through 2050. Proceedings of the National Academy of Sciences 114.34 (2017), 8945-8950.

Food sector

Food consumption and diet

For Annex I countries (see Table 15), the 2014 total food consumption is equated to the average of developed countries, 2748 kcal/person/day, taken from the OECD Agricultural Outlook 2015-2024.[157] From the same report, we calculate the average calorie consumption in Non-Annex I countries by taking the average between the «least developed» and developing countries, amounting to 2276 kcal/person/day. For Non-Annex I countries in the STS, we assume that calorie consumption remains at this average level, and by 2050, the calorie consumption per person still stands at 2276 kcal/person/day. For Annex I countries, we assume a reduction of food production that either stems from reducing calorie intake per person to 2100 kcal/day, which is in line with the WHO guidelines, or from a reduction of food waste, which is otherwise not represented in the model.

Table 15: Assumptions for total calorie consumption

Variable		2014	2030	2050
Calorie consumption (kcal/person/year)	Annex I countries	2748	2424	2100
	Non-Annex I countries	2276	2276	2276

Meat consumption in Annex I and Non-Annex I countries is shown in Figure 15 and Table 17. The figure shows average meat consumption in kcal per day per person in the world, in Annex I countries and in countries with a healthy diet (Chad, Guyana, Mali, Myanmar, Turkey, India) according to a Lancet report.[158] For the STS, we assume a reduction of meat consumption in the Annex I countries to 135 kcal/day and person by 2030 and constant levels of meat consumption from then on. 135 kcal/day corresponds to roughly 54g per day. For Non-Annex I countries, we assume no change in meat consumption. For this category, values of meat consumption for 2013 stood at about 173 kcal/person/day. The values were obtained as weighted population averages for the regions of Africa, Asia and South America from the FAO Food Balance Sheets in the FAOSTAT database.

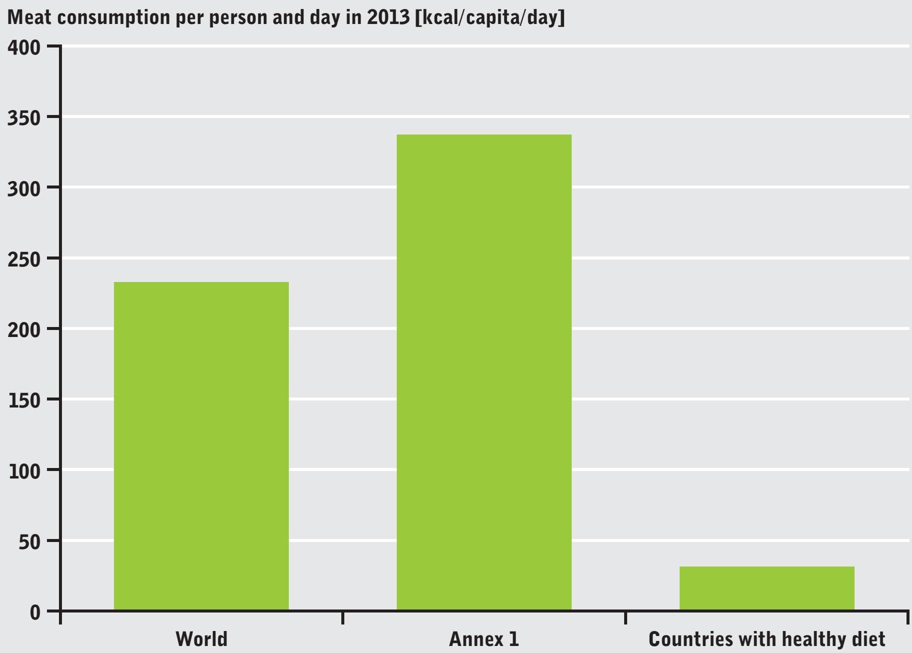
157 http://www.fao.org/3/a-i4738e.pdf

158 Dietary quality among men and women in 187 countries in 1990 and 2010: a systematic assessment

Table 16: Assumptions for meat calorie consumption

Variable		2013	2030	2050
Calorie consumption (kcal/person/year)	Annex I countries	344	135	135
	Non-Annex I countries	173	173	173

Figure 15: Meat consumption per person for the world, Annex 1 countries and countries with a healthy diet (population-weighted averages)



Source: own calculations, based on http://www.fao.org/faostat/en/

Ruminant meat

For GHG emissions, the kind of meat is important. Ruminant meat, such as beef, is more CO_2 intensive than non-ruminant meat, such as pig and poultry. For Europe, the US and Canada, the share of beef calories in total meat calories was about 21% in 2013, see Table 17. We assume a linear reduction of the share of ruminant meat to 10% in 2050.

For Non-Annex I countries, we keep the share constant to 2013. We approximate this value of ruminant shares in the total meat calories as the weighted population average of Africa, South America and Asia, resulting in approx.14%. The data used was extracted from the FAO Food Balance Sheets in the FAOSTAT database.[159]

Table 17: Scenario of ruminant shares of meat calorie consumption

Variable		2013	2030	2050
Share of meat from ruminants (%)	Annex I countries	21	16	10
	Non-Annex I countries	14	14	14

Technology, agriculture and land use parameters

The following table shows our assumption for technology, agriculture and land use in detail. For a detailed description of the parameters, we refer to Global Calculator documentation.[160]

Table 18: Technological assumptions of the STS

	2011	2050	GC level
Transport			
Efficiency for passenger car with internal combustion engine (litres of gasoline equivalent (lge) per 100 km)	8.6	4.3	3
Efficiency for car with electric engine (lge per 100 km)	2.4	1.9	3
Freight efficiency -domestic light truck (lge per 100 km)	10	5.1	3
Freight efficiency – international plane (lge per 100 km)	1200	648	3
% urban passenger cars that are either hydrogen or electric	0	35	3
% urban passenger trains powered by electricity	90	97	3
% light freight vehicles with zero emissions (electric and hydrogen)	0	25	3
% light freight vehicles with zero emissions (e.g., hybrid)	0	15	3
Buildings and appliances			
Rate of heat loss for urban homes (Gigawatt/(Million hectare °C)	17	6	3
Rate of heat loss for rural homes GW/(M ha)	19	6	3
Rate of heat loss for non-residential buildings GW/(M ha)	15	6	3

159 http://www.fao.org/faostat/en/#data/FBS
160 http://www.globalcalculator.org/

% of space heating using low-carbon technologies (heat pumps and solar)	2	45	
% of space cooling using solar cooling	0	15	3
% of hot water systems using solar hot water	3	50	3
% of cooking stoves using electricity	20	68	3
% of LED light bulbs	0	50	3
Power used by average urban TV (Watt)	250	192	3
Power used by average urban refrigerator (Watt)	66	40	3
Manufacturing			
Proportion of products that would have been made of steel in 2011but are made of timber instead	0	3.5	3
Proportion of products that would have been made of steel in 2011 but are made of aluminium instead	0	1	3
Proportion of products that would have been made of steel in 2011 but are made of plastic instead	0	0.5	3
Proportion of products that would have been made of cement in 2011 but are made of timber instead	0	8	3
Proportion of products that would have been made of cement in 2011 but are made of plastic instead	0	2.5	3
Improvements in the energy efficiency of current traditional steel blast furnace production processes (% reduction in energy required to produce 1 tonne steel, compared to 2011)	0	7	3
Improvements in the energy efficiency of current primary aluminium production processes (% reduction in energy required to produce 1 tonne aluminium, compared to 2011)	0	5	3
Improvements in the energy efficiency of current recycled aluminium production processes (% reduction in energy required to produce 1 tonne aluminium, compared to 2011)	0	5	3
Switch to different High Value Chemical production processes, causing a reduction in the energy required to produce HVCs (% reduction in energy required to produce 1 tonne HVC, compared to 2011)	0	10	3
Improvements in the energy efficiency of current HVC production processes (% reduction in energy required to produce 1 tonne HVC, compared to 2011)	0	10	3
Improvements in the energy efficiency of current ammonia production processes (% reduction in energy required to produce 1 tonne ammonia, compared to 2011)	0	15	3

Improvements in the energy efficiency of current methanol production processes (% reduction in energy required to produce 1 tonne methanol, compared to 2011)	0	15	3
Switch to different virgin paper production processes, causing a reduction in the energy required to produce virgin paper (% reduction in energy required to produce 1 tonne paper, compared to 2011)	0	10	3
Improvements in the energy efficiency of current virgin paper production processes (% reduction in energy required to produce 1 tonne paper, compared to 2011)	0	30	3
Improvements in the energy efficiency of current recycled paper production processes (% reduction in energy required to produce 1 tonne paper, compared to 2011)	0	30	3
Global captured emissions through CCS	0	0	1
Greenhouse gas removal (Gt CO_2/year)	0	0	1
Power generation			
Global average % increase in energy crop yield, compared to 2011	0	20	1
Global average energy crop yield (W per m2)	0.38	0.46	1
Global average energy crop mass yield, if energy crop in the form of woody energy crops (18 Megajoule per kg measured as Lower Heating Value (LHV))	7	8	1
Global average % of total bioenergy as liquid	40	20	1
Global average % of total bioenergy as solid	60	80	1
Share of coal (and possibly biomass)	61	0	3
Share of oil	7	0	3
Share of natural gas	32	100	3
% of coal (possibly biomass) fuel plants that are most efficient (either ultra-supercritical or supercritical)	25	50	3
% of oil fuel plants that are most efficient	30	65	3
% of natural gas fuel plants that are most efficient (combined-cycle gas turbines)	65	100	3
GW of nuclear power capacity	364	0	1
GW of wind power capacity	238	4710	4
TWh of wind electricity generated annually (net)	440	13184	4
GW of hydroelectric power capacity	970	2101	4

TWh of hydroelectric electricity generated annually (net)	3656	7919	4
GW of marine power capacity	0.5	237	4
TWh of marine electricity generated annually (net)	1	623	4
GW of total solar power capacity	71	4149	4
TWh of total solar electricity generated annually (net)	63	10400	4
GW of electricity storage capacity	11	289	4
TWh of geothermal electricity generated annually (net)	73	2153	4
GW of electricity storage capacity	120	800	4
Land and food			
Global average crop yield increase (% of 2011 yield)	100	100	1
Global average yield of food energy harvested from food crops (W/m2)	0.1	0.1	1
Global average % of cows and other bovine meat from animals in confined systems.	6	0	1
Global average proportion of sheep and goat meat from animals in confined systems.	1	0	1
Feed conversion efficiency of cows and other bovines in confined systems (% of biomass input energy converted to meat energy)	5	5	1
Feed conversion efficiency of sheep and goats in confined systems (% of biomass input energy converted to meat energy)	5	5	1
Feed conversion efficiency of poultry in confined systems (% of biomass input energy converted to meat energy)	24.4	24.4	1
Feed conversion efficiency of pigs in confined systems (% of biomass input energy converted to meat energy)	27.1	27.1	1
Feed conversion efficiency of milk from cows produced in confined systems (% of biomass input energy converted to milk energy)	7.8	7.8	1
Feed conversion efficiency of eggs from confined systems (% of biomass input energy converted to egg energy)	13	13	1
Global average number of cows and other bovine per hectare of pasture	0.6	0.6	1
Global average number of sheep and goats per hectare of pasture	3.1	3.1	1

Feed conversion efficiency of pasture fed beef cows and other bovine (% of biomass input energy converted to meat energy)	2	2	1
Feed conversion efficiency of pasture fed sheep and goats (% of biomass input energy converted to meat energy)	2	2	1
% of on-farm crop residues that are collected for energy generation	10	10	1
% of harvested crop energy content that is wasted along the food value chain (between the farm and consumption)	24	10	1
% of meat energy content that is wasted along the food value chain (between the farm and consumption)	19	5	1
% of energy from wasted harvested crops collected or bioenergy	1	30	1
% of energy from wasted meat collected or bioenergy	1	30	1
% of energy from wasted dairy products collected or bioenergy	0.1	10	1

ANNEX 2 – ON CO_2 SEQUESTRATION THROUGH ECOSYSTEM-BASED APPROACHES AND THE FALLACY OF «NET-ZERO»

Climate-just ecosystem-based approaches in the land sector

There is a vivid scientific and political debate around the potential of ecosystem-based approaches and other climate-just approaches in the land sector to contribute to the goal of limiting global warming to 1.5°C.[161] An important study from a climate justice perspective is the 2018 «Missing Pathways to 1.5°C – The role of the land sector in ambitious climate action«, published by the Climate, Land, Ambition & Rights Alliance (CLARA).[162] The report looks into the mitigation and carbon sequestration potential in transforming agriculture and in protecting and carefully restoring forests and other natural ecosystems.

It shows how ecosystem-based approaches in the land sector and agro-ecological system changes in food production and consumption could deliver over 13 Gt CO_2eq/year in avoided emissions, and almost 10 Gt CO_2eq/year in carbon sequestered into the biosphere by 2050. A key priority identified in the report is to strengthen community-based tenure systems as community-managed lands and forests continue to protect large amounts of carbon stored in them as carbon stocks.[163]

Those three key pillars build on the following more specific climate-just mitigation and adaptation strategies in the land sector.

Strengthening indigenous and community land rights

Over 1000 Gt CO_2 are stored in collectively managed lands across all forest biomes. This figure, in fact, represents only a fraction of the carbon currently stored in collectively managed land as data is lacking for large areas. Indigenous peoples and local communities are frequently at the forefront of fighting deforestation through commodity

161 See Griscom, B.W. et al., 2017. Natural Climate Solutions, PNAS, 114(44), 11645-11650 for the academic work that contributed to kickstarting the discussion on NBS potentials in the climate context; today many research programmes, international conferences and multilateral and business initiatives exist in the area of NBS.

162 CLARA is an international civil society network of organisations and movements working for a rights-based and ecosystem-based approach to climate change mitigation in the land sector. Report: Dooley, K. and Stabinski, D., 2018. Missing Pathways to 1.5°C: The role of the land sector in ambitious climate action, Climate Land Ambition and Rights Alliance, https://www.climatelandambitionrightsalliance.org/report. The remainder of this subsection draws on data and information from the CLARA «Missing Pathways» report.

163 Dooley and Stabinski, 2018, ibid, p. 3.

agriculture and mining. Indigenous and community-based forest management has protected many forest ecosystems for centuries and has also safeguarded biodiversity, food security and livelihoods of people and communities while protecting the carbon stored in those forests. Yet, land tenure rights are often insecure. A key first step is therefore to strengthen and secure indigenous and community land rights.[164]

Restoring forests and other ecosystems

Further loss and degradation of primary forests, peatlands and grasslands through conversion into croplands needs to be halted immediately. Protecting existing ecosystems must be the first priority in addressing the climate and biodiversity crises because of the carbon they store, which must not be released into the atmosphere. Biodiverse natural ecosystems are also integral to climate change adaptation.

Furthermore, there is potential in carefully and ecologically restoring degraded ecosystems. Allowing secondary forests to fully recover to primary forest is the best mitigation strategy. This recovery must include longer rotation times and reduced harvest rates. Importantly, the sequestration potential of ecosystem restoration can be achieved without any need for additional land.

Expanding the area of natural forest is a third key strategy. Restoring forest cover is particularly important for buffering remaining primary forests and helps in expanding the area of intact primary forests. From climate and biodiversity perspectives, natural or assisted regeneration of native forests is the most effective intervention. Monoculture tree plantations, in contrast, have much lower rates of sequestration, higher risks of reversal (when sequestered CO_2 is released back to the atmosphere through forest fires, for instance) and are also of lower value for livelihoods and sustenance for local communities.[165]

Transforming agriculture

A shift from industrial agriculture to, broadly speaking and used in the CLARA report in a holistic sense, agro-ecology allows much greater emissions reductions and sequestration potential in agriculture. Emissions from agriculture can be reduced through agro-ecological approaches to food production, reduction in the deployment of synthetic nitrogen fertilizer and rice cultivation changes that reduce methane emissions. Another significant mitigation option is changing the way meat and dairy are produced. The overall thrust would be to produce less and better livestock by limiting feed production and relying on natural grassland and food waste to feed livestock («ecological left-overs approach«). This thrust implies reducing the total number of livestock, and thereby the amount of meat and dairy produced and consumed.

Further emissions reductions come from healthier diets (and thus lower quantities of meat, dairy and overall calorie intake, similar to the assumptions made in the

164 See Part 1, pp. 5ff. of the CLARA «Missing Pathways to 1.5°C» report.
165 See Part 2, pp. 9ff. of the CLARA «Missing Pathways to 1.5°C» report.

STS), which also make arable land available for restoration or food-system change. Transforming food systems would include reducing food loss and waste, reducing food miles, and reducing fossil-fuel heated greenhouses.

Furthermore, where agro-forestry is possible, the integration of trees into agricultural landscapes can sequester CO_2 and increase agro-biological diversity.[166]

Limitations of modelling ecosystem-based approaches

Many of the rights-based and ecosystem-based approaches in the land sector cannot be modelled by the Global Calculator (or by any IAM, for that matter). This limitation is notably true for the shift towards agro-ecological practices, strengthening of communal land rights to protect existing carbon-rich ecosystems, and the restoration of complex natural ecosystems. However, bottom-up and qualitative research such as the CLARA «Missing Pathways to 1.5°C» report shows that these approaches are clearly feasible and ready to be implemented, and that CO_2 sequestered in natural, biodiversity-rich ecosystems is stored more stably than, for instance, that in monocultured forest plantations.[167]

However, there are legitimate concerns around ecosystem stability and, by implication, around any CO_2 stored in natural ecosystems. One set of concerns has to do with uncertainty of climate change impacts (such as floods, droughts and fires) and how they will affect the stability and integrity of our ecosystems.[168] The other set of concerns is political: A natural forest ecosystem (or indeed any other natural ecosystem) may be restored in a particular land area or region today, but there is little guarantee that future political (or economic) decisions will not reverse any progress made.

Hence, as much as we support – and think that we urgently need – ecosystem-based approaches to address the intertwined crises of climate change, biodiversity loss, species extinction, ecosystem and soil degradation, food insecurity, hunger and malnutrition, we would caution against using those approaches as a substitute for drastic mitigation action today. From our perspective, the potential of natural ecosystems – both their protection and careful restoration – is best viewed as a buffer, as a safety net.

For both reasons – because it is not possible to fully incorporate the potential of ecosystem-based approaches into the STS and because we are wary of them being used as a substitute for emissions reductions, we deliberately chose to underestimate the potential of ecosystem-based approaches to reduce CO_2 in the STS. Instead, we show that limiting global warming to 1.5°C is possible without large-scale «negative emissions» and other geoengineering technologies.

166 See Part 3, pp. 21ff. of the CLARA «Missing Pathways to 1.5°C» report.

167 Dooley and Stabinski, 2018. Missing Pathways to 1.5°C.

168 Seddon, N. et al., 2020. Understanding the value and limits of nature-based solutions to climate change and other global challenges, Phil. Trans. R. Soc. B 375: 20190120.

The fallacy of «net-zero« and land-based geoengineering

Governments, multilateral initiatives, but also corporate actors increasingly propagate so-called «Natural Climate Solutions« or «Nature-Based Solutions« (NBS) as a solution to the climate crisis. In the context of the rising tide of net-zero plans and pledges,[169] there is a specific risk of NBS being used as a replacement for actual mitigation of fossil and industrial emissions. The concept of «net-zero» risks watering down climate ambition by betting on so-called «negative emissions» generated through what is packaged as Nature Based Solutions, or through technological Carbon Dioxide Removal (CDR), a set of geoengineering technologies, to compensate for GHG emissions rather than drastically reducing them.

Also, not all of what is packaged as a «Nature Based Solution» is actually good for the climate or for biodiversity. Large-scale monocultural afforestation, or Bioenergy with Carbon Capture and Storage (BECCS), for instance, do not actually work with nature or natural ecosystems, but tend instead to further their destruction.[170] Furthermore, NBS can lead to corporate greenwashing, harmful offsetting practices and landgrabbing.[171] So, caution is in order when approaching the NBS field as well as the concept and implementation of «net-zero» pledges and plans.

Finally, a note on technological Carbon Dioxide Removal (CDR): None of the proposed geoengineering technologies to remove CO_2 from the atmosphere at scale are currently available or ready to deploy. It is further uncertain whether any of them will ever exist, and if they were available whether they would all be able to remove CO_2 from the atmosphere if full life-cycle emissions are accounted for.

All of the proposed CDR technologies involve large-scale consumption of resources such as those from energy, land, water and minerals. To remove CO_2 from the atmosphere at orders of magnitude as envisioned in many of the IAM models, new transnationally operating mega-industries would have to be set up. The amount of energy and resources consumed by such carbon-removing industries, and the emissions associated with them, are likely to wipe out any potential reductions in atmospheric CO_2 concentrations.

Geoengineering technologies as approaches to fixing the climate crisis are also fundamentally unjust. They shift the burden of the risks and adverse impacts of those technologies onto those who are already impacted the most by climate change and who have contributed the least to causes of the problem. The huge requirements of land, water, energy and other natural resources would impact millions of people's

169 For an overview, see Institute for Carbon Removal Law and Policy, 2020. Carbon Removal Corporate Action Tracker, https://docs.google.com/spreadsheets/d/1vf--uXsf6fo7MuNpPya2Kz82Dxte0hHgtOXimgpRA3c/edit#gid=0 (last accessed 14 October 2020).

170 Biofuelwatch and Heinrich Boell Foundation, 2017. The risks of large-scale biosequestration in the context of Carbon Dioxide Removal, https://www.boell.de/en/2017/10/11/risks-large-scale-biosequestration-context-carbon-dioxide-removal

171 For a more encompassing analysis of the fallacies and problems associated with NBS, see Third World Network and African Centre for Biodiversity, 2020. Nature-based solutions or nature-based seductions?, https://www.acbio.org.za/sites/default/files/documents/202009/twn-briefing-paper.pdf food security and their access to land and water and would likely spark further conflicts over land and resources, while at the same time providing the perfect excuse for polluting industries to further impede and delay the transition to a climate-just future.[172]

Regarding technological feasibility, it is also worth highlighting that many CDR technologies rely on Carbon Capture and Storage (CCS). CCS is still not available at scale and is currently economically viable only in the context of Enhanced Oil Recovery (EOR), which is the initial purpose of this technology as developed by the oil industry: EOR, also called tertiary oil recovery, is a process by which gases (such as CO_2) are injected into almost-depleted oil reservoirs with the aim of flushing out the last barrels for oil production. For obvious reasons, the result is more CO_2 emission rather than less. It is also eminently unclear whether it will be possible to permanently store CO_2 in the geological formations envisaged for it and to what extent leakages, earthquakes and ground water contamination, amongst other potential side effects, will occur.[173]

For all of these reasons, we are firmly opposed to geoengineering and its promotion as a solution to the climate crisis and have therefore excluded any geoengineering technology from our model – including CCS.

172 For an in-depth analysis of CDR technologies, their impacts and problems, see: ETC Group, Biofuelwatch and Heinrich Boell Foundation, 2017. The Big Bad Fix. The Case Against Climate Geoengineering, https://www.boell.de/en/2017/12/01/big-bad-fix-case-against-geoengineering, in particular Chapters 2 and 4; and Center for International Environmental Law (CIEL), 2019. Fuel to the Fire: How Geoengineering Threatens to Entrench Fossil Fuels and Accelerate the Climate Crisis, https://www.ciel.org/wp-content/uploads/2019/02/CIEL_FUEL-TO-THE-FIRE_How-Geoengineering-Threatens-to-Entrench-Fossil-Fuels-and-Accelerate-the-Climate-Crisis_February-2019.pdf

173 GeoengineeringMonitor, 2020. Technology Briefing: Carbon Capture Use and Storage, http://www.geoengineeringmonitor.org/2020/10/carbon-capture-and-storage/

ECONOMIC + SOCIAL ISSUES
VOLUME 23

A Societal Transformation Scenario for Staying Below 1.5°C

To stop climate change, we have to limit global warming to 1.5°C. But can we still achieve this target? And if so, what pathways can society take in transiting towards a climate-just economy? One important yardstick emerging from it was the need for global emissions to reach net-zero by 2050, the Intergovernmental Panel on Climate Change (IPCC) says in his «Special Report on Global Warming to 1.5°C». One important problem with this and other scenarios is that virtually all rely on continued global economic growth.

The Heinrich Böll Foundation and the Konzeptwerk Neue Ökonomie realised the importance of broadening the discussion's perspective and considering societal pathways that are currently not included in either the IPCC reports or the public debate. Together with researchers from engineering and the natural and social sciences, Heinrich Böll Foundation and Konzeptwerk Neue Ökonomie developed a «Societal Transformation Scenario» for this publication – a global climate mitigation scenario that explores the climate effects of limiting global production and consumptions and of envisioning a broader societal transformation to accompany these transformations to reach a good life for all.

Heinrich-Böll-Stiftung
The Green Political Foundation
Schumannstraße 8, 10117 Berlin
030 285340 info@boell.de www.boell.de