The Next Generation Policies Project

Policy Brief No. 1

Climate Change: Overview of state of research

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Key Points

- The Paris Agreement set the goal to limit global warming to well below 2°C or even 1.5°C to contain the risk of major disruptions to the Earth System ("Tipping Points").
- Global warming is roughly proportional to cumulative CO_2 emissions over time. The 1.5°C and 2°C limits imply remaining CO_2 budgets of about 320 and 1070 $GtCO_2$, respectively.
- The current climate policy commitments ("Nationally Determined Contributions" (NDCs)) by nation states are at least 10 $GtCO_2$ too high to put the World on track towards the well-below 2°C target.
- CO_2 emissions have to become net-zero around mid-century for the 1.5°C target, and only a few decades later for the well-below 2°C target.
- Demand sectors, in particular transportation and industry, account for around three fifth of energy related CO_2 emissions. They present major bottlenecks for reducing emissions and reaching the CO_2 neutrality requirement.
- For passenger mobility, electrification is the most important mitigation option. In addition, also technical efficiency improvements, demand and life-style changes can play an important role.

1. Global warming as defining challenge for humanity

Scientific evidence shows that the increase in global average temperature observed in the 20th and 21st century (so-called global warming) is the result of human activity, whereas global warming induced by natural phenomena such as solar or volcanic activity is negligible (less than ±0.1°C) (IPCC SR1.5). Overall, human-induced warming is assessed to have reached approximately 1°C above pre-industrial levels in 2017 and is likely to reach 1.5°C between 2030 and 2052 at current warming rates (Fig. 1) [1].

2. Impacts and tipping elements in the climate system

Climate change is a major threat to human well-being and ecosystems. A particularly important concern are tipping points in the earth system. Tipping elements describe components that are characterized by a threshold behavior: Once operating near a threshold, these components can be tipped into a qualitatively different state by small perturbations [2]. Also, threshold behavior is often based on self-reinforcing processes which, once tipped, can continue without further human interference. It is thus possible that the new state of a tipping element persists, even if the background climate falls back behind the threshold [3]. Tipping elements can be grouped into three main clusters, i.e. melting ice bodies, changing circulations of the ocean and atmosphere, and threatened large-scale ecosystems [2] with each of them sensitive to a critical point of global mean temperature rise (Fig. 1). A global mean temperature rise of 1.5 or 2°C may lead to exceeding a number of thresholds. For instance, a global temperature rise by slightly less than 2°C may cause a complete loss of the West Antarctic and Greenland ice sheets [4], committing the World to more than 10 m of sea-level rise in the long term.

3. Economic damages from climate impacts

Beyond tipping points in the geophysical Earth System, warming also induces direct economic damages, e.g., due to decreased labor productivity or impacts on physical capital. The key metric for such economic damages are the "social costs of carbon", defined as the economic climate damage caused by each additional ton of CO_2. In the last assessment report of the IPCC, SCC were assessed, with estimates ranging from 10-160 US$/$tCO_2$ [5]. The very high uncertainty was due both to a limited understanding of the incidence of impacts on economic sectors, and relevant value judgements such as the weighting of the welfare of future generations against the present.

In recent years, advanced empirical estimates based on large collections of local temperature and indicators of economic activity have brought substantial progress in economic climate impact research. A seminal study by Burke et al. [6] found indications that warming not only impacts economic activity at a given point in time, but also economic growth, suggesting more severe and longer-lived impacts than assumed. Such persistent economic impacts translate to social costs of carbon of around 80-150 $/$tCO_2$ (PIK, own estimates), or even several hundred dollars per ton CO_2 if regional heterogeneity in socio-economic vulnerability is accounted for [7].

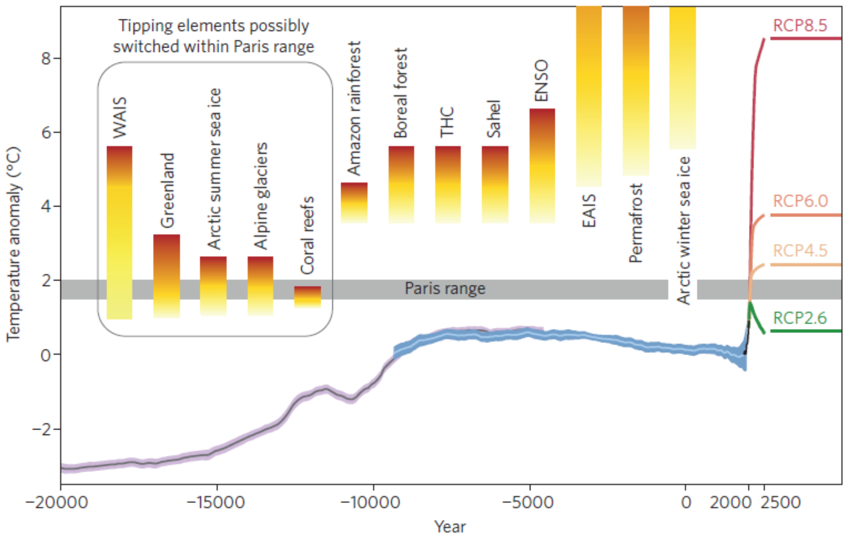

Figure 1: Surface mean temperature in the last 20k years and predictions according to different scenarios for the near future. The values are subtracted by the average temperature in the last 10k years. A grey bar indicates the temperature range associated with the Paris agreement. Bars indicate the temperature ranges for different tipping elements in the Earth System with colors ranging from yellow (low probability) to dark red (very likely). Source: [4].

4. Remaining carbon budget

To avoid dangerous climate change, 196 nations decided in Paris in 2015 to limit global warming to well below 2°C while pursuing efforts to limit it to 1.5°C ("Paris Agreement"). The remaining carbon budget (i.e. the estimated cumulative net global CO_2 emissions from 2018 to the time that CO_2 emissions reach net zero) for limiting global warming to below 1.5°C is estimated to approximately 320 gigatonnes (Gt) of CO_2 - or 10 years worth of current emissions [1]. The budget for staying below the 2°C threshold is approximately 1070 Gt of CO_2 - or 26 years of current emissions. On the operational level this means that for limiting global warming to below 1.5°C, global CO_2 emissions need to be reduced by around 45% from 2010 levels by 2030, and reach net zero in around 2050. For limiting global warming to below 2°C CO_2 emissions need to decline by about 20% from 2010 by 2030 and reach net zero around 2075 [1].

5. Nationally determined contributions

To achieve the long-term goals of the Paris Agreement, countries adopted the so-called nationally determined contributions (NDCs) that document their planned efforts to reduce emissions and adapt to the impacts of climate change. However, current NDCs are not sufficient to reach the Paris goals (Fig. 2) [9]. GHG emissions reached a record high in 2017 [8] and the gap between emission levels consistent with NDC implementation and those consistent with the 2°C and 1.5°C targets is larger than ever, i.e. 13 and 29 $GtCO_2$ respectively. Also, global emissions are not expected to decline within the next decade under the NDCs. Nations would need to triple their ambition levels to achieve the 2 °C target and make five times the current effort if they are to achieve no more than a 1.5 °C increase in global temperature [10].

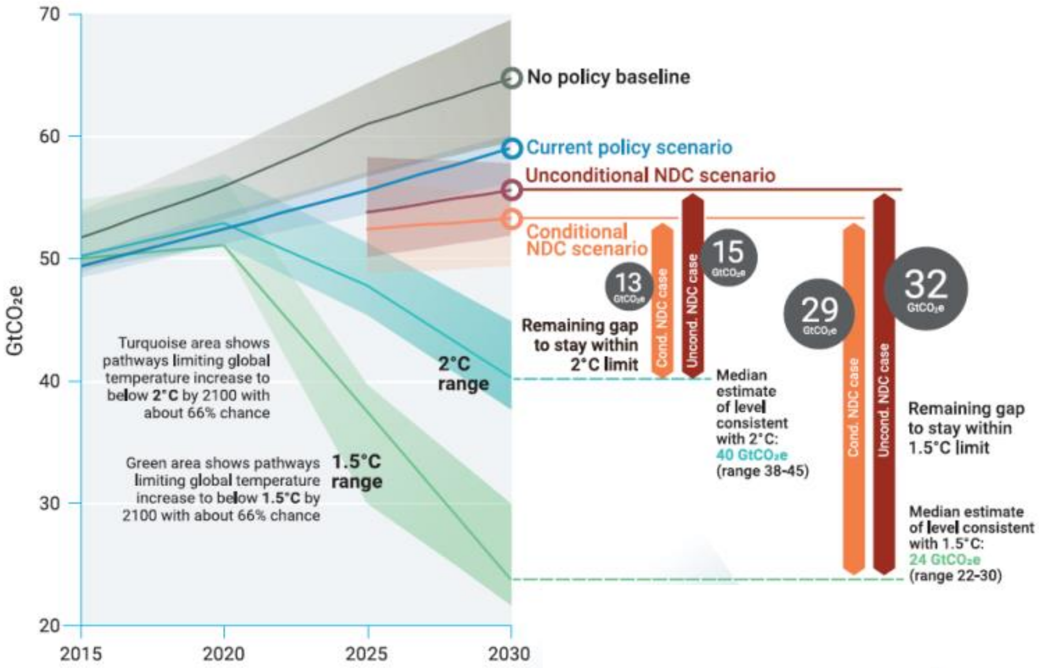

Figure 2: CO_2 emission trends without climate policies, a continuation of current policies and efforts pledged by countries under the Paris Climate Agreement ("Nationally Determinend Contributions (NDC)"). Currrent and planned efforts are much weaker than required to put the world on track towards limiting global warming to 2°C stabilization or even 1.5°C (blue and green ranges). Source: UNEP Emissions Gap Report [10].

6. Sectoral perspective

Currently, the energy supply sector, predominantly electricity generation, accounts for 42% of global energy-related CO_2 emissions. Transportation is the most important source of emissions on the demand side, accounting for 24% of CO_2 emission (Fig. 3).

Overall, more and cheaper emission reduction options exist on the supply side, in particular by replacing fossil-based power supply with renewables, see Fig. 3. With 2°C and 1.5°C scenarios requiring net-zero emission around 2050, however, both technological and behavioral transformations on the demand side become inevitable [1], [11].

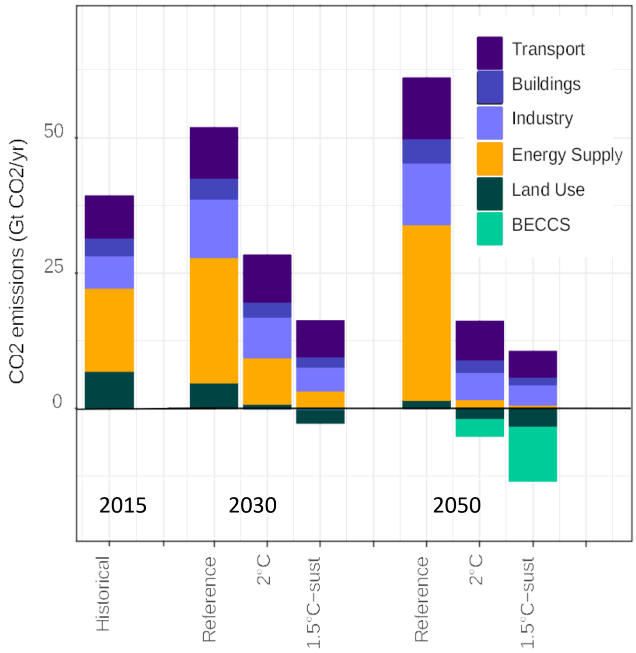

Figure 3: CO_2 emissions by sector in REMIND (BECCS = bio energy with carbon capture and storage). Climate policies lead to strong reductions on the supply side, leaving contributions from consuming sectors almost unchanged. The three scenarios describe a continuation of current policies (Reference), well below 2°C stabilization (2°C), and 1.5°C stabilization with additional sustainability policies (1.5°C-sust) [12].

As the increasing penetration of renewables decreases emissions from power supply, the transportation and industry sectors are the most important determinants of the remaining CO_2 emissions under climate policies.

Despite very strong climate change policy efforts in 1.5°C scenarios, residual cumulative fossil emission remain at around 1000 $GtCO_2$ (Fig. 4). These residual CO_2 emissions exceed the remaining CO_2 budget for the 1.5°C target by as much as 600 $GtCO_2$ or more, and thus need to be compensated by a corresponding amount of negative emissions, e.g. from combining bioenergy use with CCS, or afforestation. Negative emissions technologies are, however, subject to major sustainability concerns, mainly due to their demand for land for either energy crop production or afforestation, and the resulting competition with the food demands of a growing population [13].

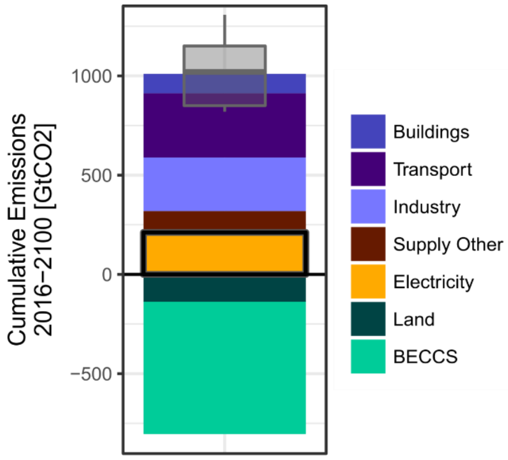

Figure 4: Cumulative CO_2 emissions in the years 2016-2100 for different sectors based on an ensemble of six climate change mitigation scenarios limiting warming below 1.5°C. The grey shaded box indicates median and 16th–84th percentile range across different models [11].

7. Transport sector emissions trends

Transport sector emissions have grown by 2.5 % per year since 2010 and almost doubled since 1990 (Fig. 5). They show the fastest growth rates of all sectors. With the exception of a temporary stabilization in the years 2008 – 2013 in the EU and the US due to tighter fuel standards (e.g., Directive 2003/17/EC in the EU, EPA Tier 2 in the US), the growth in emissions from transport is driven mainly by GDP growth explaining 80-90% of variations. Moreover, it is the least diversified sector in terms of energy demand: 92% of the energy is supplied by oil products (IEA, 2017a). In terms of transport modes, emissions from road transport account for three quarters of the total emissions, see Fig. 5. Thereby, light duty vehicles emit roughly twice as much as trucks in total (Chapman, 2007).

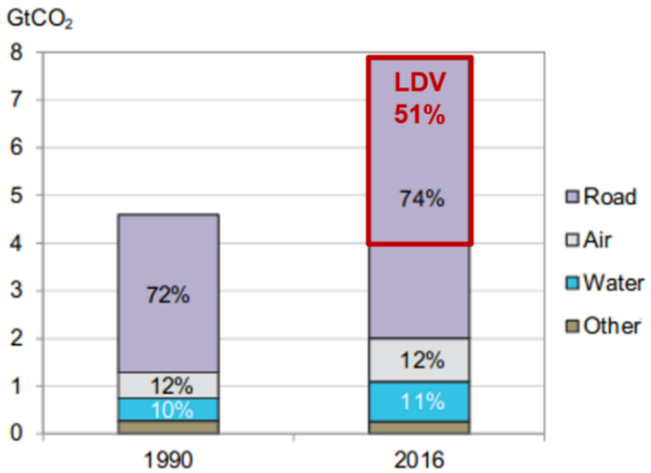

Figure 5: CO_2 emissions in the transport sector by mode. The total contribution almost doubled with respect to 1990. The largest portion of emissions can be attributed to road transport. Source: International Energy Agency (2018).

By midcentury, the IEA projects roughly a doubling of the global number of light-duty vehicles, driven by rising affluence especially in China, India, and South-East Asia. The demand for freight transport (road, rail, shipping, and air) and passenger aviation will increase by at least one half.

8. Mobility in deep decarbonization scenarios

The scenarios assessed by the IPCC feature CO_2 emissions from transport reduced by 50% in 2050 compared to 2010 [1]. To reach this ambitious goal, a broad range of mitigation options have to be considered.

Mitigation measures can be classified as either reducing energy demand (i.e., by reducing travel demand, modal shifts and increasing fuel efficiency), or reducing the carbon intensity of energy inputs, e.g., by electrification or by a switch to biomass, hydrogen or synthetic fuels.

Demand reductions are particularly relevant in the urban context: compact urban development, bus rapid transit, bicycle highways, car-sharing and telecommuting not only reduce CO_2 but could also have considerable co-benefits for urban communities [14]. From the full reduction potential of the transport sector, the IEA attributes one half (by 2050) to measures on the demand side in a beyond 2° scenario (B2DS). More specifically, 29% could be mitigated by efficiency improvements and 20% by reduction measures [15].

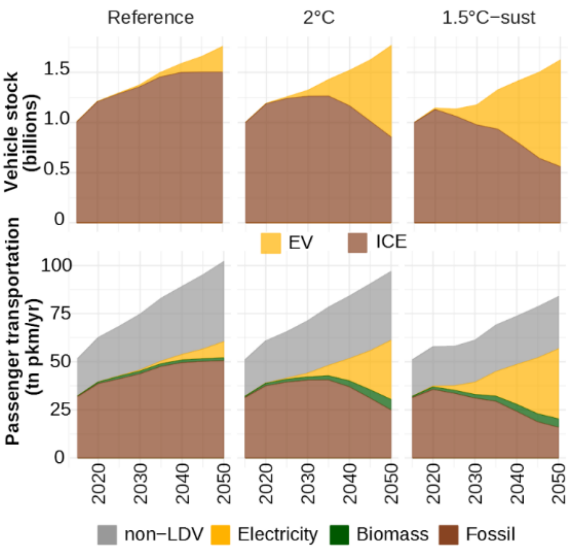

Figure 6: Vehicle stocks and energy services in three REMIND scenarios.

The CO_2 reduction potential on the supply side, i.e., by fuel switching, constitutes the other half of reductions by 2050. The transformation scenarios assessed in the IPCC 1.5°C report [1] project an increase of the share of low-carbon fuels (including electricity) in the total transport fuel mix of 10% (IAMs) and 16% (sectoral studies) by 2030 and to 40% and 58% by 2050. The share of electricity in final energy consumption increases to 25% in IAMs and 30% in sectoral studies, the share of biofuels to 15% in the IAMs and to 25% in sectoral studies, resulting mainly from fuel-switching in the aviation and freight transport modes. The exemplary REMIND scenarios shown in fig. 6 for the business-as-usual reference case, the 2° target and the ambitious 1.5° target are well aligned with these numbers: in the 1.5° scenario, 37% of the fuel demand is supplied by electricity (19%) and biofuels (18%). Consequently, highly efficient electric cars supply more than half of all required LDV transportation demand by 2050, see Fig. 6, lower panel. In the same scenario, 62% of LDVs are electric and so are 68% of newly sold cars.

For further in-depth analysis of transport decarbonization, the prospects of these policies have to be analyzed with high regional and sectoral granularity. As part of the Next Generation Policies Project, efforts are under way to increase the level of detail in representing mobility in integrated assessment models (IAMs) used to derive transformation scenarios towards limiting global warming.

9. Co-benefits of mitigation

Beyond reducing CO_2, climate policies are foreseen to yield considerable co-benefits, which may, in monetary terms, exceed mitigation costs by more than a factor of two [16, 17]. Such monetization relies, however, on controversial normative judgements and is highly uncertain. In the context of transport decarbonization, health benefits from reduced air pollution is discussed most prominently. Shindell et al. report more than 100 million avoided premature deaths from air pollution for a 1.5° pathway [18]. Another study quantifies monetary co-benefits in terms of reduced air pollution of about 80-300 $ per ton of CO_2 abatement in 2030, adding considerably to the societal benefit of reducing fossil fuel use [17]. Additional positive side-effects of modal shifts towards public transport or human powered vehicles, in particular in urban areas, are a reduced noise level, less urban heat islands, less severe accidents, and more space available to the public [14]. Importantly, the positive side effects of mitigation are effective on a much shorter timescale and more locally than the benefit in terms of avoided climate damages. Consequently, they can present a strong incentive for the implementation of decarbonization policies, especially in fast-growing developing economies [19].

Cited references are available at [add link]

For more information

https://www.mcc-berlin.net/next-generation-policies

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