Dialog zur Klimaökonomie

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Background paper for the Forum Climate Economics 7

PHASING OUT FOSSIL FUELS -

HOW TO ACHIEVE A JUST TRANSITION?

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Preamble

In 2020, Germany has passed a Coal Phase-out Act. Coal exits in different regions in the past provide experience to learn from, but important challenges remain. The 7th Forum on Climate Economics "Phasing out fossil fuels - How to achieve a just transition?" addresses three key questions concerning the phasing out of fossil fuels. Firstly, how can the system transformation be implemented in the light of European climate targets and international commitments, in particular in times of COVID-19? Second, how can the transformations be implemented in a socially just way? Third, what potential new path dependencies might appear if we phase out coal? This background paper to the 7th Climate Economics Forum is based on ongoing research by institutions that participate in research projects supported by the funding measure "Economics of Climate Change" of the BMBF (Federal Ministry of Education and Research). The projects deal with different aspects of phasing out fossil fuels. The paper provides the reader with an overview of recent scientific findings and summarises them in key messages and political recommendations.

The Climate Economics Forum is an event series organised by the Dialogue on Climate Economics on up to date issues of climate and energy policy. The Dialogue project accompanies the BMBF funding measure and aims to provide a platform to intensify the exchange between science and practice on economic aspects of climate change. This background paper is part of the activities of the Dialogue's priority topic "Climate protection and transformation: Decarbonisation - Competitiveness - Quality of Life". Eleven projects of the funding measure have contributed to this paper. They organise the 7th Forum under the coordination of MCC, PIK and TU Berlin.

The authors would like to thank the participating projects for their active support. They have been involved in the development of the structure of this background paper, have contri-buted with their results and provided comments on the draft version of this paper. We would moreover like to thank Gernot Klepper, who is coordinating the Dialogue on Climate Economics together with his colleagues at IfW Kiel, for reviewing the paper. Furthermore we would like to thank Jérôme Hilaire, PIK, for his collaboration on Figure 1 and Lena Bednarz and Defne Akin, IfW Kiel, for the layout of this document.

CONTRIBUTING PROJECTS OF THE NETWORK ECONOMICS OF CLIMATE CHANGE

BeSmart Smart-metering and Dynamic Electricity Tariffing: Energy Consumption Choices, Regulatory Policies and Welfare Effects

DECADE De-Carbonizing Economic Development in Sub-Saharan Africa

DecarbLau Mobilising Endogenous Potentials for Structural Change - Decarbonisation in a Lignite Mining Region

DeGeb Decarbonizing Building Heating Systems

DIPOL Deep Transformation Scenarios for Informing the Climate Policy Discourse

FFF Future of Fossil Fuels in the wake of Greenhouse Gas Neutrality

FoReSee Fossil Resource Markets and Climate Policy: Stranded Assets, Expectations, and the Political Economy of Climate Change

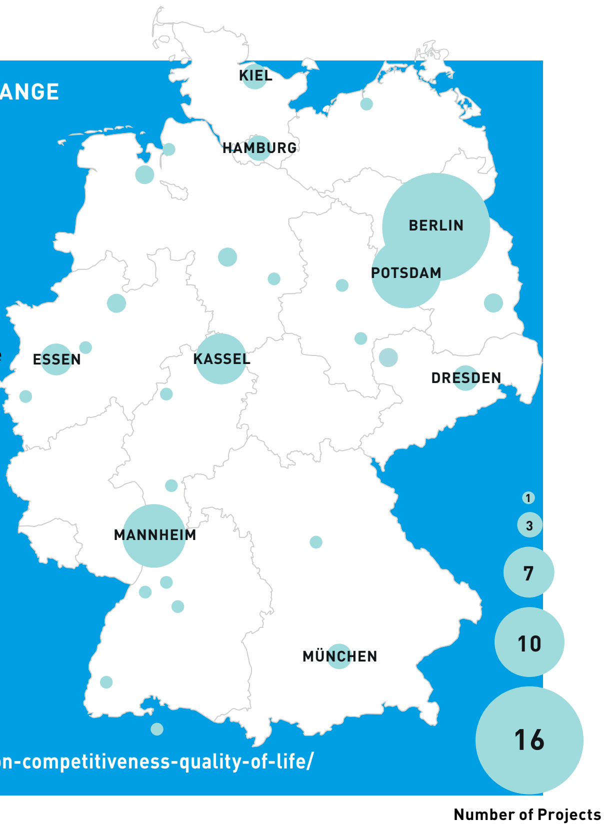
NostaClimate The Role of Non-state Actors and their Interactions with State and Individual Actors

PEGASOS The Political Economy of a Global Coal Phase-out

REsCO Transformation of the Energy System towards Sustainability Focussing on Community-based Activities

ROCHADE Mitigation Policies in a Globalized and Developing World: The Role of Structural Change and Distributional Effects

https://www.klimadialog.de/themes/climate-protection-transformation-decarbonisation-competitiveness-quality-of-life/



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Phasing out fossil fuels - How to achieve a just transition?

KEY MESSAGES AND POLICY RECOMMENDATIONS

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As described in this paper, there exists a rich body of literature and a set of established research findings by institutions participating in the BMBF funding measure Economics of Climate Change on the topic of fossil fuel phase-out to combat climate change. We synthesize these findings in terms of key insights on the important role of fossil fuel phase-out for reaching the goals of the Paris Agreement and a number of key policy recommendations to implement such a phase-out.

CLIMATE GOALS AND FOSSIL FUEL PHASE-OUT

Reaching the goal of limiting warming to 1.5-2°C requires a rapid global phase-out of coal, oil, and gas use. Coal exit should happen most rapidly, while oil and gas also need to be phased out in the process of decarbonisation. Oil and gas use is phased out more slowly due to their lower carbon intensity and higher energy value.

Bottlenecks in phasing out fossil fuels exist particularly in heavy industry, the buildings sector, aviation and shipping. A combination of electrification, sector coupling, and the deployment of alternative fuels is needed to overcome these bottlenecks. This requires far-sighted and coordinated policy action across sectors and policy instruments.

Current climate action directed to phasing out fossil fuels needs to be ratcheted up substantially to hold warming to well below 2°C as called for by the Paris Agreement. Current national climate action plans (NDCs = Nationally Determined Contributions) are not aligned with the goals of the Paris Agreement and do not reduce global fossil fuel use sufficiently until 2030. The EU Commission proposed to tighten the medium-term emissions reduction target (from -40% to -55% by 2030) in order to meet the climate targets of the Paris Agreement (see the section on the EU). Germany´s reaction (current reduction target: -55% by 2030) to this strengthening of the EU target is still pending.

Global coordination of ratcheting up climate action and particularly fossil fuel phase-out policies requires international burden sharing mechanisms. Such policies impose a higher burden on fossil fuel exporting regions and developing countries in need to improve energy access. A fair distribution of the burden, be it via differentiated targets and timetables, international emissions trading, direct transfers, other international support schemes, or a combination of these, will be a prerequisite to initiate global concerted action in line with the Paris Agreement.

Fossil fuel phase-out has substantial co-benefits in terms of reducing air pollution and enhancing energy security. In the case of the EU and other major emitters like India and China, these co-benefits are large and can outweigh the costs of climate change mitigation.

POLICY INSTRUMENTS FOR PHASING OUT FOSSIL FUELS

Eliminating fossil fuel subsidies helps to reduce fossil fuel use, but alone is insufficient to phase out fossil fuels to the extent and at the speed it would be required under the Paris climate goals.

Carbon pricing, a targeted phase-out of existing coal power generation and a moratorium on new coal power plants and mines are important policy instruments to implement a rapid coal phase-out. At sufficient price levels and in the absence of loopholes or grandfathering schemes for polluting power stations, carbon pricing alone can initiate a complete phase-out of coal power. In case sufficient price levels cannot be implemented, carbon pricing needs to be accompanied by national coal phase-out plans.

Phasing out coal must not result in locking in new fossil fuel dependencies. Coordinated sequencing of national policies across sectors is needed to avoid such fossil fuel leakage between sectors. Economy wide carbon pricing can prevent fossil fuel switching from coal to oil and gas. Such a shift to oil and gas would not be in line with the Paris climate goals that demand the use of alternatives with significantly lower CO_2 intensity (such as green electricity or green hydrogen).

On the international level, fossil fuel phase-out in major economies can lead to emissions leakage to other countries if not controlled internationally. Lower demand in international fossil fuel markets will depreciate fossil fuel prices which would lead to larger fossil fuel consumption in regions without stringent emissions control or fossil fuel phase-out policies.

Policies redirecting investments towards financing the transition to carbon neutral economies are important complements to climate and fossil fuel phase-out policies. Such policies need to be able to leverage private and public investments and incentivize investors to de-invest in fossil fuels in addition to re-investing in green technologies.

The introduction of fiscal stimulus packages of multiple trillions of dollars globally to recover from the COVID-19 pandemic shock has largely amplified the leverage of tax and fiscal policies to support the transition to a carbon neutral economy. This offers a window of opportunity, but also carries the risk of increased carbon lock-in should the stimulus packages include elements to keep fossil fuel-intensive activities alive. Currently, the picture is mixed. More than a third of the funds are earmarked for investment in sectors relevant to the climate. Especially in the EU and some of its member states, including Germany, the recovery money is planned to be channelled to exploit synergies with climate policy goals. Outside of Europe, on the other hand, the majority of investment is aimed at preserving traditional CO_2-intensive economic activities.

DISTRIBUTIONAL IMPLICATIONS OF FOSSIL FUEL PHASE-OUT

Increasing electricity access is a key component of development. Therefore, climate and fossil fuel phase-out policies that adversely affect electricity access would have a strong detrimental impact on development. This can be avoided by combining climate and fossil fuel phase-out policies with policies targeting electricity access.

In medium and high-income countries, carbon pricing or the removal of fossil fuel subsidies without redistributive policies will likely be regressive, implying that poor households would be hardest hit by increases in energy prices. In least developed countries, carbon pricing can be progressive as most of the fossil fuels are consumed by medium to high-income households in these countries.

Those most vulnerable to economic hardship do not necessarily stand to lose from fossil fuel phase-out. It depends on the policy design. Redistributive policies can compensate for regressive effects or even be used to make climate and fossil fuel policies progressive.

Fossil fuel producing regions and communities need to be offered opportunities to gain a new livelihood. Historic experience has shown that such regions and communities can be hard hit from abandoning fossil fuels. Farsighted and gradual investments into structural change in these regions is key to offer new and sustainable jobs and allow communities to adapt.

Fairness perceptions play a big role for the public acceptance of fossil fuel phase-out. Taking into account the "ability to pay" and "polluter pays" principles in the design of climate and fossil fuel phase-out policies can help to ensure that the distribution of costs and benefits among those affected is deemed acceptable.

OVERCOMING BARRIERS TO FOSSIL FUEL PHASE-OUT

Barriers are diverse and dependent on the regional, social and political context. Nevertheless, lessons can be learned from stories of success and failure of implementing fossil fuel phase-outs. Such lessons are particularly transferable between countries with similar national circumstances.

Reducing the political influence of the coal industry will facilitate overcoming lock-ins and reorienting the energy economy. G20 states are still spending around 39 billion US Dollar on coal production each year. These investments and subsidies should be abolished.

Participation enables locally adapted solutions and higher acceptance. The involvement of local stakeholders is important for identifying strengths and weaknesses of the regions in terms of adjusting, developing, and implementing local strategies. Workers and communities can be given a larger stake in their future and be actively involved in decision making processes, e.g. through participation in round tables or (regional) commissions. This increases the identification with alternative pathways and local acceptance for resulting and implied changes. For this, information should be prepared individually for different target groups.

There is no silver bullet. Instead: diversify and cooperate. It is difficult to attract and predict the success of new industries. The German Saarland moved relatively successfully and swiftly out of hard coal, but its new dependence on the automotive industry creates the next threat. In contrast, the Ruhr economy transformed slower but is now more diversified. Developing joint post-carbon strategies for entire mining regions should be encouraged, independent from administrative federal or national borders. Political institutions focused on social, labour, spatial, and energy planning should combine efforts, facilitating the establishment of an integrated, coherent policy mix.

IMPLEMENTING A FOSSIL FUEL PHASE-OUT IN THE EUROPEAN UNION

The European Commission proposed to increase its 2030 emissions reduction target from 40% to 55% relative to 1990. Research has shown that this is technically and economically feasible. Even higher goals, of up to 65%, would be feasible and more in line with the EU´s goal to become emissions neutral by 2050. This will require an accelerated fossil fuel phase-out across Europe. Fossil fuel consumption in the power sector will have to be largely phased out before 2040.

Achieving the EU 2030 target will require strengthening the cap in the EU Emissions Trading System (ETS) and the effort sharing agreement between the EU member states for emission reductions in the Non-ETS sectors. This will require coordination between EU and national policies (e.g. coal phase-out by regulation) to ensure the right price signals. In particular, national phase-out plans for fossil fuel installations covered by the ETS should be accompanied by cancellations of associated emission allowances in the ETS. National or EU-wide CO_2-price floors could balance fluctuations of prices in the EU ETS and accelerate the phase-out of fossil fuels.

A stepwise broadening of the sectors covered by the EU ETS is important to more effectively tap into emissions reduction potentials across Europe, reduce the pressure on the effort sharing agreement and the risk of carbon leakage between EU member states, and limit potential price differentials between ETS and non-ETS sectors.

The coordination between climate-relevant taxes, national and EU climate regulations and the ETS are essential to ensure the successful implementation of the Green Deal. Reforms of national tax codes and the EU Energy Taxation Directive can help reduce conflict between taxation schemes with mixed signals for fossil fuel phase-out and emissions reductions and ensure the long-term (fiscal) sustainability of the Green Deal. A key element of a credible and comprehensive tax reform is to reduce (with a clear plan to eliminate) fossil fuel subsidies in the EU.

The EU COVID-19 recovery packages offer an opportunity to facilitate and accelerate the implementation of the Green Deal, if synergies between the recovery packages and Green Deal policy packages can be exploited and trade-offs largely avoided. It is positive that 30% of the 750 billion Euro recovery package "Next Generation EU" invests in green initiatives and all loans and grants are to be subjected to an environmental safety assessment. The German economic stimulus program with its 45 billion Euro future program helps to promote climate-friendly technologies and emissions reductions in Germany. However, Germany has also supported CO_2-intensive companies without regulating their environmental footprint. The recovery packages should offer opportunities for strengthening the effort sharing agreement for non-ETS sectors and support just transitions in regions strongly affected by fossil fuel phase-out.

Burden sharing considerations, taking into account the different situations of Member States within the EU, are key for resource allocation and the success of the Green Deal. Compensation of the most affected will be very important to increase the acceptance of the measures. This should involve measures to limit or reverse regressive effects of climate action, including subsidies for poor households in the context of Green Deal policy packages (e.g. building renovation and energy efficiency subsidies, etc). It is also important to consider the perceived fairness of policies among the general population, in particular when it comes to compensation or "rescue" of fossil fuel intensive companies and owners.

Contents

1. INTRODUCTION

The rapid decarbonization of energy use plays a key role in reaching the ambitious climate policy goal of limiting global mean temperature increase to well below 2 °C, as stated in the Paris Agreement. There is a broad consensus among scientists that a dramatic reduction in the use of fossil fuels is required to meeting these limits. To this end, an effective policy mix should not only include instruments promoting green innovations but also measures pushing the phase-out of fossil fuels (Rogge & Johnstone, 2017).

Countries should therefore develop plans for the transition away from fossil fuel use, ensuring that this transition is well managed and just. The goals outlined in the Nationally Determined Contributions (NDCs) submitted by Parties under the Paris Agreement are insufficient to stabilize global mean temperatures at 'well below 2 °C' (Roelfsema et al., 2020; UNEP, 2019). This is particularly true for plans and targets relating to the reduction and phase-out of fossil fuel use (Edenhofer et al., 2018). Sharper goals and regulations, on the national and international level can help to increase ambition. On the EU level, the European Green Deal aims to reach net-zero emissions by 2050. In Germany, a new climate protection law (*Klimaschutzgesetz*) aiming to reduce emissions by 55 % in 2030 and to reach climate neutrality in 2050 has been adopted recently. Also a Coal Phase-out Act (*Kohleausstiegsgesetz*) was passed by parliament. Coal-fired power generation is to be phased out gradually, ending completely no later than 2038.

This background paper tries to take a comprehensive look at various aspects that are to be considered in relation to a fossil fuel phase-out to achieve more ambitious climate goals. **Chapter 2** discusses decarbonisation scenarios in line with the Paris Agreement and phase-out pathways for different fossil fuel types, sectors and regions. It is shown that such transition pathways towards net zero are feasible.

Chapter 3 deals with the political implementation of fossil fuel phase-out. It becomes clear that there is no one-size-fits-all solution for the most suitable way of implementation. However, investigating the specific policies, legal frameworks, governance arrangements and stakeholder involvement that have been introduced or proposed to support a transition away from fossil fuels helps to identify effective approaches and how to adopt them in different regional contexts. By referring to regional experiences, it is discussed how fossil fuels can be phased out in an effective way and how future lock-ins can be avoided.

A key factor to successfully phasing out fossil fuels is to do it in a socially just way. In **Chapter 4**, potential positive and negative distributional implications of fossil fuel phase-out on households and consumers on the one hand, and companies and fossil fuel owners on the other, are analysed. In this context, also related compensation measures are discussed. Based on the aspects discussed in these chapters, **key messages and policy recommendations** are summarised at the beginning of this paper to support the design of fossil fuel phase-out strategies.

BOX 1: Fossil fuel phase-out and the pandemic shock: How can the economic slowdown due to COVID-19 and recovery packages impact a global phase-out of fossil fuels?

The rapid and ongoing spread of the COVID-19 pandemic in the past eight months has led to societal lockdowns and unprecedented policy measures in most countries around the world. The lockdowns and other COVID-19 response measures like international travel bans, school closures, and social distancing rules, have introduced a large and multifaceted shock on the world economy pushing many countries into a deep recession. The shock is global and affects both supply and demand. It is expected that as a result of the economic downturn, greenhouse gas emissions will decrease by 4-8 % in 2020 (IEA, 2020b; Le Quéré et al., 2020). However, this will only be a short-term effect if the economy recovers quickly and returns to its CO_2-intensive behaviour. In this case the temporary decrease of emissions would be insignificant from a climate perspective (Forster et al., 2020).

The key question is whether and how the COVID-19 shock will affect emissions and climate change mitigation efforts in the medium term. Among the fossil-fuel intensive sectors hit hardest is the transportation sector. On the peak of the lockdown in April 2020, mobility was significantly reduced compared to the previous year. Road traffic decreased by almost 50 % and air traffic by almost 75 % (IEA, 2020a). These significant changes could lead to a change in mobility also in the longer term. Whether the COVID-19 shock will lead to a shift in mobility behaviour towards less CO_2-intensive modes of transport will depend very much on policy guidance and the design of the COVID-19 stimulus packages to boost the economy. In this context, the German government's economic stimulus package, with the doubling of the purchase premium for electric vehicles and the decision to forego purchase premiums for internal combustion engine cars sends an important signal. On the other hand, the government rescued Lufthansa without imposing requirements on reducing its environmental footprint.

As a result of the pandemic and the associated health protection measures, the energy demand for industry and transport has fallen significantly. The data up to mid-April 2020 show that nationwide initial restrictions have led to a reduction in energy demand of up to 25 %. In a scenario with months of restrictions and slow economic recovery, global energy demand is estimated to fall by 6 % in 2020, which would be more than seven times the impact of the 2009 financial crisis (IEA, 2020b). This decline will also have a major impact on fossil fuels. The scenario predicts a decline in oil demand by 9 %, mainly due to the effects of the pandemic in the transport sector, and a drop in demand for coal by 8 %, as demand for electricity is also falling. The reduction in oil demand during the first phase of the lockdown in spring 2020, combined with other factors like the price war between Saudi-Arabia and Russia, has send oil prices on international markets to record lows, heavily affecting oil producing countries.

The pandemic and its economic repercussions has hit poor households and disadvantaged population groups and regions hardest, further exacerbating inequalities (Furceri et al., 2020). This increases the challenge to phase out fossil fuels in a just way by compensating potential losers and offering structural change to fossil-fuel dependent regions and communities.

On the demand side, consumer uptake of digital technologies accelerated, and it is likely that some of the activities that had to be moved into the virtual space will remain there. This could accelerate the transition to less carbon intensive lifestyles, but counteracting trends like shunning of public transport and agglomeration of people exist as well. It is too early to tell in which way the pandemic will affect the fossil fuel intensity of consumption in the future (Boons et al., 2020). Also in this case guiding policy instruments could play an important role.

The COVID-19 pandemic has led to the adoption of stimulus packages to rebuild the economy currently amounting to almost 12 trillion US Dollars. Of this amount, around 3.7 trillion US Dollars are dedicated to the agriculture, industry, waste, energy and transport sectors, whose restructuring is central to climate protection (Vivid Economics, 2020). This gives tax and fiscal policy an enormous leverage to support or hinder the transformation process towards a CO_2-neutral economy. It will be crucial that COVID-19 economic stimulus packages and accompanying tax and regulatory measures have a steering effect in order to facilitate the transformation towards green energy use and the phasing out of fossil fuels. In an expert survey, Hepburn et al. (forthcoming) identify five investment measures with particularly high value for the transformation process: investment in CO_2-neutral energy infrastructure, funding research on alternative technologies, investment in nature conservation and sustainable land use, promotion of building refurbishment and investment in training and education programmes.

An analysis of the economic stimulus packages already adopted gives a mixed picture. While in Europe an attempt is being made to combine the COVID-19 stimulus packages with measures to implement ambitious climate protection plans, in other countries the focus is often almost exclusively on stimulating growth and regaining lost jobs (Vivid Economics, 2020). Countries such as the US ($3 trillion), China ($600 billion) and India ($270 billion) score poorly in the assessment of their stimulus packages, as they are essentially focusing on their existing carbon-intensive economic structures. The European Union, on the other hand, is planning to implement its 750 billion Euro package "Next Generation EU" closely linked to the implementation of the EU Green Deal. 30 % of the loans and grants will go to green initiatives such as increasing energy efficiency, reducing dependence on fossil fuels and sustainable land use. In addition, all support will be linked to an environmental impact assessment, with the aim to largely exclude the promotion of fossil fuel use. The German economic stimulus packages also score positively in the assessment, mainly due to the fourth economic stimulus package of June 2020 (130 billion Euros) and the "future package" of 45 billion Euros contained therein. 31 % of the planned investments are identified as green and the rest as largely environmentally neutral (Dafnomilis et al., 2020). However, not all of the German government's economic stimulus and rescue measures can be considered green or environmentally neutral. Especially the rescue of Lufthansa for 9 billion Euros without imposing requirements to reduce its environmental footprint stands out.

2. TRANSITION SCENARIOS - TRANSLATING LONG-TERM TARGETS INTO NEAR- TO MEDIUM-TERM ACTION

To limit warming to well below 2 °C with no or low overshoot, the world needs to bring net CO_2 emissions to zero (also called "carbon neutrality") in the second half of the century. This is due to the fact that humankind's remaining carbon budget is tightly constrained by the Paris climate goals (Rogelj et al., 2019). Should the focus be put on limited warming to 1.5 °C, carbon neutrality would need be reached even earlier, by around mid-century (see Figure 1) (Rogelj et al., 2018). The "net zero" concept includes that any remaining emissions that cannot be reduced to zero (e.g. from aviation or heavy industry) would be balanced by Carbon Dioxide Removal (CDR), for example by restoring forests or the use of bio-energy with CCS (BECCS).

Reaching carbon neutrality in 2050 requires a rapid peak and decline of global greenhouse gas emissions underpinned by transformational changes in energy systems and land use. The required changes are investigated with scenarios of transition pathways towards a range of future warming levels, from pathways consistent with the goals of the Paris Agreement to pathways extrapolating current trends and reaching 3-4 °C warming by the end of the century (Clarke et al., 2014; J. Rogelj et al., 2018).[1] Scenarios can help translating long-term targets into implications for near- to medium-term action. Those implications depend on key uncertainties determining the scenario results, in particular:

- **Implementation of climate action:** How fast are emissions reduced in the coming decade? The larger the emissions gap in 2030 to scenarios acting immediately and in a globally coordinated manner on the Paris climate goals, the larger the transition challenge after 2030 (Strefler et al., 2018). The degree to which near-term emissions can be reduced depends on the political willingness of countries and constituencies, and the social, political and economic feasibility of transformational and concerted action.

- **Availability and costs of technologies:** Which climate change mitigation technologies become available at which pace? How fast can fossil fuels be replaced and at which costs? The more limited the portfolio of mitigation technologies and the more abundant fossil fuel resources, the higher the opportunity costs of transitioning to a carbon neutral economy and the larger the barriers to overcome.

- **Socio-economic and lifestyle changes:** How will consumer preferences and demand for energy services (relating to e.g. mobility, housing, and communication) and agricultural products (food, feed, and materials) develop in the future? Can these developments be directed towards climate-friendly lifestyles and consumption patterns? The less individuals adopt climate-friendly lifestyles, the higher will be the demand for fossil fuels as well as animal products, and the higher will be the challenge to decarbonize energy supply and achieve sustainable carbon-neutral land management (Grubler et al., 2018; van Vuuren et al., 2018).

1 See climatescenarios.org/primer for an introduction to climate change scenarios.

2.1 FOSSIL-FUEL FUTURES IN 1.5-2 °C PATHWAYS

Scenarios illustrating a development towards net zero CO_2 emissions project transformational changes in energy systems, implying a phase-out of fossil fuels. In the following, fossil-fuel futures in 1.5-2 °C pathways are presented.

All mitigation scenarios project a clear sequence of phasing out coal, oil and gas (Figure 1). Coal is phased out first, with gas and oil following more slowly (Bauer et al., 2016). This is due to three factors:

1. the different carbon intensity of these fuels (highest for lignite, then hard coal, then oil, then gas). For example, the carbon content per energy unit of coal is about 30 % higher than that of crude oil.
2. the different usage of these energy sources for producing different types of energy carriers which affects their economic value in providing energy services (highest for oil, then gas, then coal). For example, the price of oil per unit of energy content was 480 % higher than that of imported hard coal in 2019 (BP, 2020).
3. the easier replacement of coal. Coal is mainly used for electricity generation, where renewable sources provide mature and cheap alternatives. In contrast, oil and gas are mainly needed in buildings, industry and transport.

Though direct electrification can replace the use of fossil fuels e.g. in road transportation, heating of buildings and industry processes, some applications lack low-cost low-carbon alternatives. Potential bottlenecks for replacing fossil fuels are high-temperature applications in the industry (e.g. steel production) and the use of liquid fuels in aviation, shipping and freight transport. The heating infrastructure in the building sector also has certain characteristics, which makes phasing out fossil fuels more difficult than in other sectors (Box 2).

In most 1.5-2 °C scenarios in the literature, an almost complete global phase-out of coal use takes place by 2050 (see Figure 1). The phase-out trajectory of oil and gas, on the other hand, depend much more on assumptions about target stringency, consumer behaviour and technological availability, in particular of CDR measures.

Under optimistic assumptions regarding the availability of CDR, a 1.5 °C target leads to stagnation of oil and gas consumption over the next decade followed by a 25-50 % reduction by 2050. Limited availability of CDR leads to a much earlier and faster reduction in both oil and gas consumption, by about 60-80 % by 2050 relative to the peak in 2020 (cf. Figure 1).

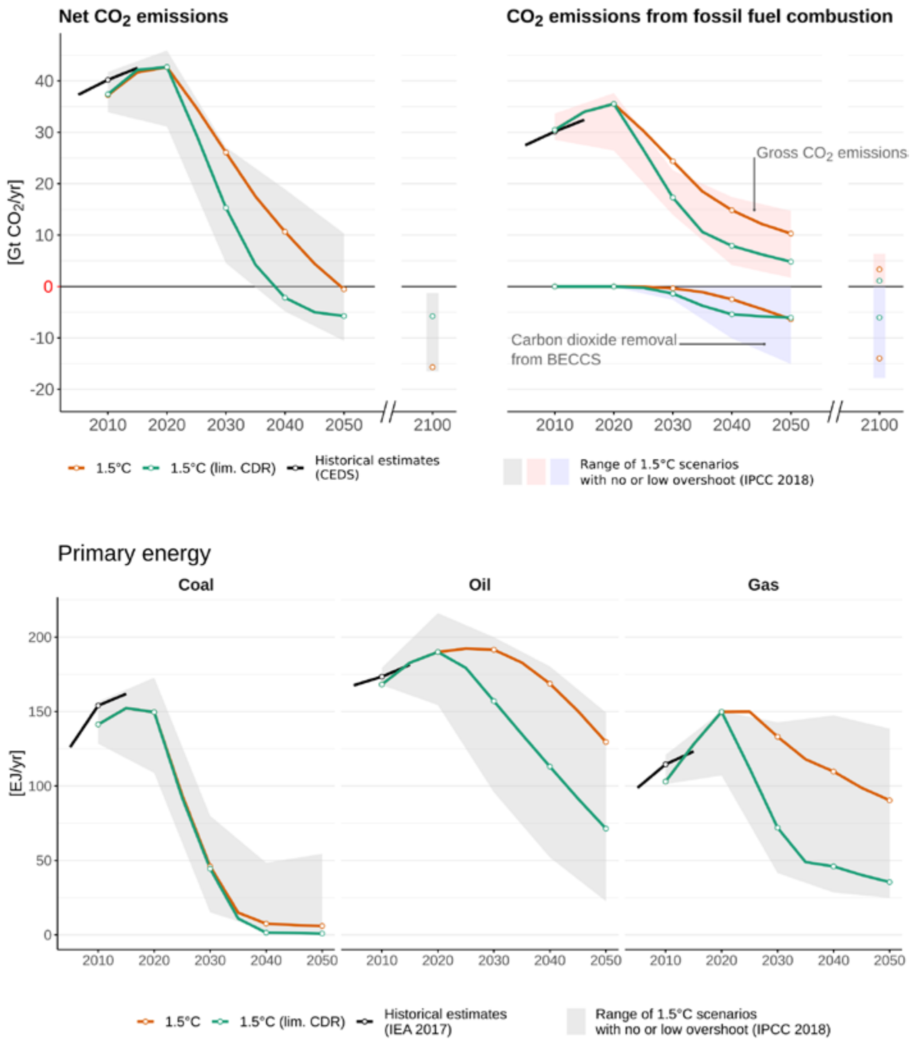

Figure 1 *Global CO_2 emissions (upper figure) and primary energy use of coal, oil and gas in the 21st century for two 1.5 °C scenarios with optimistic (orange) and limited (green) availability of CDR availability (Kriegler et al. 2018). Net CO_2 emissions include emissions from agriculture, fossil energy use and industrial processes like cement production. The upper right figure shows the gross emissions from fossil energy use. In many 1.5-2 °C scenarios, part of these gross emissions is compensated by BECCS. In the background the range of 1.5 °C scenarios from the IPCC emissions database for the Special Report on 1.5 °C global warming is shown that project no or low overshoot. The estimated data on past energy use are derived from the International Energy Agency (IEA, 2017), the emissions data are based on CEDS (Hoesly et al., 2018).*

If climate policies for 2020-2030 are not strengthened beyond the NDCs, this may result in postponing emission reductions and fossil fuel phase-out, especially coal phase-out. This could result in 250 Gt CO_2 higher cumulative emissions in 2050 (Luderer et al., 2018), putting carbon neutrality by mid-century and the 1.5 °C target out of reach (Rogelj et al., 2018).

The mere implementation of NDCs, without further climate policy efforts, would not lead to a significant reduction in fossil energy use, including coal, by 2030. Phasing out fossil fuels, thus requires concrete and immediate policy action in addition to accelerated support for alternative power system solutions.

Global adoption of policies already implemented successfully in some countries, like the support of renewable energies, moratoria for new coal power plants, energy efficiency improvements and moderate CO_2 prices, could already at least partially close the 2030 emission gap and reduce the transformation challenge past 2030 (Kriegler et al., 2018). To strengthen climate policies and accelerate the phase-out of fossil fuels shifting investments away from fossil fuels towards energy efficiency, renewable electricity production and transmission and storage plays an important role (McCollum et al., 2018). Most 1.5-2 °C scenarios show annual investments into low-carbon energy overtaking fossil investments globally already before 2030.

A clear signal from policy makers that strong climate policies will be implemented in the future encourages investors to invest in alternative energy infrastructures instead of fossil fuels (Kriegler et al., 2018). In Germany and the EU, this signal is increasingly given by climate protection legislation (see Chapters 3 and 4) and the announcement of the EU Green Deal (Chapter 2.3). What matters now is to send out consistent signals about the policy mix at German, EU and international level. For India, Malik et al. (2020) find that early action in the power sector could reduce stranded assets. In particular, they consider a policy limiting coal plants to those under construction combined with higher solar targets to be politically feasible, while preventing significant stranded capacity. Also for China, Wang et al. (2019) find that an immediate transformation of the Chinese power sector could avoid additional stranded assets. This would require accelerated promotion of alternatives between 2020 and 2030, like nuclear, wind and solar power.

The use of fossil fuels in industry, buildings and transport can partly be substituted via technological innovation (e.g. direct electrification of industrial processes or cars), a fuel switch to low-carbon alternatives such as biofuels or synthetic fuels, and demand reduction (e.g. circular economy, energy efficiency, demand shifts like modal switches in transportation and economic adjustment to emission regulation through the fossil-fuel-price channel). In order to achieve emission neutrality around mid-century, it seems important to invest early in the development of low-carbon alternatives where possible, e.g. direct electrification of freight transport and the usage of hydrogen or electricity for high-temperature industrial processes, and at the same time invest into the development of carbon removal options. New infrastructure investments have to be planned accordingly to avoid delays or stranded assets later on.

2.2 REGIONAL DIFFERENCES OF FOSSIL FUEL PHASE-OUT IN 1.5-2 °C SCENARIOS

While the general structure of fossil fuel phase-out trajectories in 1.5-2 °C scenarios, i.e. first coal, then oil and gas, is similar across regions, they impact different regions to different degrees (see Chapter 3). Low-income countries generally have low carbon and energy productivities. This means that they usually require relatively large amounts of energy and carbon emissions to generate economic values measured in GDP. Advanced economies such as Germany have developed towards highly industrialized and innovation oriented service economies that generate economic values at lower consumption of energy and, thus, lower emissions. Globally, improvements in energy and carbon productivities are expected and projected in the future, but structural differences will remain.

This has significant implications for international coordination of climate policy. Uniform carbon pricing across regions would cause developing and advanced economies to phase out fossil fuels in a synchronous manner. In this case developing countries would be faced with higher relative costs due combination of low energy and carbon productivity. This leads to political resistance from these countries in international climate policy. Thus the cost efficient solution from a global perspective can violate international fairness considerations, which calls for mechanisms of burden sharing (Tavoni et al., 2015).

Regions which rely on the extraction and export of fossil fuels for international markets are hit hardest by a fossil fuel phase-out. Coal producing regions, for example, are directly hit by the rapid phase-out of coal combustion, which causes coal markets to collapse until mid-century in 1.5-2 °C scenarios. Reduced oil demand will lower oil prices, potentially pushing medium to high cost oil producers out of international markets. Many owners of low-cost endowments of oil will also suffer losses of their natural asset values from lower prices even if oil use continues for several decades into the second half of the century (Bauer et al., 2016). Modelling analyses consistently show the highest relative mitigation costs for fossil fuel producing regions (Tavoni et al., 2015). There is an ongoing debate on whether fossil fuel producers should also be considered in burden sharing considerations related to potential adverse effects of mitigation. On the other hand, it is those countries with abundant reserves of fossil fuels that have produced comparatively high emissions in the past and thus bear a larger share of the historical responsibility for climate change.

To address fairness considerations, the international community could agree on direct transfers or international emissions trading, which can reach very high levels though (Tavoni et al., 2015; van den Berg et al., 2019; Leimbach and Giannousakis, 2019). Alternatively, carbon prices can be differentiated across regions so that relatively capable economies lower emissions faster. But to equalize effort, those carbon price differentials would need to become very large distorting international markets and making global climate action inefficient. For example, the different speeds in fossil fuel phase-out could lead to the paradoxical situation that developing countries expand coal use in relatively inefficient domestic heating and cooking, while advanced economies phase out gas use in more efficient heating systems (Bauer et al., forthcoming).

Potential distributional impacts of fossil fuel phase-out are discussed in more detail in chapter 4 of this paper.

2.3 DECARBONIZING EUROPE´S ELECTRICITY GENERATION

For Europe, analyses of energy and climate action scenarios have shown that a full decarbonization of the European and German power sector by 2040 can be achieved but much higher rates and targets with respect to capacities of renewables and fossil fuel phase-out have to be set compared to the current political targets (Hainsch et al., 2020; Oei, Hainsch, et al., 2019). A recent impact assessment by the European Commission (2020) recommends an increase in the EU's climate targets for 2030 from 40 % emission reduction to 55 % compared to 1990. Analyses by Hainsch et al. (2020) and Oei et al. (2019) show that even an increase in the EU´s 2030 target to 60-65 % reduction in greenhouse gas emissions compared to 1990 is technically and economically feasible and much more in line with the EU goal to become carbon neutral by 2050. In order to achieve these ambitious climate targets, wind and solar

On 11 December 2019, the European Commission presented its Communication on the **European Green Deal**. The Green Deal is presented as a new growth strategy proposed for the EU and aims for a emissions-neutral society with a resource-efficient and competitive economy by 2050. To this end, initiatives in various areas are kicked off, including biodiversity, recycling management and transport. The goal of emissions neutrality is to be pinned down in an **EU climate law**. To achieve the goal, on 17 September 2020 the European Commission presented its proposal to reduce greenhouse gas emissions of the EU by at least 55 % by 2030 (instead of 40 % as previously envisaged) compared to the level of 1990. The new target is based on a comprehensive impact assessment of the social, economic and environmental impacts caused by emission reductions of 55 % by 2030 compared to values of 1990. The assessment shows that this is a feasible goal. In a next step, the European Commission will examine various political instruments and work out detailed legislative proposals to define how this objective can be achieved. The new target for 2030 will also provide the basis for discussions on the revision of the EU´s NDC for 2030 under the Paris Agreement.

energy infrastructure needs to be expanded significantly. On the flipside, ongoing investments in fossil fuel based power generation technologies need to be ended, also because CO_2 capture technologies are not an economically suitable option in the power sector (Gerbaulet et al., 2019). Our calculations show that by 2040, to be in line with the targets set by the Paris Agreement, almost all electricity will be generated by a combination of photovoltaics, onshore and offshore wind power and hydropower (cf. Figure 2), with the industry, heating, and transportation sector being electrified to a high degree (Hainsch et al., 2020; Löffler et al., 2019).

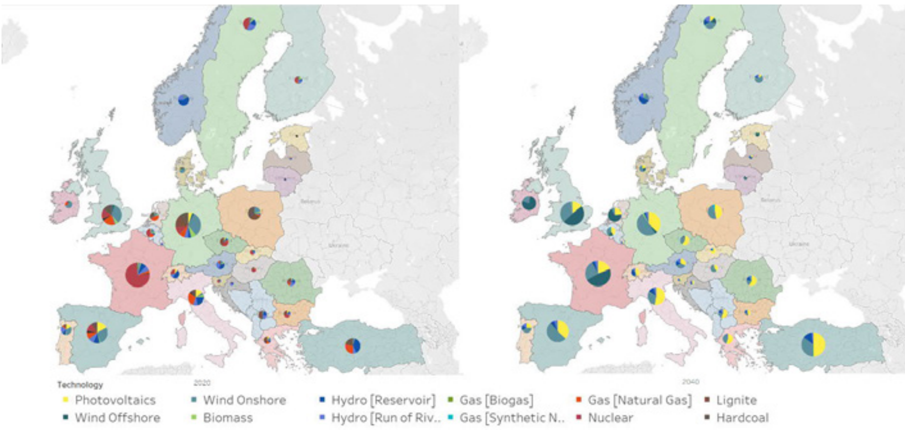

Figure 2 *Changing electricity mix within Europe between 2020 (left) and 2040 (right) in a net decarbonization scenario, values in TWh (Hainsch et al., 2020).*

When considering policies to achieve the goal set by the Paris Agreement, both the economic development of the individual member states as well as the regions affected by structural change in the energy sector must be taken into account (Oei, Hainsch, et al., 2019; Oei, Hermann, et al., 2020). Some countries and regions, e.g. within Poland, face higher difficulties due to their prevailing energy mix (i.e. a high reliance on coal) and will need more financial and political support in the upcoming years (Oei, Burandt, et al., 2020). These regions are often in close proximity of fossil fuel reserves (e.g. coalmines) or international fossil fuel trading infrastructure (e.g. terminals or pipelines). Some, but not all of these regions, have access to domestic renewable energy resources (Bódis et al., 2019; Pai et al., 2020). Hence, strengthening cross-border energy links in between countries can help to overcome temporal bottlenecks of renewable input and therefore increase synergies across regions.

2.4 CO-BENEFITS OF FOSSIL FUEL PHASE-OUT

Apart from emission reductions, phasing out fossil fuels also leads to other positive effects, e.g. those connected with energy security and air quality.

Air quality: Phasing out coal will come with an improvement in air quality and a reduction of premature deaths. In a recent analysis, researchers monetised environmental and human health costs, caused by respiratory diseases and biodiversity loss. This enabled them to compare these with mitigation costs, being mostly economic growth reductions and costs for investments in the energy system. They find that benefits from reduced health and ecosystem impacts are higher than the direct economic costs of a coal exit. They amount to a net saving effect of about 1.5 % of global GDP in 2050. China and India in particular, with high reliance on coal and severe air pollution problems, would have high air quality benefits (see Figure 3) (Rauner et al., 2020).

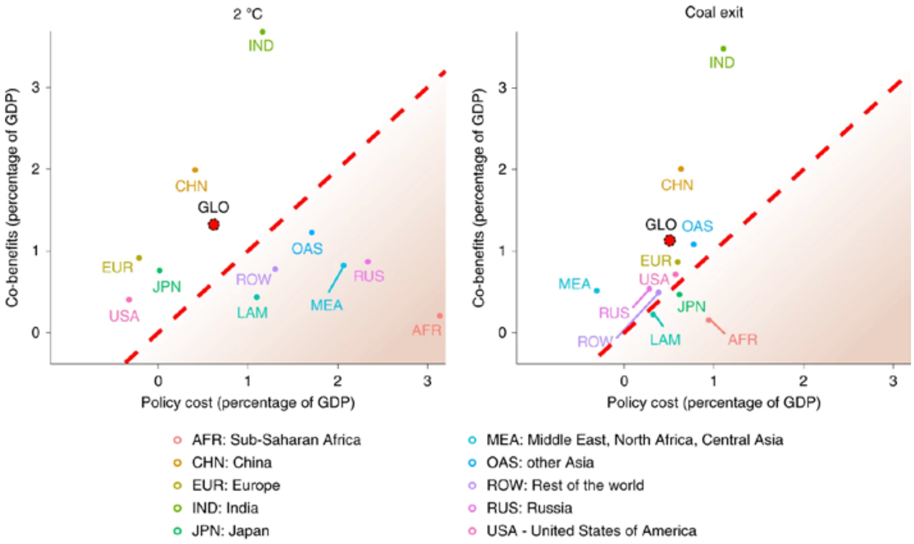

Figure 3 *Regional analysis of local co-benefits and direct policy cost relative to annual GDP PPP. Discounted co-benefits and direct policy cost for all world regions in the 2 °C and coal-exit scenarios until 2050 with a discount rate of 5 %. The dashed line indicates the break-even line between cost and benefits (Rauner et al., 2020).*

Energy security: Another co-benefit of a decarbonized energy system is decreased dependency on fossil fuel imports (Hainsch et al., 2020; Oei, Hainsch, et al., 2019). In the case of a scenario which would be in line with the 1.5 °C climate target, the costs of importing and extracting fossil fuels can be reduced by more than two thirds until 2030 and nearly reach zero by 2040. The respective model calculations also show that regional differences of renewable generation profiles across Europe can help balancing out local fluctuations with no power or hydrogen import from outside Europe necessary (Hainsch et al., 2020). However, as indicated in the first part of this chapter, the reduction of the dependency differs between fuel types. Calculations based on a computable general equilibrium model (CGE; Lanz & Rutherford, 2016) indicate that while the dependency on coal and gas imports decreases rapidly for Germany and Europe, the dependency on oil import poses itself as a bottleneck — the inefficiencies brought about by oil phase-out can create delays and higher production costs. In a scenario, in line with the global 2 °C climate target, in 2030 fossil fuel imports of coal, natural gas, and oil reduce by about 80 %, 40 %, and 10 % respectively in Germany and by nearly 70 %, 55 %, and 15 % in the rest of Europe.

BOX 2: Phasing out fossil fuels in the building sector – an unattainable target?

Residential heating and provision of hot water amounts to about 25 % of total final energy consumption in Germany (dena, 2016). Decreasing energy consumption (behavior changes, insulation, efficient appliances) and less carbon intensive fuels (solar, electric heat pumps, biomass, power-to-gas) can reduce emissions and did so over the last decades. Decarbonization scenarios for the building sector highlight heat pumps as the dominant and most important technology.

However, these reductions are far from sufficient to reach the goal of a carbon-neutral building stock by 2050, which the German government aims for since 2012 and laid out in the "Klimaschutzplan 2050" in 2016 and the "Klimaschutzprogramm 2030" in 2019. Given that investment periods in the building sector last twenty to thirty years, reaching the goal requires radical improvements in the effectiveness of modernizations. Regulatory law mandating efficient new buildings and minimum efficiency standards for modernizing existing buildings (Energieeinsparverordnung 2016, Gebäudeenergiegesetz 2020) only partially addresses the issues.

Carbon pricing, which is foreseen for the building sector from 2021 onwards might help here. It is however unlikely that it will create sufficient incentives for refurbishment of buildings as it would at least need to fully reflect the external climate damages and address three specific obstacles that the building sector is facing: First, in Germany, more than half of the building stock is rented out, resulting in the landlord-tenant-dilemma. Landlords will not accept high modernisation costs if they are not allowed to increase the ancillary costs and cannot expect an increase in rent which would approximately offset the investment. In one sample, a reduction in annual energy costs of 1 Euro per m^2 only led to an increase in annual rental income of about 0.23 Cent per m^2 (sample average) (Kholodilin et al., 2017). Therefore, policies focusing on consumer prices show little effect. Second, amateur homeowners' bounded economic rationality and – compared to a building's life span – short time horizons cause under-investment in about 75 % of all residential units. Third, complex decision structures in apartment buildings with shared ownerships tend to delay retrofits for many years in more than 20 % of all housing units. Many apartments and their owners suffer from more than one of these problems. Even if focused on the windows of opportunity resulting from transfer of ownership, regulatory duties as in the Gebäudeenergiegesetz and financial incentives like the carbon price of initially 25 Euro per ton and later 55 to 65 Euro per ton will remain insufficient to achieve a carbon neutral building stock by 2050.

Reaching the goal requires incentivizing or enforcing modernization beyond (private) economic efficiency, and thus will necessarily entail distributional effects, which need to be understood and managed. Taking appropriate housing and heating as a necessity, political decision makers will have to accept substantial transfers to the building sector – or to give up the zero-emissions goal for 2050.

3. ZOOMING INTO REGIONS, CASE STUDIES TELL A MORE COMPLICATED STORY

3.1 THE POLITICAL ECONOMY OF FOSSIL FUEL PHASE-OUT

Coal is abundant and comparatively cheap (Steckel et al., 2015), but also the most carbon-intensive fossil fuel (Edenhofer et al., 2018). The committed emissions of the current coal infrastructure, emissions resulting from existing power plants or from those designated to be built, are reducing the remaining carbon budget (Edenhofer et al., 2018; Tong et al., 2019). And recent surges in global emissions were strongly driven by a renaissance of coal particularly in developing countries (Steckel et al., 2015). While coal is relatively easy to substitute, developing countries in particular still struggle to forgo the further expansion of coal power in developing their energy systems (Steckel et al., 2020; Steckel et al., 2015). There is also the question of how to offer new perspectives to the coal regions concerned and those employed in the coal industry. To phase out coal by 2030, Canada and the UK launched the "Powering Past Coal Alliance" in 2017. But while the Alliance counts 104 members states to date, it lacks commitment of major coal producers and consumers, with pledged early retirements accounting for less than 1 % of carbon emissions committed by the existing coal infrastructure (Jewell et al., 2019). So while the scenario literature suggests a pending coal phase-out (see chapter 2), evidence from case study research indicates that there is actually an intricate political economy at play within countries as well as at the international level that impedes implementation. Organizing a global coal exit therefore remains the elephant in the room of global climate negotiations (Edenhofer, 2015).

	Analytical focus	Potential influence on climate policy
Interests	Power and motives of collective actors, such as industrial associations, political parties, or social movements	Powerful interests, depending on the institutional setting, can shape the political agenda and determine priorities, opening or closing windows of political opportunity by support or veto powers
Institutions	Organizational structure and capacity of policy making bodies, e.g. nation state	Institutions mediate the distribution of power resources among interests, the ability and procedures to promote and discuss ideas, and the quality of policy implementation
Ideas	Frames and narratives embedded in social, political and cultural discourses	Ideas shape the underlying worldviews that frame public debates on the need for (and possibility of achieving) reform

Table 1 *Interests, ideas and institutions form an architecture of opportunities and constraints (based on Lamb & Minx 2020).*

Country approaches to climate change mitigation, and by extension the phase-out of fossil fuels, are determined by individual configurations of interests, institutional performance and prevailing ideologies (Table 1). While these configurations are specific to individual countries, similar types of constraints manifest across countries that enable a typology of countries (Figure 4). One of these indicators is a high dependency on coal. The distinct pattern of constraints linked to coal dependency characterizes a cluster of countries that share not only their reliance on coal, but also an institutional design more susceptible to vested interests and highly vulnerable to corruption (Jakob et al., 2019; Lamb & Minx, 2020). Typically, these countries are fast emerging economies such as Russia, India, China, Turkey, or South Africa (Figure 4 indicates this cluster of coal-dependent countries highlighted in magenta). In these "coal development" nations, a strong development of the coal industry coincides with less stringent climate policies, higher fossil fuel subsidies, a shaky performance on democracy indicators and higher levels of corruption. This cluster accounts for 47 % of the global population and 48 % of global emissions (Figure 4). OECD countries (Figure 4, indicated in blue) also form a distinct cluster that despite widely shared values of climate protection frequently also is characterised by a high dependency on coal (Lamb & Minx, 2020). Climate policy constraints are strongly co-dependent, including a North-South divide in institutional quality, trust and climate awareness that limits full participation in climate legislation and the removal of fossil subsidies.

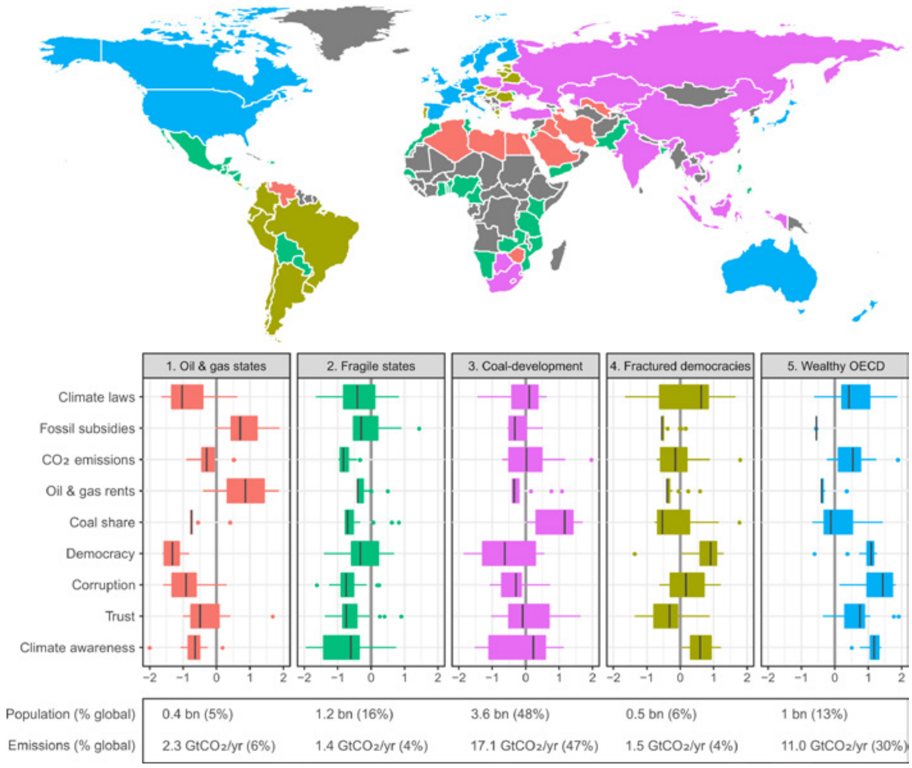

***Figure 4** Country clusters show that the architecture of political economy constraints to effective climate change mitigation varies across countries, but also that a distinct typology of constraints is possible. This helps us understand the individual challenges that countries are facing when phasing out fossil fuels and phasing in climate protection (Lamb & Minx 2020).*

3.2 LEARNINGS FROM CASE STUDIES

While various established economies are struggling to organize coal phase-outs, coal remains the "fuel for development" for many in the Global South (Figure 4). Emerging economies, especially in South East Asia, are currently expanding their coal capacity. In January 2020, coal-fired power plants with a capacity of 199 GW were under construction and additional 299 GW planned (Shearer et al., 2020). Coal has historically been a cheap source of electricity when excluding environmental and health impacts, but economic factors can only partially explain ongoing investments in coal-fired power plants today. Political drivers of current plans to expand coal capacity indicate potential policy responses.

Why do some countries favour coal? Current research involving a global partner network drills into the political economy factors at work in many coal developing countries, producing a large sample of comparable case studies based on a common methodology. First results feature four Asian countries, namely India (Montrone et al., forthcoming), Indonesia (Ordonez et al., in prep.), the Philippines (Manych & Jakob, forthcoming) and Vietnam (Dorband et al., forthcoming) highlighting emerging insights:

- **Electricity alleviates poverty, lending leverage to vested interests.** In all four Asian countries, expanding electricity access and ensuring low electricity prices is important for poverty alleviation. Additional new power capacity therefore is a top political priority and determines political survival of any government. Renewable electricity could also address these demands, but studies find that the politically well-connected coal industry is so far successfully ensuring that additional electricity demand will be met by coal. The relevance of vested interests and the ability of institutions to keep these at bay points to the importance of social and societal learning to improve governance (Bardhan, 2002; Pahl-Wostl, 2009). Despite those similarities, there are no political one-size-fits-all solutions. Political systems, institutions and resource endowments differ strongly between the four countries. For instance, India and Indonesia have large domestic coal resources while Vietnam and the Philippines almost exclusively rely on imports.

- **Emerging economies could substitute coal with renewable generating capacity.** Absolute levels of carbon emissions are still relatively low in many emerging economies of the Global South. However, China's rapid economic development and the relevant share of coal in driving emissions point to the close connection of economic growth and carbonization. As the economy grows, the use of coal intensifies and emissions increase. Examples of Sub-Saharan Africa show that emerging economies, besides relying on coal as a cheap and abundant source of energy, also expand renewable energy use. This indicates that alternative pathways of economic growth may be underway but require international support (Steckel et al., 2020), underscoring the importance of the international community.

- **The international community matters, as a frontrunner and investor.** European countries, particularly Germany with the largest European economy, can contribute to preventing additional international carbon lock-in. First, industrialized countries like Germany can act as frontrunners and role models by demonstrating that a renewable energy system is compatible with a modern industry (Jakob et al., 2020). Second, financial institutions from the EU and North America could stop financing coal power plants and redirect financial flows towards renewable investments (Manych et al., in prep.). However, the influence of international financial institutions and donors varies. India's energy market for example seems less affected by foreign donors while the Vietnamese government, by contrast, seems highly susceptible to the influence of foreign capital. Third, technology and knowledge transfers from Germany and Europe can further reduce costs of renewable energy systems abroad and successfully contribute to international climate change mitigation.

BOX 3: **Phasing out fossil fuel subsidies: Success and failure of policy change in Latin American countries**

Fossil fuel subsidies amount to 5.2 trillion US Dollars globally each year – equivalent to about 6.5 % of GDP– where coal, oil, gas and electricity output account for 44 %, 41 %, 10 % and 4 % of global subsidies respectively (Coady et al., 2019). More than 400 billion US Dollars are subsidies to fossil fuel consumption (IEA, 2019, p. 73). At the same time, there are estimates that efficient fossil fuel pricing could lower global carbon emissions by as much as 28 % (Coady et al., 2019). Other studies, defining subsidies more narrowly and leaving out the low pricing of environmental externalities, estimate that potential emission reductions amount to 1-5 % (Jewell et al., 2020; Schwanitz et al., 2014; IEA, 2011; Burniaux and Chateau, 2011; Burniaux and Chateau, 2014).

In other words, phasing out fossil fuel subsidies – in particular consumption subsidies – is an important complement to phasing out fossil fuels. Evidence from Latin America suggests that most (former) fossil fuel producing countries provide subsidies to fossil fuel consumption, but they are not alone. In the region, Mexico, Bolivia, Argentina, Ecuador, Colombia, but also Brazil to some extent as well smaller countries like Antigua & Barbuda, the Dominican Republic, Haiti, and Trinidad & Tobago, subsidize fossil fuels, most often gasoline, but also LPG or natural gas.

Countries such as Bolivia, Ecuador and Mexico have attempted to reduce or even phase out their fossil fuel subsidies, albeit not for climate reasons but rather for fiscal reasons. Their experience shows that the design of the phase-out is crucial for a successful reform. Bolivia and Ecuador attempted strong subsidy removal but quickly reversed their phase-out policy under public pressure. By contrast, the gradual gasoline subsidy phase-out in Mexico has gone unchallenged by the public. These examples show that it is not the extent of the subsidy reduction that determines whether it can be supported by society, but rather its design.

In contrast to Latin America, where subsidies on the consumer side predominate, Germany subsidises fossil fuels both on the supply side (e.g. coal production) and on the demand side, for example in the agricultural sector and in the conversion of fossil fuels, e.g. in the refinery sector. Direct subsidies in Germany amount to about 15 billion Euro (G20, 2017) and, with a broader definition of subsidies, to 72 billion US Dollars (Coady et al., 2019). This is about a quarter of the EU-wide subsidies for fossil fuels. The EU as a whole is the world's fourth largest subsidy provider with 289 billion US Dollars in 2015 (Coady et al., 2019).

3.3 HOW TO LOCK OUT FOSSIL FUELS? THE CASE OF GERMAN COAL

The German coal sector includes both hard coal and lignite. Previous experience with coal phase-outs of both where not driven by climate change mitigation, however (Brauers et al., 2020; Oei, Brauers et al., 2019; Stognief et al., 2019). Still, these experiences offer important lessons with respect to the political and economic constraints and opportunities identified in the context of coal dependency. Moreover, these transformation processes facilitate the remaining coal phase-out in Germany - which, by comparison, entails fewer structural policy challenges.

The phasing out of domestic hard coal production was done for purely economic reasons and led not only to a reduction in demand but also to a shift in consumption to imported hard coal. The affected Ruhr and Saarland regions experienced a decline of their coal industries since the 1960s, connected with the loss of hundred thousands of jobs. Extensive transfer payments supported companies and employees financially but failed to provide perspectives of structural change providing new sources of income to the regions affected (Oei, Brauers, et al., 2019).

More recent, and much more dire in its societal implications, was the first and highly abrupt phase-out of lignite in the former German Democratic Republic (especially in Lusatia) following German reunification. In under a decade, these regions lost both jobs and identities connected to lignite mining and respective electricity production. While this amounts to a considerable share of the strong emissions decline in the Federal Republic of Germany in the 1990s, it also led to devastating structural decline in these regions (Box 4). The regions were further aggravated by the fact that other industries in addition to coal were also closed. As a result, the lignite regions in Lusatia and Central Germany face much greater challenges than the lignite mining area in the Northern Rhine area (Stognief et al., 2019).

With installation of a "Commission on Growth, Structural Change and Labor", dubbed "Coal Commission", in 2018, German policy makers tried to comply with climate goals and at the same time organise the structural change in the affected regions. The phase-out date of 2035-2038 suggested by the German coal commission in its final report in 2019 was put into legislation in 2020 in form of a Coal Phase-out Act ("Act on the Reduction and Termination of Coal-based Electricity Generation"). Apart from some encouragement, however, there was also criticism that the final law does not follow all recommendations of the Coal Commission (Oei, Kendziorski et al., 2020). One third of former Commissioners criticise in particular the fact that the coal phase-out path is insufficient from a climate policy perspective. Similarly, the commissioning of the coal-fired power plant Datteln 4, the irreparable destruction of villages, the bypass ("island solution") of the Hambach forest and the lack of development of renewable energies is being criticised (Praetorius et al., 2020). It is feared that the deviation from the negotiated compromise also implies that the Commission´s work to settle a dispute about the future of coal in society as a whole may have been in vain.

The "Act on the Reduction and Termination of Coal-based Electricity Generation", or **Coal Phase-out Act**, which was passed by the Bundestag and Bundesrat on 3 July 2020, sets out the interim targets to be achieved on the road to the complete phase-out of coal in 2038. The share of coal-fired power generation by hard coal-fired and lignite-fired power plants will be reduced to around 15 GW each by 2022. By 2030, further reductions to around 8 GW capacity for hard coal-fired power plants and 9 GW capacity for lignite-fired power plants are planned.

The phase-out of coal-fired power generation is to be completed by 2038 at the latest. The operators of lignite-fired power plants are offered 4.35 billion Euro for the decommissioning. Power plant operators of hard coal-fired power plants can receive decommissioning premiums, the amount of which is determined by tenders on the market.

In addition to this law, a package of 40 billion Euro ("Strukturstärkungsgesetz") was adopted in 2020 to support structural change in the lignite regions. Among the most important measures, especially in the structurally weak region of Lusatia, are the expansion of digital and transportation infrastructure as well as the promotion of research and development and the improvement of soft location factors. Part of the money, 14 billion Euro, will be distributed directly by the federal states concerned. Another 26 billion Euro will be provided by the Federal Government until 2038. Experiences from previous transformation processes show that structural support should foster innovation in order to be as adaptable as possible and well equipped to handle future disturbances (Oei, Hermann, et al., 2020; Stognief et al., 2019).

Challenges remain, also with regard to coordination of energy policies on the EU level, so as to avoid negative interactions between them. While in the UK, a change of institutional setting was reinforced by EU legislation on environmental protection and climate change mitigation (most notably this refers to the introduction of a Carbon Price Floor and an Emissions Trading Scheme, see Box 5 for the case of the UK), the German mandated phase-out could incur a substantial "waterbed effect". That is, emission reduction in Germany resulting from the coal phase-out could be more than offset by increased energy and industry emissions across EU members unless policies are implemented to prevent this (Pahle et al., 2019). This is because lower demand for emission allowances from coal plants in Germany will decrease prices and thus encourage emissions elsewhere. Acknowledging this, the recently enacted Coal Phase-out Act foresees the cancellation of allowances equalling additional emission reductions due to the phase-out of coal plants. While national cancellation counteracts such an offsetting of emissions, the exact volumes are very difficult to determine and cancellation could incur negative feedback effects that can destabilize the allowance market (Pahle, 2020). As an alternative the implementation of an EU-ETS carbon price floor has been recommended – and is called for in the joint initiative by France and Germany in May 2020 (Ministère de l'Europe et des Affaires étrangères, 2020). In combination with a price ceiling, it could also replace the Market Stability Reserve (MSR), whose design flaws might open up opportunity for speculators to squeeze the market (Osorio et al., 2020; Pahle & Quemin, 2020). It remains to be seen if this measure will be considered in the proposal for the revision of the EU-ETS that the EU Commission will present in Summer 2021.

BOX 4: **Transition in "Fly-over Country"**

The attitude towards structural economic change of the population in Lusatia is strongly influenced by the experience of large-scale unemployment in the wake of German reunification in the early 90s. Within a few years, the working force in the mining and generation sector dropped from 80'000 to 8'000 (for a forecast see Scholz et al., 2019). The remaining population experienced a considerable demographic downturn. Over the last 25 years, the population in parts of Lusatia has shrunk by almost a third. These experiences were labelled as a structural collapse ("Strukturbruch") and shaped the expectations of the population towards any further structural change, in particular towards a transition that is driven by climate policy. These experiences relate to the entire economic development and not only to the coal industry, but were projected onto climate protection through the planned phase-out of coal production in Lusatia.

Protest of those feeling left behind is expressed at the ballot box. The share of votes cast by populist parties in elections in Brandenburg and Saxony in 2019 was around 30 %, which is considerably higher than the national average. Before the phase-out of lignite mining and generation, regional policy was guided by conventional economic textbook wisdom: large cities and prosperous regions were the main recipients of government support. Against the backdrop of the populist wave, political actors are now in strong need of new economic concepts for the development of peripheral regions, in particular for Lusatia.

The new political agenda includes not only the question of how much tax payer's money should be spent in peripheral regions in comparison to regions with a better economic performance, but also how much money such regions can absorb in a reasonable way. In particular, there is a mismatch between the promotion of research activities on the supply side (e.g. through the establishment of new research institutes) and the ability of the regional economy, which consists primarily of small and medium-sized enterprises, to absorb such stimuli and develop new business cases (Berger et al., 2019). An important pillar of the new strategy is the improvement of infrastructure in order to bring the less favoured regions closer to the big city centres.

BOX 5: Positive and negative lessons from UK coal phase-out

The UK is an example for a once coal reliant European country, which has decided to phase out coal by 2024 and is a founding member of the "Powering Past Coal Alliance". The share of coal in the electricity mix declined from 70 % in 1990 to around 30 % in 2010, reaching less than 1 % in 2018 (UK Department for Business, Energy & Industrial Strategy, 2019). This rapid reduction was made possible by the relatively low level of remaining institutional support from interest groups and can therefore be cited as a very good example from a climate policy perspective (Brauers et al., 2020).

At the same time, the UK is also a negative example of poorly implemented structural change. The state withdrew support in the 1980s when coal mining became uneconomic (while the German Government subsidised hard coal mining for more than 50 years (Oei, Brauers, et al., 2019)). Resistance of miners was suppressed – not for climate but other political reasons to diminish the influence of trade unions. Without domestic coal resources, opposition to coal phase-out in the following decades was negligible. The resulting negative socio-economic effects on mining regions however, prevail to this day (Brauers et al., 2020).

In the 2000s, the UK government introduced environmental and climate policies including a Carbon Price Floor and a minimum price for CO_2 that would apply if the EU-ETS price would fall below this minimum price (some industries in international competition were exempted). By setting carbon intensity standards, construction or retrofitting of coal-fired power plants was banned. The minimum price for CO_2 also reduced the competitiveness of the remaining coal plants. In addition, many older coal-fired power plants that did not have in place new filter systems could not comply with European environmental laws. Companies were thus pushed to redirect investment to renewables and natural gas projects. NGO campaigns additionally drove public opinion in support of climate change mitigation, and EU environmental legislation reinforced national level action (Brauers et al., 2020). While the UK successfully overcame vested interests in coal, investment did not turn completely to renewables but partly shifted to natural gas, creating new fossil fuel path dependencies. Enforcing stringent climate and environmental regulation for new investments in the future can prevent stranded investments in ostensive "bridging technologies" that turn out not to be needed.

4. ADDRESSING DISTRIBUTIONAL IMPLICATIONS OF FOSSIL FUEL PHASE-OUT – THE KEY TO SUCCESS?

Distributional implications must be considered when designing policies to phase out fossil fuels. Policy options are needed to mitigate adverse distributional impacts on consumers and producers. In this chapter, we provide key research insights on such policy options and strategies to increase the acceptance and perception of fairness[2] of climate policies, which is very relevant in the context of ongoing discussions around just transition, and social cohesion.

4.1 DISTRIBUTIONAL IMPACTS OF FOSSIL FUEL PHASE-OUT ON CONSUMERS AND HOUSEHOLDS

In the case of Germany, households accounts for 25% of final energy consumption. A frequent concern is that measures to reduce emissions might have regressive effects on the distribution of income, i.e. put an over-proportional burden on the poorest segments of society. Economically vulnerable households have been especially burdened, allocating upwards of 5% of their disposable income on electricity alone (Frondel et al., 2015). Another example is the residential sector, which accounts for a large share of final energy consumption, and can be substantially impacted by changes in energy prices resulting from the energy transition. It is therefore not a surprise that a large part of the population perceives the cost distribution of the energy transition in Germany as unfair (Groh & Ziegler, 2018). However, the outlook for the energy transition in the coming decades looks very different. The very positive trend in the cost of renewable energy and flexibility and storage technologies observed in the last decade is expected to substantially reduce the costs of the energy transition, and therefore reduce the impact on energy users. In future energy transition scenarios[3] in Germany, distributional effects seem to be moderate, with households' expenditure on electricity slightly decreasing relative to all consumption expenditures (Blaufuß et al., 2019; Pothen & Hübler, 2018).

Different policies, such as emission pricing or regulated coal phase-outs, might have very different distributional impacts in some countries than in others (Steckel et al., in prep.). A cross-country comparison of the distributional effects that could be expected if a carbon price was imposed on the national level (Dorband et al., 2019) highlights that this policy would in fact result in progressive outcomes (i.e. put a lower relative burden on the poorest segments of society) for countries with per-capita incomes below 15.000 US Dollar (at PPP-adjusted 2011 US Dollar). This is confirmed by a recent meta-analysis of the available academic literature (Ohlendorf et al., 2018), which finds that carbon pricing is more likely to have progressive outcomes in poorer countries than

2 We follow here the definition of the Guidelines for Better Regulation of the European Union (https://ec.europa.eu/info/sites/info/files/better-regulation-guidelines.pdf), which characterizes fairness (under the criteria for evaluation of efficiency of policies and measures) as that the distribution of costs and benefits among the stakeholders affected is deemed acceptable. However, we recognize that fairness is a complex multidimensional concept and the project results referred here only consider a limited amount of dimensions of the fairness and perceived fairness of the policies.

3 The scenario examined here (Future Development Scenario FDS5) assumes a successful cross-sectoral transformation of the German energy system, with almost 100% of electricity coming from renewable energies by 2050. This includes a complete phase-out of nuclear energy and an extensive phase-out of coal, accompanied by carbon taxation in the remaining sectors. As a result, Germany's total CO_2 emissions will decrease by around 75% by 2050 compared to 2011.

in richer countries. This is due to the fact that in low-income countries the poorest segments of the population have low levels of energy consumption, whereas more well-off parts of the population are more likely to possess goods that consume energy, such as cars or electrical appliances.

Distributional issues might not only arise between income groups, but also between counties or regions within countries. For instance, in India, coal resources are located in relatively poor, northern-eastern states, whereas the most promising solar sites are in comparatively wealthy western ones, such that a transition from coal to solar would clearly create winners and losers (Ordonez et al., in prep.). Also in Germany, there has been a certain shift in recent years from coal regions (especially in the Rhine area, Brandenburg, Saxony) to PV regions in southern Germany and wind regions in northern Germany (von Hirschhausen et al., 2018).

Revenue recycling potential to address distributional impacts on households

Redistribution policies can play an important role in preventing disproportionally strong impacts of climate policies on low-income households. In this way, climate policy goals can be achieved with comparatively lower burdens or even benefits for low-income households. This also offers the opportunity to make use of synergies with other societal and policy goals beyond emissions reduction.

At the same time, if climate policies are implemented without consideration of potential undesired distributional impacts, they can slow down progress in the achievement of other important goals for a sustainable development (Sustainable Development Goals, SDGs). For instance, Sörgel et al. (in prep.) investigate the potential of undesired side effects of a 1.5°C mitigation scenario on poverty reduction in developing countries. Implementing a high carbon price, without any pro-poor redistribution policy could result in millions of people locked into poverty, with the poor in Sub-Saharan Africa being most affected (see Soergel et al., in prep.). This analyses however, does not account for the distributional effects of climate damages, which also would hit poorest households the hardest – taken together climate policy could benefit the poor even without pro-poor policies. Furthermore, Sörgel et al. (in prep.) show that by distributing the revenue from a CO_2 price on an equal per capita basis or progressively in income, climate policy could simultaneously lead to reduced poverty. Additionally, if benefits from reduced climate damages and co-benefits of climate action (e.g. avoided air, water and soil pollution; see Chapter 2.4 and Rauner et al., 2020) were factored in, the resulting synergies would outweigh remaining trade-offs between ambitious climate goals and other SDGs.

Evidence from different countries shows that there are multiple policy options to deal with potential distributional impacts arising from climate policies. In the case of policies that either put a price on greenhouse gas emissions or lower subsidies for fossil fuels, revenues can be recycled to improve distributional outcomes (Malerba et al., in prep.). For instance, such revenues could be used to invest in public infrastructure, such as education and healthcare, or expand social security. Franks et al. (2018) demonstrate that measures to put a price on carbon that is in line with reaching the 2°C temperature target would raise sufficient revenues to finance a substantial share of the investment needs to achieve the SDGs, especially in middle-income countries, e.g. in South-East Asia.

Similarly, analysis for OECD countries shows that adverse distributional impacts related to carbon pricing can also be mitigated or even reversed through appropriate revenue recycling. For instance, Edenhofer et al. (2019) find that for Germany, the negative distributional impacts of a new carbon price for non-ETS sectors could be avoided by lump-sum revenue recycling (climate dividend, see Figure 5). Lump-sum transfers or social cushioning could also increase acceptability of higher energy taxes in the population (Carattini et al., 2017).

In summary, there is robust evidence that redistributive measures like carbon tax recycling can help supporting those people that are mostly affected either by climate change impacts or mitigation – and thus to also increase acceptance of climate policies.

The German "**Climate Package**" was adopted by the Bundestag in November 2019 and subsequently strengthened in negotiations with the Bundesrat. It was adopted in December 2019 by both chambers and entered into force in early 2020. It contains a "Climate Protection Programme 2030", which sets an **emission reduction target of -55 % in 2030** compared to 1990 levels, sets out timetables for the reduction of emissions in the different sectors and mechanisms to ensure adaptation of emission reduction measures if needed, including an expert council to monitor the progress. The law was accompanied by an implementation package which includes (i) **the introduction of a CO_2 price** for fossil fuels in the transport, building and industrial sectors, (ii) investment in low carbon technologies, rail transport and local public transport, (iii) subsidies for the replacement of oil heating systems, and (iv) guidance instruments in the transport sector such as a slight increase in air travel tax, a reduction in VAT on rail travel and an increase in subsidies for the purchase of electric cars. The CO_2 price was originally supposed to be starting at 10 €/tCO_2 in 2021 and rising to 35 €/tCO_2. The chambers however, later agreed to increase the prices to €25/tCO_2 in 2021 and to €55/tCO_2 in 2025. The package includes a series of **compensatory measures**, partly financed by the CO_2 price revenues. This includes a reduction of the electricity surcharge to promote renewable energies (EEG levy; currently 6.75 cents/ kWh) by 1.75 cents/kWh in 2021 (originally proposed 0.25 cents/kWh) increasing to 4.65 cents/kWh (originally 0.875 cents/kWh) kWh) in 2025, as well as an increase in the housing allowance for low-income households and an increase in the commuter allowance. The compensatory measures were strengthened during the negotiations between the two chambers, in particular the reduction of the "EEG levy", through which the burden on households with low and middle income through the climate package has been considerably mitigated (Figure 5).

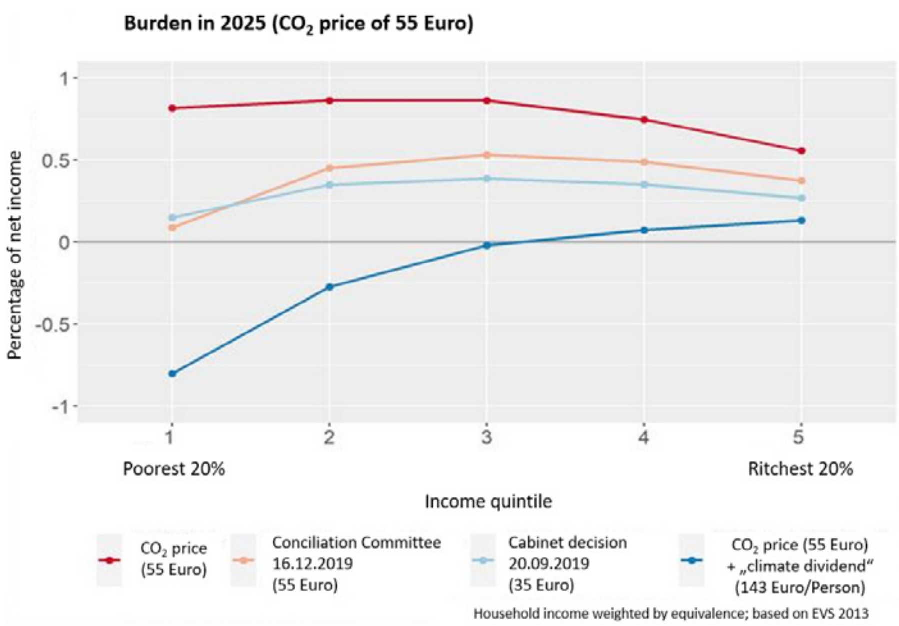

***Figure 5** shows the burden on households in 2025 on the basis of the cabinet decision in September 2019 (light blue line) compared to the measures decided by the mediation committee (orange). Despite higher CO_2 price (55 Euro instead of 35 Euro in 2025), the burden for all income groups increases only slightly and for lower incomes not at all, among other things because compensatory measures such as a reduction of the EEG levy are planned. The red line shows the effect of a CO_2 price of 55 Euro as a percentage of net income without compensatory measures. The dark blue line indicates the effect of a refund in the form of a "climate dividend". This option would have a strongly progressive effect (Edenhofer et al. 2019; captions in figure were translated by the authors).*

4.2 IMPACTS OF FOSSIL FUEL PHASE-OUT ON COMPANIES AND FOSSIL FUEL OWNERS

Various climate policies can be implemented to reach a phase-out of fossil fuels, including e.g. moratoria, carbon taxes and cap-and-trade systems. Such policies alter the distribution of profits and devaluate fossil fuel assets and therefore harm asset owners. But not only owners of fossil fuel reserves are affected directly: complementary investments are also at risk of stranding and include e.g. power plants and energy-intensive factories (Ploeg & Rezai, 2019).

While different policy-measures can be theoretically equally efficient, their distributional effects on companies and fossil fuel owners might differ substantially (Hübler & Löschel, 2013; Muttitt & Kartha, 2020). With policies that target the supply-side and reduce supply of fossil fuels (e.g. moratorium for expansion of exploration and extraction activities), market prices increase and producers could be paid more for their remaining output. In contrast, policies that target the demand side, e.g. via a carbon tax, reduce fossil fuel demand and thereby reduce the prices that producers are paid (Asheim et al., 2019).

Compensations for companies, fossil fuel owners and affected regions

The extent of the impacts of climate policies on companies and fossil fuel owners can determine their success, since larger losses for companies and fossil fuel owners can be expected to lead to stronger political resistance from organized interest groups and to impede policy-implementation (Meng & Rode, 2019; Persson, 1998). The same applies to regions and countries that are highly dependent on fossil fuel extraction and would be disproportionately affected by a phase-out of fossil fuels (see Chapter 3).

To tackle these distributional effects of climate policies and thereby ease their implementation, they can be combined with compensatory transfers towards stakeholders (e.g. companies, regions) that are heavily affected. However, a problem with such compensation payments is that large parts of the benefits from mitigated climate damages arise in the future and partly also globally, whereas the costs for compensation are incurred at the time of implementation and mostly locally (Hagen et al., 2019). The need, scale, and form of these compensations needs to be carefully considered to avoid unintended consequences that diminish the effectiveness or public perception of the fairness of the policy. For instance, the scale and need for the planned compensation to some coal companies, resulting from the German coal phase-out regulation has been criticized by civil society organizations (see box on Coal Phase-out Act) (Matthes et al., 2020).

Depending on the moral point of view, it could also be argued that fossil asset owners should rather be targeted with litigation instead of compensation because they are responsible for significant climate damages ("polluter pays principle") (Ploeg & Rezai, 2019).

In a recent study Sen & von Schickfus (2020) provide a good example of another problematic side effect of potential compensation policies. They analyse the gradual development of a German climate policy proposal, the climate levy ("Klimabeitrag") , and analyse its effect on the valuation of energy utilities. Strikingly, they find that investors take the risk of asset stranding into consideration but also expect to be compensated for their stranded assets. Such expectations could then result in a "carbon bubble" of overvalued fossil fuel dependent companies (Carbon Tracker Initiative, 2011; Delis et al., 2019). An increase in the stringency of climate policies could in that case lead to a sudden decrease in the value of fossil fuel assets (Hagen et al., 2019; Sen & von Schickfus, 2020). This causes risks of financial instability that are recognized by financial regulators (e.g. Carney, 2015) and researchers (e.g. Battiston et al., 2017; Ploeg & Rezai, 2019) and also influence companies and fossil fuel owners.

The German "**Klimabeitrag**" was publicly proposed in March 2015 with the aim of decommissioning lignite-based electricity generation capacities. In a first phase, the proposal foresaw an additional levy on CO_2 emissions of all power plant units older than 20 years and of "dirty" power plants whose emissions exceed a threshold only exceeded by lignite-fired power plants. Due to the resistance of the industry, this scheme was not finally approved. Instead, in July 2015, the payment of premiums for a so-called „capacity reserve" in return for taking lignite-fired power plants off the grid was introduced.

4.3 PERCEPTION OF FAIRNESS AND ACCEPTABILITY OF CLIMATE POLICIES

The regressive distributional impacts of climate policies are frequently criticized to be unfair and often claimed to fuel opposition against climate policy measures (e.g. Frondel et al., 2017). Therefore, also in Germany, the discussions on the climate package focused on the issue of greater burdens on poorer households and especially commuters. Research has made numerous proposals to cushion this burden, for example through a climate dividend (Bach et al., 2020; Edenhofer et al., 2019) (Figure 5). Cai et al. (2010) show that the national cost distribution affects citizens' support for climate policies. Rivers and Schaufele (2015) show that British Columbia's introduction of a carbon tax gained public acceptance largely owing to the reduction of the tax for low-income households. Along similar lines, Andor and colleagues (2018) find that reducing disproportional cost burden of low-income households (compared to those with higher income) for the promotion of renewable energy in Germany would significantly increase households' willingness to pay for green electricity. The debate on the German climate package made it clear that the perceived burden of a CO_2 price, especially for lower income groups, is an important aspect of its acceptability to the population. The adaptation of the climate package shows that a CO_2 price does not have to over-proportionally burden low income households, if the instrument is well designed. The disproportionate burden of low income households could for example be avoided by lowering the EEG levy (see Figure 5 and box on the climate package).

A cost distribution that is perceived to be unfair constitutes a barrier for the implementation of climate policies such as the fossil phase-out. It is therefore important to investigate how the distribution of climate policy costs could be designed to be perceived as fair. Research on the international experiences shows that to increase (or maintain) political support for actions that promote decarbonisation, two considerations are of particular importance for policy design: (1) careful consideration of households' ability to carry the burden of increasing energy costs and (2) the perceived fairness in how the burden is shared.

Households ability to carry the burden: Recent research has documented that the responsiveness to changes in energy costs depends on several mediating factors, including household income, geography, and macroeconomic conditions. Income and residential location are especially important since they determine the range of measures that households can undertake to cope with price increases, be it by purchasing more efficient appliances in response to electricity price increases (Frondel et al., 2019; Schulte & Heindl, 2017) or by switching to public transit in response to fuel price increases (Frondel & Vance, 2011). Frondel and Vance (2017) note, for example, that higher fuel costs are associated with a higher likelihood of using a bicycle and that the magnitude of this effect is much greater for people living in urban areas. For households facing financial constraints or constraints with regard to their residential location on their ability to undertake such actions, compensation measures – such as subsidies for appliance purchases, discounted transit passes, or direct cash transfers – can reduce their exposure to energy price shocks arising from climate protection policies. A clear example of this are the implementation of increasing CO_2 prices for the transport and heating sector in Germany. Despite being very low compared to levels that encourage consumers to substantially change their behaviour (Bach et al., 2020), they require additional mechanisms to help poorer households in order to be implemented (Ismer et al., 2019).

In addition to compensation, mechanisms to increase the citizen participation have huge potential to increase the acceptance of the energy transition. Instruments should be adapted to the target group. Often, pure information campaigns to increase acceptance are in vain, as people rarely change their original attitudes (Shamon et al., 2019). Acceptance is also influenced by social and psychological factors such as social networks (Jager, 2006; Wolske et al., 2017), peer effects (Bollinger & Gillingham, 2012; Palm, 2016, 2017; Rai & Robinson, 2013), trust and local ties (Perlaviciute & Steg, 2014), which in turn underlines the importance of participatory approaches.

Perceived fairness of burden sharing: Studies focusing on the distribution of costs across the population find clear evidence for preferences for a cost distribution following the "ability-to-pay" rule, i.e. a cost distribution in relation to income (e.g. Brännlund and Persson (2012) for Swedish households, Gevrek and Uyduranoglu, (2015) for Turkish households, Frondel et al. (2017) for German households) or a cost distribution following the "polluter-pays" rule, i.e. a cost distribution in relation to emissions which is also the most efficient rule (e.g. Hammar and Jagers (2007) for Swedish households). A direct comparison shows that the polluter-pays rule is preferred by the population (e.g. Groh & Ziegler, 2018; Ščasný et al., 2017).

While it is clear that coupling climate policies with revenue recycling schemes to offset potentially adverse distributional impacts could increase public support for these policies, historic cases draw a more nuanced picture about public acceptance. In the case of Germany, despite the fact that households have borne a substantial share of the costs, public support for the energy transition has remained durable, with most polling suggesting a solid majority in favour of public financing for renewable energy sources (Andor et al., 2017; Setton, 2019).

In contrast, the fuel subsidy reforms implemented in 2012 in Nigeria (Dorband et al., in prep.) and in 2019 in Ecuador (Schaffitzel et al., 2020)[4] have resulted in mass protests and strikes, which in both cases led to a (at least partial) revision. In these cases, opposition cannot be fully explained by the distributional implications of the proposed measures. In the first case, analysis for Nigeria suggests that introducing a carbon price and using the associated revenues to expand infrastructure would result in lower-income households bearing a relatively lower pricing burden, while enjoying greater gains from access to infrastructure, such as to water, sanitation, electricity, and telecommunication infrastructure. In a similar vein, in Ecuador removing subsidies for petroleum products could free up enough fiscal space to expand social security programmes to an extent that would increase the real income of the poorest quintile by 10% while at the same time leaving more than 1.3 billion US Dollar for the heavily strained public budget (Schaffitzel et al., 2020). Compared to an industrialised country like Germany with high average household incomes and thus comparatively low energy costs, parts of the population in emerging countries such as Nigeria or Ecuador are at or below the poverty line and are therefore directly dependent on favourable fuel prices, so that the medium-term advantage of improved infrastructure does not appear to be very relevant in the short term.

These examples show that even when fairness aspects are taken into account, public support is still influenced by country-specific factors, such as low governmental trust, vested interests of relevant stakeholders or communication campaigns of political opponents. This leads to the need to analyse distributional effects embedded in a broader political economy framework to understand the acceptability of climate policies. Nevertheless, fair policy implementation remains an important prerequisite for political success.

4 In 2012, Nigeria announced the abolition of a petrol subsidy - which more than doubled petrol prices - leading to labour strikes and nationwide protests. In Ecuador, the government announced the abolition of subsidies in October 2019 for petrol and diesel as part of a major austerity package in response to a loan from the International Monetary Fund, which was linked to tax reforms. This resulted in a 25 % increase in petrol prices and a roughly doubling of diesel prices, followed by massive violent protests for about two weeks.

5. CONCLUSION

In the previous chapters, a number of research findings have been presented on the topic of "phasing out fossil fuels". These show that a rapid phase-out of fossil energy sources is essential for achieving the climate targets and describe how such a phase-out can be implemented.

In addition, various policy instruments for phasing out fossil fuels were discussed and political hurdles for their implementation were described. Instruments include the removal of subsidies for fossil fuels, a price on CO_2 emissions, targeted phase-out plans, moratoria on coal production and use, increased development of renewable energy infrastructure and incentives for investments in green technologies. Sectoral and national measures should be cross-sectoral and coordinated at European and international level in order to avoid a shift of fossil fuel use between sectors and countries.

Other key policy measures for the implementation of a phase-out of fossil fuels concern the compensation of negative distributional effects. In order to promote global action to achieve the Paris climate targets, international mechanisms for burden sharing between countries are needed. In developing countries, a phase-out of fossil fuels must not lead to a slowdown in the expansion of energy supply. Also within a country, it should be ensured that the regions and communities where fossil fuels are produced are offered opportunities to create a new livelihood. On the consumer side, redistribution measures are important to minimise the burden of energy price increases on low-income households. Involving the population in the development of locally adapted solutions will lead to greater acceptance, which in turn increases the chances of political success.

At present, the global COVID-19 stimulus packages offer an opportunity to exploit synergies between these stimulus packages and national climate change packages and the implementation of the EU Green Deal. This could facilitate and accelerate the implementation of measures to achieve the climate targets.

This background paper is preceded by a summary of the key messages and policy recommendations.

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