SECTOR DECARBONISATION PATHWAYS FROM DIFFERENT ANGLES:

TECHNOLOGY, MODELLING, POLITICS
SECTOR DECARBONISATION PATHWAYS FROM DIFFERENT ANGLES: TECHNOLOGY, MODELLING, POLITICS

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The IPCC special report on the impacts of global warming of 1.5 °C, published in October last year, provides clarity on what it might take to reach the long-term goal of the Paris Agreement to stay well below two degrees of warming: decarbonisation needs to happen not ‘sometime in the second half of the 21st century’ as was the understanding until recently, but rather in 2050 or shortly thereafter. By 2030 sector transformations need to be well on their way. While all signatories to the Paris Agreement need to submit their new and updated Nationally Determined Contributions (NDCs) next year, it is widely acknowledged that at the moment we are not progressing fast enough collectively and countries are not ambitious enough to meet the Paris goal.

This mid-year edition of the NDC Update Report focuses on sector decarbonisation pathways. We discuss what it takes to think through the choices involved in shaping a Paris-compatible sector future from a number of different perspectives.

Chapter 2 presents the main decarbonisation options for five main sectors – power, industry, transport, buildings, and agriculture and land-use – and shows that in each sector there are choices and decisions to be made. These choices cannot be left until after 2030 and will need to feature in the next rounds of NDCs, ideally as a reflection of a well-informed long-term strategy. Key decarbonisation options have different requirements for the development of technology and associated infrastructure and if the right choices are not made in a timely manner, there is a risk of path-dependency, locking a country into sub-optimal sector pathways.

Time is an important consideration here: introducing alternatives at a later stage would likely be inefficient and costly and might not be achievable given the long lead times for planning and delivery of large infrastructure. Consumer campaigns will likely need to be put in place quite far in advance of the introduction of major policies and regulations, which means they may be necessary within pre-2030 timescales. Moreover, interactions between sectors, for example related to the increase in power demand as a result of electrification across sectors or the multiple uses of biomass, call for deliberate economy-wide coordination.
Chapter 3  looks at how global scenarios and goals can be translated into feasible policies, plans, and strategies to enable sector decarbonisation. It presents different modelling approaches to translate science and global pathways to sector and sub-sector contexts. The power of scenario modelling lies in its ability to explore potential future developments under varying assumptions, and to provide an evidence base to better understand the implications of different pathways options. Bottom-up modelling approaches such as least-cost optimisation to determine cost effective mitigation pathways, can be complemented with equity approaches which use top-down methods to allocate the global mitigation burden fairly among countries or sectors based on specific criteria.

Because the choice of model and approach has a significant impact on the results, it is important to understand the options and potential of each one. Models can by no means capture the full breadth of dynamic complexities of entire sectors and economies given computational constraints. Hence for a nuanced perspective, a combination of different approaches may be needed. When developing Paris-compatible pathways, stakeholders may have different perspectives on assumptions, plausibility, and political feasibility. Transparency, dialogue, and communications are key in aligning stakeholders with potentially conflicting needs, perspectives, and expectations; transparent modelling exercises provide a solid basis to enable this and governments can play a key role as mediators in this process.

Chapter 4  looks at Political Economy Analysis (PEA) as an approach to understanding the politics of sector transitions. Sector transitions are not only technical or economic challenges, but also involve political processes regarding stakeholders who might gain or lose income and opportunities as a result of choices made. A better understanding of the political dynamics in the sector will allow for a more realistic assessment of which actions and pathways are feasible – important when shaping effective policies and programmes to drive Paris-compatible sector transitions. Since the late 1990s, development assistance agencies have been developing and using diagnostic tools to analyse why ‘lack of political will’ prevents technically feasible and properly funded projects from being effective. PEA is the diagnostic approach that has emerged, with the aim of finding out what is ‘really going on’ in a situation: who influences change and whether and where competing interests exist.

Most examples of PEA are conducted from an external perspective, for example by donors analysing the national and sectoral political dynamics in partner countries, and not by governments as part of their own stakeholder engagement thinking and processes. We are however optimistic that political economy analysis can also be used in support of sector planning (i.e. from inside the process) in one way or another: especially for ‘big decisions’ about technology pathways and for achieving the most difficult (and obviously last) 10-20% of emissions reduction, where political dynamics matter in identifying which actions are feasible and which are not.
The final chapter, Chapter 5, contains contributions from experts in the NDC Cluster working groups, looking at the medium-term challenges of sector decarbonisation and the short-term implications for policy makers and planners.

From a transparency perspective, clarity on sectoral pathways is needed to guide domestic implementation. Transparency can significantly strengthen the quality of the sectoral decarbonization strategy, as well as its legitimacy and durability. This includes considerations of transparency of inputs and methodology, transparency of the development process, and transparency of communication.

From a finance perspective, the challenge is to mobilise Paris-compatible investments at scale and avoid ‘carbon lock-in’ through sub-optimal technology pathways. This will require significant use of public resources and close collaboration with private sector actors (in particular the financial sector and institutional investors). Short-term interventions are needed to make green investments financially attractive and to provide access to affordable early-stage financing.

From a governance perspective, the following short-term enablers need to be in place by 2025 in order to lay the foundations for a global net-zero emissions future in 2050: Developing a clear long-term vision; upgrading governance capacities for a systemic, whole-of-society approach; integrating decarbonization strategies with sustainable development pathways; and developing clear implementation plans, including short and medium-term goals that are clearly stated in revised NDCs and related plans.

Looking ahead at 2020, we see a risk that the new NDCs will focus on intermediate targets without a robust underlying long-term strategy towards 2050, and that pathways compatible with medium-term targets in NDCs may not be ambitious or comprehensive enough to reach the long-term target of full decarbonisation across sectors. In order to avoid such incompatibility and prevent the need for potentially more costly corrective actions later, it is crucial that governments start to seriously and coherently develop long-term sector strategies towards 2050 as new NDCs are considered and updated.

For many countries, and developing countries in particular, answering questions related to which options to implement and when, and how and why to involve stakeholders and consumers may seem complex and daunting.

However, as this report shows, there are approaches that can help such as scenario modelling, analysis of the political dynamics, and forward-looking approaches relating to transparency, public and private finance, and governance.
SECTOR DECARBONISATION PATHWAYS FROM DIFFERENT ANGLES:

Technology, modelling, politics.

To reach the long-term temperature goal of the Paris Agreement, most countries will need to reduce emissions to net-zero in 2050 or shortly thereafter. This report considers this challenge from a sector perspective, examining decarbonisation from several different angles.

For the following five key sectors: power, industry, transport, buildings, and agriculture, forestry and other land-use, it highlights the leading mitigation options and their implications for longer-term planning.

The report further describes how modelling and developing scenarios can support mitigation planning, and how political economy analysis can complement technology-focused approaches to get a better understanding of the feasibility of sector transition pathways.
## Abbreviations

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<th>Description</th>
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<tr>
<td>A2A</td>
<td>Ambition to Action</td>
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<tr>
<td>AFOLU</td>
<td>Agriculture, Forestry and Other Land Use</td>
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<td>BAU</td>
<td>Business as usual</td>
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<td>BECCS</td>
<td>Bio-energy with carbon capture and storage</td>
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<td>BMU</td>
<td>German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety</td>
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<td>CAT</td>
<td>Climate Action Tracker</td>
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<tr>
<td>CCS</td>
<td>Carbon capture and storage</td>
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<td>CGE</td>
<td>Computable general equilibrium</td>
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<tr>
<td>COP</td>
<td>Conference of the Parties (to the UNFCCC)</td>
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<td>CSP</td>
<td>Concentrated Solar Power</td>
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<td>ECN</td>
<td>Energy research Centre of the Netherlands (part of TNO)</td>
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<td>ESM</td>
<td>Energy system models</td>
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<td>EV</td>
<td>Electric vehicles</td>
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<td>GDP</td>
<td>Gross domestic product</td>
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<td>GHG</td>
<td>Greenhouse gas</td>
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<tr>
<td>GIZ</td>
<td>Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH</td>
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<td>HFCs</td>
<td>Hydrofluorocarbons</td>
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<tr>
<td>IAM</td>
<td>Integrated Assessment Model</td>
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<td>ICE</td>
<td>Internal Combustion Engine</td>
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<tr>
<td>IEA</td>
<td>International Energy Agency</td>
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<tr>
<td>IKI</td>
<td>International Climate Initiative (of the BMU)</td>
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<td>INDC</td>
<td>Indented Nationally Determined Contribution</td>
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<td>IPCC</td>
<td>The Intergovernmental Panel on Climate Change</td>
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<td>LEAP</td>
<td>Long-range Energy Alternative Planning</td>
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<td>LTS</td>
<td>Long-term Strategies</td>
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<td>NDC</td>
<td>Nationally Determined Contribution</td>
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<td>PEA</td>
<td>Political Economy Analysis</td>
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<td>PV</td>
<td>Photovoltaic</td>
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<td>TNO</td>
<td>Netherlands Organisation for Applied Scientific Research</td>
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<td>TWG</td>
<td>Thematic working group</td>
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<td>UNFCCC</td>
<td>United Nations Framework Convention on Climate Change</td>
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ABOUT...

...THIS REPORT

This report is part of a series of biannual NDC Update Reports, published ahead of international climate change negotiations, presenting recent developments, analysis, opinion, and discussion pieces. Drawing on the Ambition to Action (A2A) project and insights from a wide range of climate change experts and practitioners, the reports aim to be a platform for learning, sharing insights, and discussing topics around the implementation of the Paris Agreement. The NDC Update Reports focus on mitigation ambition and action in developing countries and emerging economies (with an occasional look at industrialised countries for contrast or comparison). The reports offer a podium for the working groups under the NDC Cluster to reflect on the topics covered in it from their perspective (financing, governance, and transparency).

For previous editions, see http://ambitiontoaction.net/outputs/

...THE AMBITION TO ACTION PROJECT

This report is an output of the Ambition to Action project, which supports NDC implementation through technical assistance and thought leadership. The project is implemented collaboratively by the Energy research Centre of the Netherlands (ECN part of TNO) and NewClimate Institute, over a three-year period until the end of 2019. Project funding is provided by the International Climate Initiative (IKI) of the German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU).

Ambition to Action’s technical assistance aims to support the mainstreaming of climate and development goals at the sector level, through the development of evidence on social, economic and environmental benefits of mitigation actions and pathways. This benefits evidence, for example detailing employment, energy security, and air pollution impacts, will show how sector planning decisions can support NDC implementation as well as national development priorities and can help reduce policy costs, identify trade-offs, and build stakeholder support for ambitious mitigation approaches at the sector level. The project focusses on the energy sector and provides direct support to Argentina, Kenya, Indonesia, and Thailand. A benefits assessment methodology and guidance will be published for use in other sectors and countries.

In addition to sharing insights and lessons on the development and use of benefits evidence, the project’s thought leadership work will consider the broader topic of NDC implementation progress. Through a series of biannual reports (of which this is the fifth edition) and additional research papers, the project provides a platform for discussion, analysis, and sharing of lessons learned about NDC implementation in developing countries and emerging economies.

The Ambition to Action project is part of the NDC Cluster established by the BMU in 2015. The NDC Cluster currently exists out of seven projects, with a total funding volume of approximately EUR 56 million, ten climate and development implementing partners coordinate their activities to allocate resources effectively and efficiently in 27 selected partner countries.
It has been almost four years since 174 states and the European Union signed the landmark climate agreement in Paris. The Paris Agreement on climate change and the IPCC special report on 1.5°C make clear that, in order to reach the temperature goal of ‘well below two degrees’, all countries will need to reduce emissions to net-zero in 2050 or shortly thereafter. But what does this really mean? It means countries are ‘required’ to reduce the volume of greenhouse gas emissions that human activity releases into the atmosphere until our total output is no greater than the emissions we remove. This also means that all sectors of the economy will need to move away from fossil fuels and more generally limit greenhouse gas emissions. Countries already pursue different actions and activities to realize this. However, according to António Guterres, Secretary-General to the United Nations:

“There are different technology pathways to achieve decarbonisation, but what is optimal from a techno-economic or climate perspective, may not be feasible or desirable for other reasons – including social or political pressures. It is one of the reasons we are not ‘doing enough’. Getting sectors from their current situation to a decarbonised world entails overcoming challenges along the way as it requires a fundamental transformation of the economy.

By 2020, which is just around the corner, countries need to communicate their second round of pledges to the United Nations Framework Convention on Climate Change (UNFCCC). These pledges need to be more ambitious than the pledges communicated in 2015 and should put us better on track to deep decarbonisation. In further supporting governments prepare for their next round of pledges, this thematic edition of the 5th NDC Update Report zooms into actions and activities to limit greenhouse gas emissions. More specifically, it dives into sector decarbonisation pathways. Such insights can help nations, countries and actors to better understand what to expect for the different sectors, which is needed to ‘do more’ and be more ambitious. While adaptation and resilience are an integral part of the Paris Agreement, this report focuses on mitigation actions because the direct link with the ambition mechanism and the long-term temperature goal.

This report has four chapters. Chapter 2 starts by laying out the main decarbonisation options available in five key sectors: power, industry, transport, buildings, and agriculture, forestry and other land-use (AFOLU). It further highlights how selecting some of these options may have implications for decarbonisation planning that should be thought about in the context of NDC design. Chapter 3 considers the challenges of modelling sector pathways and anchoring transformational pathways in economic and political realities. Next, Chapter 4 looks into what taking a political economy view can reveal about the likelihood that a government is able to accelerate sector transformation and achieve ambitious targets. Finally, to wrap it all up, Chapter 5 explores challenges and short-term actions on the road to low-carbon success from the following three perspectives: ‘transparency’, ‘financing’, and ‘governance’.

The IPCC special report on 1.5°C concluded (with high confidence) that in order to limit global warming to 1.5°C, global greenhouse gas (GHG) emissions must reach net zero around 2050 (IPCC, 2018). The long-term target for reducing emissions to (net-) zero has implications for decisions that need to be made in all sectors in the short to medium term.

With NDCs focused on intermediate targets there is a risk of losing sight of the 2050 goal and that NDC-compatible pathways may not be compatible with long-term targets. In order to avoid such incompatibility and prevent the need for potentially more costly corrective actions, it is crucial that governments start to seriously and coherently develop long-term sector strategies towards 2050 as new NDCs are considered and updated.

In this chapter we will look at the main decarbonisation options available in five key sectors - power, industry, transport, buildings, and agriculture, forestry and other land-use – and highlight how selecting some of these options may have implications for decarbonisation planning that should be thought about in the context of ongoing NDC development.

There is a range of decarbonisation measures that can contribute to achieving net-zero emissions in these sectors, each with its strengths and challenges. The chapter is informed by available recent research and analysis on decarbonisation pathways (e.g. IPCC, 2018; CAT decarbonisation series 2016-2018; CAT, 2019; Climate Analytics, 2019; UK CCC, 2019). The discussion about decarbonisation options in each sector is not meant to be exhaustive or provide solutions to observed dilemmas. It rather intends to illustrate some of the sectoral challenges, key decisions that need to be taken, and the consequences those decisions can have. The chapter seeks to provoke thought about zero emission sectors, sectoral transformations, and the importance of considering long-term targets in NDCs.

2.1 POWER

In a zero-emissions power sector, emissions from fossil fuel combustion need to be eliminated. To achieve the 1.5°C Paris Agreement target, fossil fuel capacity will need to be largely phased out by mid-century, with complete phasing out of coal power plants (Climate Analytics, 2019). Natural gas power plants can play a transitional role in replacing fossil fuels, but in the long term will need to be phased out as well to achieve zero emissions (Climate Analytics, 2019; CAT, 2017a).

Renewable energy sources, already deployed at meaningful scale in many countries, must be vastly scaled up to replace fossil fuels in the power sector. Renewable power capacity is growing fast, with global installed capacity more than doubling from 1,136 GW in 2009 to 2,351 GW in 2018 (IRENA, 2019). Meanwhile, the cost of renewables has decreased substantially, especially for solar PV and wind energy (IRENA, 2018). There are a variety of renewable power technologies available, with technology-specific advantages and disadvantages. Some technologies, for example, can provide baseload power (e.g. hydro, geothermal, and biomass) while others are more variable in nature (such as solar and wind energy) and require additional grid balancing services. Innovation in network balancing and storage technologies will help address the variability of solar and wind energy: in particular storage technologies, such as batteries and thermal storage for concentrated solar power (CSP) will enable further expansion of renewable energy capacity in the future.

Nuclear power offers an alternative source of fossil
fuel-free baseload power, but its future is uncertain because of rising costs and limited provision of co-benefits compared to renewables (Climate Analytics, 2019). It also faces considerable opposition from civil society, not least because of concerns about safety and the disposal of nuclear waste. Despite these challenges, some countries still consider nuclear energy to be a viable and complementary zero-emission technology (UK CCC, 2019).

Carbon capture and storage (CCS) could allow continued use of gas-fired power plants, providing low (but not zero) emissions baseload power. While some countries foresee a role for CCS as a necessary technology for deep decarbonisation (see e.g. UK CCC, 2019), CCS technology has yet to be commercialised at scale, and it does not address the broader negative environmental impacts of e.g. coal mining and burning, such as water and air pollution (indeed due to the extra energy required to capture CO₂, it may worsen them). Furthermore, with CCS capture rates generally not expected to exceed 95%, some residual emissions remain even with CCS deployment. Thus in order to achieve net-zero emissions, these residual emissions would need to be compensated for with negative emissions from biomass energy with CCS (BECCS) (or other negative emission technologies – see Box 1).

**BOX 1: THE ROLE OF NEGATIVE EMISSIONS IN (SECTORAL) DECARBONISATION**

Negative emissions can compensate for residual emissions which are very hard or expensive to eliminate, for example where it is not technically or economically feasible to replace fossil fuels, eliminate process emissions, or completely remove non-CO₂ emissions. Negative emissions can be achieved by combining biomass energy with CCS (BECCS), where CO₂ absorbed by the biomass during its lifetime is captured and stored after combustion for power or heat. The AFOLU sector can also potentially contribute with negative emissions through increased storage of CO₂ in forests, soil, or other locations.

The potential for BECCS is largest in the power and industry sectors. BECCS or negative emissions in the AFOLU sector could therefore be employed for cross-sectoral emissions reductions. If net-zero emissions is not within reach in a sector, negative emissions in another sector can compensate and net-zero emissions can still be realised across the entire economy.

While BECCS and other sources of negative emissions can contribute to achieving net-zero emissions, they face multiple feasibility and sustainability constraints (IPCC, 2018). The IPCC expects there is limited potential for a single carbon removal option to sustainably achieve the large-scale deployment required in deep decarbonisation pathways (IPCC, 2018). Measures delivering negative emissions are also unproven at commercial scale. Most negative emissions options are not mature enough to realistically estimate their long-term reduction potential, scalability, costs, and potentially negative environmental and social impacts. Due to the uncertainty about scalability and reduction potential, as well as the unproven status at commercial scale, the use of negative emissions is considered complementary to other decarbonisation measures in this report. The potential availability of negative emissions should be carefully assessed and should by no means delay other decarbonisation efforts.
Negative emissions technologies are yet unproven at commercial scale and the low stage of development of these technologies makes it challenging to have accurate estimations of their potential (see Box 1). Given the uncertainty around both CCS and negative emissions technologies, the fact that CCS deployment would require negative emissions to compensate its residual emissions makes for a high level of compound uncertainty; total phase out of fossil fuels is surely the more sensible course.

There are also important interactions between the power sector and end-use sectors, where the decarbonisation choices made in those sectors can have important implications for the power sector. Electrification is a key decarbonisation option in a number of end-use sectors, for example for transport, or to generate heat in buildings and industry. Increased electrification will increase power capacity requirements and can have an impact on power consumption patterns (e.g. leading to greater differences between peak and base loads) and thus creating additional network and balancing infrastructure requirements. The long-term development of power demand, based on decarbonisation choices in other sectors, will therefore need to be taken into account when considering the decarbonisation of the power sector.

2.2 INDUSTRY

Net-zero emissions can be achieved in the industrial sector by reducing emissions from fossil fuels and eliminating non-energy (process) emissions. Complete elimination of emissions in the industrial sector is more complex than decarbonisation in the power sector due to the great diversity in industrial sectors, processes, and technologies. Due to this diversity, there is no “one-size-fits-all” solution and decarbonisation can take very different forms in each industrial subsector and each industrial facility.

Fossil fuels used for energy in the industrial sector can be replaced through electrification and by switching to alternative fuels like hydrogen from non-emitting sources, or biomass. Energy efficiency can play an important role by reducing the amount of alternative fuel and zero-emission power required. The reduction of demand for industrial products leads to lower energy consumption and energy-related emissions. Demand for raw materials can be reduced through increased reuse and recycling of materials and products, more efficient use of resources (e.g. more efficient use of steel in end-products will reduce the demand for steel), or product switching (e.g. switching from cement to wood or other construction materials will reduce the
demand for cement). Process emissions can be eliminated by switching to alternate processes or reduced by lowering demand (e.g. increased reuse and recycling, more efficient use of resources, or product switching).

Emissions from fossil fuel use for energy and process emissions can additionally be reduced through energy efficiency measures and CCS, but these options are not sufficient to achieve zero-emissions by themselves – they will need to be paired with zero-emission fuels or negative emissions technologies. As discussed in the previous section, there are limitations to the deployment of CCS and negative emissions technologies. The priority to achieve a net-zero emissions industry should be switching to zero-emission fuels and processes. Any remaining emissions will need to be reduced as much as possible to make compensating with negative emissions technologies attainable. Box 2 discusses decarbonisation in the cement sector, including potential measures for the elimination of process emissions and the implications of reliance on CCS.

A major challenge in the industrial sector is that industrial facilities and equipment are infrequently replaced because of long lifetimes (e.g. blast furnaces in the steel sector or production plants in the chemical industry), and due to the cost of shutting processes down for replacements. Changes therefore need to be known far in advance to avoid lock-in of emitting technologies and increased cost of replacing equipment before the end of its lifetime. Where additional national infrastructure is also required (e.g. piping networks and storage sites in the case of industrial CCS), well-timed coordination is required between government and industry players to ensure decarbonisation approaches and timetables are aligned.

**BOX 2: A ZERO-EMISSIONS CEMENT SECTOR**

There are two types of GHG emissions in the cement sector which need to be mitigated to reduce emissions to zero: emissions from fossil fuel combustion and emissions from the cement making process (in particular the conversion of limestone to clinker, the main constituent of cement). Fossil fuels can be replaced by electrification or by switching to alternative fuels such as biomass. Process emissions can be reduced by improving the cement making process, moving to alternate production processes, or by capturing and storing the CO₂ released (CAT, 2017b). Emissions reductions can also be achieved by reducing the demand for cement (e.g. by replacing cement with other construction materials or recycling) (CAT, 2017b). Complete elimination of process emissions could be challenging however, and some emissions could remain. These residual emissions can potentially be compensated for by negative emissions through the deployment of BECCS (or carbon removal in other sectors). As discussed in Box 1 negative emissions technologies are not mature enough to properly assess their potential long-term contribution to emissions reductions. Deep reduction of residual emissions will therefore be required if negative emissions are relied upon to achieve net-zero emissions. Due to the uncertainty about the scale on which CCS and negative emission technologies can be utilized, the primary focus in the cement sector should be fuel and process switching.

As there are multiple potential decarbonisation measures, the approach to eliminate emissions can differ across production facilities and countries. Available decarbonisation plans already show a large range of proposed ideas (see e.g. Cembureau, 2013; UK DECC & BIS, 2015; UK BEIS, 2017).
2.3 TRANSPORT

There are multiple options for the elimination of emissions in the transport sector, most prominently fuel switching to low carbon energy sources, and structural changes that avoid or shift transport (e.g., cars, trucks, and airplanes to bicycles, buses and trains) (IPCC, 2018). Transport can be avoided through methods such as increasing vehicle occupancy rates, improved urban planning, and behavioural changes. Shifting to alternative modes of transport only leads to a zero-emissions sector if the alternatives do not emit GHGs. While some modes of transport currently already operate at zero emissions (such as bicycles and renewables-powered electric trains), the elimination of fossil fuels from transport will be required in order to fully decarbonise the transport sector.

For road transport, electric vehicles, biofuels, and hydrogen all already offer opportunities for zero-emission transport. Fossil fuel fired rail transport also needs to be replaced by trains powered by zero carbon electricity or alternative zero-emission fuel options (such as hydrogen from non-emitting sources). Electric trains are commonplace today and further electrification of rail, along with continued power sector decarbonisation, presents a relatively straight forward way to reduce transport emissions. Decarbonisation of shipping and aviation is more challenging, because it is uncertain whether alternative fuels such as hydrogen, biofuels, and synthetic fuels can satisfy technical demands (e.g., weight/space and range), and can be supplied at a sufficiently large scale and at acceptable costs.

While there are some electrification projects the large-scale feasibility remains unproven (IEA, 2018). Meanwhile, demand growth in the shipping and aviation sectors is projected to be higher than other transport modes (IPCC, 2018). Even so, efforts to identify, develop, and provide sustainable low-carbon or zero-carbon fuels are slowly gaining traction in both the maritime and aviation sectors (IMO, 2018; ICAO, 2017; Transport and Environment, 2018).

Renewable-based synthetic fuels are also being developed, but have lower efficiency than direct use of electricity and are still at an early stage of development. For the time being the application of synthetic fuels is therefore only expected to occur in cases where alternatives are difficult to implement, for example when biofuels cannot be supplied at a large enough scale, or if the implementation of electricity or hydrogen cannot meet required weight, space, or range requirements for use in the aviation, maritime, or freight transport sectors.

While there are multiple options for the decarbonisation of the transport sector available and under development, many options have implications for consumers. For example, switching from fossil fuel internal combustion engine (ICE) vehicles to electric vehicles or hydrogen fuel cell vehicles, or modal shifting to alternative transport modes all requires action and engagement from consumers. Consumer behaviour therefore plays a crucial role in realising decarbonisation in the transport sector and consumers will need to be engaged and willing to play their part in the transition. The success of these options thus depends for a large part on the
willingness of consumers to make changes in their behaviour – as well as the reaction of consumers to policy stimulating decarbonisation options or disincentivising polluting alternatives.

Decarbonisation of transport also relies on infrastructure development and replacement of the vehicle stock. Transport infrastructure such as new charging facilities for electric vehicles, fuel stations for hydrogen, and new rail infrastructure take time to decide, design, and implement. Switching production from fossil fuel ICE cars to alternative cars and replacing the existing car fleet will also take time. Engaging consumers about the need to make different vehicle purchasing decisions or to travel less will also be a slow process. Timely action therefore needs to be taken considering the development requirements for infrastructure and the phasing out of the sales of fossil fuel vehicles.

2.4 BUILDINGS

Emissions from the use of fossil fuels in buildings for cooking, and for water and space heating, can be eliminated through electrification or by replacing fossil fuels with zero-emission fuels such as solid biomass, biogas, and hydrogen from non-emitting sources. The demand for water and space heating can also be centralized through district heating systems operating on a zero-emission basis. Emissions can also be decreased through changes in consumer behaviour and through end-use energy efficiency measures (IPCC, 2018). End-use energy efficiency includes measures targeting electrical appliances, cooling and heating appliances, and building energy performance improvements such as improved insulation.

Another source of emissions from the buildings sector that will need to be eliminated are non-CO₂ emissions from cooling equipment. These emissions are caused by hydrofluorocarbons (HFCs), which are used as cooling agents, escaping during operation or at the end of the lifetime of cooling equipment. It is expected that emissions of HFCs will increase over the coming decades, in part due to an increase in global demand for air conditioners (IPCC, 2018).

The emission of HFCs can be reduced by improving cooling equipment, replacing HFCs with alternate cooling gases that do not cause global warming or through improved service and maintenance practices.

Many of the interventions available to decarbonise the buildings sector, such as electrification and

2 Synthetic diesel production from electricity has an approximate efficiency of 45-55% (Detz et al., 2018).
improved insulation, will require significant amounts of time to roll out to national scale. New buildings will have to be constructed to be zero-emissions and the existing building stock will have to be renovated to meet the same standard. With new energy efficiency, heating, and cooling technologies it will take time to build up the necessary skilled workforce capable of performing the renovations and the construction of new zero-emission buildings. Renovating millions of existing buildings will also require a number of years to implement and suitable starting dates need to be decided upon, taking into consideration the availability and size of the skilled workforce and the rate at which renovations can realistically be performed.

2.5 AGRICULTURE, FORESTRY AND OTHER LAND USE

Net-zero emissions in the AFOLU sector can be achieved through reducing supply side (CO₂ and non-CO₂) emissions, demand reduction, and, if necessary, the use of negative emissions to compensate for any residual emissions.

Supply side emissions can be reduced through interventions such as improved farming practices (such as reduced fertiliser use) and reducing waste in the food supply chain (IPCC, 2018; CAT, 2018). Two interventions with high potential for emissions mitigation on the demand side are waste reduction and consumer behaviour changes (CAT, 2018; IPCC, 2018). Demand side waste reduction is a cross-cutting solution that can decrease the demand for agricultural and forestry products (e.g. in the case of paper). Influencing consumer behaviour to decrease demand for agricultural and forestry products in general can reduce emissions and also reduce other environmental strains in the land sector. Shifting consumer patterns to less emission intensive consumption habits (e.g. shifting diets high in livestock-based protein to diets higher in plant-based protein) can also contribute to lowering emissions (CAT, 2018; IPCC, 2018). Agricultural intensification can contribute to reducing emissions in the AFOLU sector by reducing the amount of land required to produce agricultural products. Lower demand for land can mitigate deforestation for the creation of agricultural or pasture land and can free up land for increased forest coverage, both of which
can contribute to the mitigation of emissions in the AFOLU sector.

Despite the abundance of decarbonisation options, some emissions from the sector may be difficult to completely eliminate, such as non-CO\textsubscript{2} emissions from the agricultural sector (mainly methane and nitrous oxide) (CAT, 2018). Negative emissions from the forestry and other land use sectors (or BECCS in other sectors) could therefore be required to compensate for residual emissions (see Box 1).

Bioenergy is a potential low carbon energy carrier in all other sectors and the use of bioenergy in those sectors will lead to important interactions between the AFOLU sector and the other key sectors. Major growth in the demand for bioenergy feedstocks will have large implications on the AFOLU sector. The demand for biomass feedstocks can create competition with food supply and lead to natural ecosystems being converted to agricultural land, with negative implications for biodiversity as well as broader environmental impacts. Higher demand for biomass can also lead to increased emissions from deforestation and other land-use change related emissions (IPCC, 2018).

CONCLUSIONS

Significant sectoral transformations are required to realise zero-emissions in the five key sectors looked at in this chapter. There are many measures that could contribute to the deep emissions cuts required, including demand reduction, and most especially phasing out of fossil fuels and replacing them with alternatives such as renewable energy sources. Importantly, deployment of these options to the extent necessary for full decarbonisation has, in many cases, implications that require a step-change in the depth and breadth of decarbonisation planning in most countries, and with timeframes that make them relevant to ongoing NDC development processes.

Key sector decarbonisation options have different requirements for the development of technology and associated infrastructure (e.g. refuelling / charging infrastructure in the transport sector). There may be a risk of path dependency, locking a country into a sub-optimal pathway if the right decarbonisation choices are not made. Introducing alternative decarbonisation options at a later stage would likely be inefficient from an investment perspective and might not be achievable within the required timeframe given the long lead times for planning and delivery of major infrastructure. In particular, the feasibility of using CCS at scale needs to be carefully considered, as there will always be residual emissions that need to be compensated for and there is uncertainty about the scale at which negative emissions technologies can compensate for these residual emissions. Such pathway decisions or choices cannot be left until after 2030 and thus will need to feature in NDCs, which will need to reflect and be consistent with the need for well-informed longer term decision making.
A number of interventions depend on the role of consumers and their willingness to make behavioural changes or investment choices. For example when switching away from fossil fuel based transport (modal shift, or to electric or hydrogen vehicles), and dietary changes. Effective policy stimulating the uptake of these options will be essential, but will also need to be complemented by consumer education and engagement, which will take time to achieve. Thus consumer education campaigns will likely need to be put in place quite far in advance of the introduction of major policies or regulations, which means they may be necessary within pre-2030 NDC timescales.

Implementation itself also will take considerable time. The development of new infrastructure, replacement of industrial equipment, replacement of vehicle stocks, renovation of buildings, education of capable workforces, and realisation of behavioural changes are all complex and will need to take place over decade, or multi-decade timescales. These interventions will therefore need to be planned well in advance of the target to achieve net-zero emission economies by 2050 and the timing of the implementation of decarbonisation measures should be a key consideration in long-term planning. These considerations will need to be taken into account when new NDCs are contemplated and developed.

There are also a number of sector interactions, where decarbonisation options in one sector have implications for other sectors. Electrification of energy use and energy demand reduction in end-use sectors will impact the required transformation of the power sector. The use of bioenergy and the use of bio-based carbon removal measures to compensate for residual emissions will have an impact on the AFOLU sector. The existence of these important interactions and the requirement for sectors to therefore plan their decarbonisation in a coherent, joined up way also will require a departure from the current, largely siloed planning seen in NDCs.

Many choices will need to be thought through and decisions made in order to achieve long-term decarbonisation, and many challenges will need to be addressed along the way. For many countries the questions that need to be answered – about what options must be implemented, and when, and about how and why consumers and other stakeholders can be engaged to play their part – may seem complex and daunting. However there are approaches that can help, and these are explored in the following chapters.
Chapter 2 discussed the main decarbonisation options available in different sectors, and some of the implications those options have for decarbonisation planning. In Chapter 3 we look at how global scenarios and goals can be translated into feasible policy, plans and strategies to enable decarbonisation. Beyond looking at the difficulties around the modelling of pathways, we consider the challenges of anchoring transformational pathways in economic and political realities and finding consensus on a commonly accepted vision. The following questions guide the chapter:

- How to translate science and global pathways to specific country, sector and subsector contexts?
- How to deal with different perspectives on assumptions, plausibility, economic and political feasibility?
- How to align stakeholders and deal with potentially conflicting needs, perspectives and expectations?

Two practical examples illustrate some of the challenges, barriers and solutions addressed in this chapter.

### 3.1 MODELLING GHG EMISSION PATHWAYS

Modelling long-term greenhouse gas emission pathways is an important quantitative exercise to support sector and national policy planning and to inform NDC processes and the development of long-term strategies. There are different ways to model emissions pathways ranging from high level integrated perspectives to granular bottom up approaches (Figure 1). The selection of an approach depends very much on the end goal, the question that is being asked, and available data and capacities to undertake the exercise. Because the choice of model and approach has a significant impact on the results, it is important to understand the options and potential of each one. Models can naturally not capture the full breadth of dynamic complexities of entire sectors and economies given computational constraints. Hence for a nuanced perspective, a combination of different approaches may be needed.

Top-down models, such as Integrated Assessment Models (IAMs) and computable general equilibrium (CGE) models, tend to take a broader view of the economy and can simulate interactions between different economic sectors to better understand the impact on macroeconomic variables such as, for example, GDP, employment, government spending etc. Bottom-up models focus on technologies, and are therefore often more granular than top-down models. They may or may not include optimisation routines, and can be useful for quantifying policies that impact specific sectors and technologies. Hybrid models try to combine these two, including technology detail and also exploring the macroeconomic effects (DEA, OECD, 2013; Krey et al., 2019).
Models use different approaches to project developments into the future. The most widespread and well-established approach is to model pathways on the basis of least-cost optimisation. Essentially this means modelling the “cheapest” technology pathway by expanding the least cost technology, then expanding the second least cost technology and so forth, until the modelled demand is reached (e.g. energy demand in MWh or cement demand in tonnes). Alternative approaches may use GHG reduction potentials, technical or geographical parameters as the basis or a combination thereof.

Beyond the choice of the type of model, many assumptions about input data are required. The assumptions greatly influence the results of the modelling exercise and hence have to be treated with care. Assumptions on future (core) parameters, such as GDP growth, technology availability, impact of learning curves3 and cost assumptions involve a high degree of uncertainty and can be subjective. Scenarios are reflections of present conditions and the expectations of stakeholders/modellers about future developments. These expectations can vary greatly and can reflect specific interests beyond the unintentional subjectivity of the modeller. For example, GDP growth is typically used to determine future energy demand, greatly affecting energy supply projections and associated GHG emissions. The choice about the level of future GDP growth is often a political decision, intended to present an optimistic view of the future. In any case, growth is hard, if not impossible, to predict into the (long-term) future with any degree of certainty.

Models cannot capture the full complexity of a transition to a low carbon economy, which includes technical, economical, behavioural, and political aspects, sector interactions, and more. Each parameter features a certain level of uncertainty, and modelling parameters (including the required data gathering) can be resource intensive. Availability of data is a common barrier affecting the level of uncertainty of modelled results. Oversimplified models, relying on fewer data points, bear the risk of missing important variables. In contrast, more complex models account for numerous variables and potential inter-linkages, magnifying the risk of uncertainty and data unavailability. Whatever the level of detail, it is paramount to be transparent in any

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3 Learning curves represent the correlation of technology uptake (mainstreaming) and the consequent reduction in cost of that technology over time.
modelling exercise about data sources, assumptions and other parameters, in order to understand, compare, replicate and use the results in decision-making processes.

Modelled scenarios cannot predict the future and often get it wrong as (often disruptive) changes occur, that could not be captured at the time of modelling. Typical examples are the shale gas revolution and exponentially steep learning curves seen in solar and wind power technologies. Nevertheless, scenarios provide guidance on GHG emission development in a business as usual context, and on the potential impact of variables such as behavioural change or technology uptake, or on the impact of specific polices. In other words, scenarios can help to get a sense of future developments under certain assumptions. They can be used for open debate and as a basis for visioning exercises amongst different stakeholders. On a very practical level, modelling can help to foster cooperation across ministries and non-state actors during data gathering, definition of assumptions and other parameters. (DEA, OECD, 2013).

### 3.2 FROM GLOBAL MODELS TO NATIONAL AND SECTOR PATHWAYS

In order to develop national policies and plans, global pathways need to be broken down to the national and sector level. Such an exercise is difficult and again relies on many assumptions. For example, the IPCC special report on 1.5°C presented a range of Paris Agreement compatible IAM-based pathways to keep global warming below 2°C and close to 1.5°C. In order to break this down to national Paris Agreement compatible pathways, a typical approach is to use least cost optimisation which distributes mitigation efforts where the mitigation costs are lowest (IPCC, 2018). However, such an approach does not take into account countries’ right to develop (Newell and Mulvaney, 2013; Höhne, den Elzen and Escalante, 2014). The effort sharing approach is a more complex way to apply rules or criteria to allocate emissions reduction effort to countries or regions with the aim of meeting the global emissions target equitably, on the basis of historical emissions (responsibility), or a combination of responsibility, capacity and development needs. Other approaches are based on, for example, converging per capita emissions (equality)\(^4\) (Höhne, den Elzen and Escalante, 2014; Parra et al., 2017). These different approaches can have strong implications: for example, Robiou du Pont et al. (2017) found that to be Paris Agreement compatible and satisfy equity principles, some countries would need to peak emissions and fully decarbonise around a decade earlier than 2050.

Having said this, it is important to keep in mind that the least ambitious pathways, that include carbon intensive lock-in, decrease the already small degree of freedom and possible decarbonisation options (Germanwatch & NewClimate Institute, 2018; IPCC, 2018; Climate Analytics, 2019). In fact, as observed by the Climate Action Tracker, because most

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\(^4\) More information can be found at [https://climateactiontracker.org/methodology/comparability-of-effort/](https://climateactiontracker.org/methodology/comparability-of-effort/)
countries’ current NDCs are far from Paris Agreement compatibility, it is unlikely that one country (or sector) is able to significantly compensate for the emissions of another country or sector, and therefore all sectors and countries should aim to decarbonise as deep and as fast as possible (Climate Action Tracker, 2019).

Downscaling pathways from the global to the national level is difficult, and similarly it is challenging to distribute mitigation efforts among sectors within a country. Sector interaction plays a significant role in the transition to a low-carbon economy, but the inter-linkages are difficult to model and rely on substantial assumptions. From the IPCC special report on 1.5°C we know that to achieve the Paris Agreement goal, GHG emissions need to peak by 2020, and rapidly decline by about 45% by 2030 (from 2010 levels); net zero CO₂ emissions needs to be achieved by 2050; and GHG emissions need to reach net zero by 2070. For some sectors the technology pathways to achieve net zero are better known, through extensive research and concrete action plans (e.g. the power sector), than for others (e.g. agriculture) (see Kuramochi et al., 2018). Because decarbonisation pathways are more straight-forward in some sectors than others and inter-linkages between sectors exist, avoiding silo thinking and hence planning the transition across sectors is crucial. Inevitably this will involve cooperation to discuss and “negotiate” expectations, parameters and their assumptions with different sector stakeholders. Modelling exercises can provide a good basis for such dialogues, especially with clear and transparently defined techno-economic parameters (DEA, OECD, 2013; Krey et al., 2019).

3.3 ALIGNING PERSPECTIVES AND VISIONS

The development of transition pathways and long-term visions requires more than quantitative modelling exercises. The techno-economic dimensions of transitions can typically be relatively well captured in models – within discussed constraints – however transitions have a strong social and political component. Socio-technical transitions typically involve structural changes over generations across all sectors, relating to technologies, policies, scientific knowledge and behavioural change (Newell and Mulvaney, 2013). Because the transition to a low-carbon economy affects all stakeholders, arriving at a vision for a country or specific sector requires dialogue and to some extent negotiations between different and often competing interest groups and expectations. As GHG emissions are typically linked to GDP, the highest emitting sectors often have the highest vested interests, and thus demonstrate higher resistance to fundamental change by what Geels (2014) calls “incumbent regime actors”. Furthermore, different interests have different time dimensions, which can be conflicting e.g. short to medium term political timelines and mandates versus long-term climate policy planning needs, short to medium term investment return expectations versus long-term actions and returns, or generation gaps, where generation’s interests are framed within each generation’s time perspective. Transitions are also typically not linear but complex and often characterised by disruptive change, which is difficult to plan for and hence requires flexible management to adjust to changes as they happen. There is also a heterogenous geographical dimension to transitions, with pronounced differences in the expectations and needs of urban and rural populations, or of more or less developed regions.
The Plataforma initiative was set up in 2011 with the objective to provide a space for engagement and dialogue on the future of the energy sector in Argentina. It has recently completed a third round of scenarios which provide different perspectives on how the sector may develop until 2040. The initiative brings together key stakeholders in the energy sector representing diverse interests, from the industrial union, the federation of generators and large energy users, to academic institutions, regional governments as well as environmental NGOs. It closely engages with the national government. The Ministry of Energy has been accompanying the process as a member of the Executive Committee.

The scenario exercise is based on the LEAP model, which is used by all participants to model the scenarios to 2040. A technical committee guided the process of defining and agreeing on key parameters and assumptions in order to ensure comparability of results. The exercise of agreeing assumptions, for example on future costs of different technologies, was one of the main challenges and proved to be a highly valuable process to foster exchange and understanding of different perspectives.

The modelling exercise covered different indicators across the economic, environmental, and social dimensions. Indicators included, for example, GHG emission, GHG intensity, land use, NOx and SOx emission, energy diversity, costs, import dependence, trade balance and employment. Figure 2 shows the results of the nine different scenarios regarding the total GHG emissions of the electricity sector until 2040. It illustrates the diversity of scenarios resulting from the exercise.

Figure 2: Total GHG emission electricity sector Plataforma scenarios (Secretariat of Energy, 2018)
To align perspectives and visions and to achieve the transition to a low carbon economy, policymakers need to jointly address environmental and social factors. Some of the most prominent social and political pressures in the transition to a low carbon economy relate to job losses, economic decline, energy security and energy poverty. Ultimately, it is about dealing with all those communities and stakeholders that may be negatively affected by the transition, and alleviating potential impacts through effective policy measures. Because we live in political economies (see chapter 4), governments play a key role in addressing those social pressures and mediating between competing interests and steering the transition to a low carbon economy (Newell and Mulvaney, 2013). Political trade-offs between different decarbonisation pathways are inevitable. It is important to understand if, how and when different parts of the economy and communities are affected by the transition.

Scenario modelling beyond technological parameters, including broader social and economic dimensions, can help in this process to identify pathways and measures which maximise benefits and minimise disruptions. Inclusive, transparent and open dialogues and communication based on solid evidence and involving all those affected by the transition are essential to guide policymakers in the transition process.

For further information please visit: https://www.escenariosenergeticos.org/
BOX 4: GERMANY’S COAL COMMISSION AND ITS COAL PHASE OUT COMPROMISE

Germany’s coal industry developed based on a historically cheap and abundant domestic coal supply, predominantly used for power generation. Energy security concerns, the significant role of the coal industry in Germany’s economy (17% of global lignite production) as well as jobs that depend on that industry render a coal phase out difficult (Brauers et al., 2018). Although economic feasibility and environmental standards lead to coal plants closing, a trend that even subsidies could not reverse, there is considerable political resistance from a coalition of (local) politicians in states with coal reserves, union members and power plant operators (ibid.).

Figure 3 illustrates the dimensions of a just transition in coal regions, which is useful as a frame to understand the development in Germany. In June 2018, the German federal government created the commission „Growth, structural change and employment“ to design a structural change plan in line with energy and climate policies and to ensure a broad consensus from society (BMWi, 2019). The commission was composed of representatives from coal regions, politics, industry, trade unions, research, organized civil society. In February 2019, after many months of difficult discussions and negotiations, that already started with the problematic task of assigning a chair to the commission (in the end there were four), a 39 page long, complex compromise was reached with the following main items:

Figure 3: Dimensions for a just transition in coal regions.
A coal phase-out by 2038, potentially 2035 (or 2-5 years earlier than the latest possible date) coupled with:

- 65% renewable energy by 2030
- Subsidies for combined heat and power plants
- Not selling additional CO₂ certificates resulting from coal power plant closures (which is currently a prominent debate in Germany)

Build up new capacities and compensate in coal regions for the next 20 years with 40 billion Euros from EU budget, federal budget and with the support of federal states’ budget:

- For education/retraining and research
- Innovation and digital infrastructure, e.g. 5G pilot projects, E-health to make up for decreasingly available doctors
- Transport infrastructure e.g. new high-speed train lines and new roads (incl. highways), more frequent trains
- Revitalization of hard coal power plant sites for commercial, industrial or energy use
- Guaranteed retirement payments.

The energy companies are to be compensated from the early 2020s for the premature shutdown of power plants

Whilst from a social and economic aspect the compromise was celebrated by many, especially trade union and industry representatives, climate scientists strongly criticized the compromise, as its outcomes are not in line with Germany’s climate targets (Carbon Brief, 2019, Höhne et al., 2019), which in turn aren’t ambitious enough to be compatible with Paris Agreement commitments (Höhne et al., 2019).

CONCLUSIONS

It is essential to understand the complexity of decarbonisation pathways both from a techno-economic as well as socio-political perspective. Scenario modelling can help to do so and provide an evidence base to better understand the implications of different pathway options along the different dimensions. At the same time such exercises have limitations given system complexities, uncertainties, data availability as well as the inevitable subjectivity of any modelling exercise. Transparency on the assumptions and approach is key to ensure credibility and comparability of results.

Transitions towards a decarbonised economy are not primarily technical challenges. Ultimately, such transformations involve all parts of society and require careful management of potential disruptions. Those negatively affected by the transition need to be brought on board and their concerns taken seriously. Dialogue and communication between different interest groups aiming to align visions, find solutions and compromise are essential in a transition process. Transparent modelling exercises provide a solid basis to enable and inform such dialogues. Governments play a key role as mediators in this process. At the same time transitions are often driven by disruptive change, and are difficult to plan in particular in liberalised market economies. Hence such exercises need to be flexible to respond to change and seen as a continuous process of engagement as circumstances change.
Whether, how, and when ambitious sector climate targets are initiated and implemented, ultimately depends on the political dynamics within and beyond the sectors concerned (Edelmann, 2009). A better understanding of the political dynamics in the sector will allow for a more realistic assessment of which actions and pathways are feasible. As the previous chapters show, Paris-compatible sector transitions involve many choices and challenges that need to be thought through, and scenario modelling and pathway construction can provide a valuable evidence base for dialogues on long-term strategies (LTS) and medium-term (NDC) targets and ambition. It is however also noted that these models are of limited use when investigating the feasibility of specific pathways. Sector transitions are not only technical or economic challenges, but also involve political processes regarding stakeholders who might gain or lose income and opportunities as a result of choices made; this holds true for both wealthy and powerful elites and for the wider public who might need to make personal sacrifices.

Actors, and how context shapes their behaviour, take a central place in the analysis of politics. This requires a quite different approach to the tools and approaches most commonly used for LTS/NDC planning and implementation. Models for emissions accounting and (optimisation) projections are focussed on stocks and flows of capital, technology, or emissions. Analysis into whether and how the effectiveness of mitigation action depends on political dynamics is largely absent. This chapter discusses political economy analysis (PEA), a structured approach to analysing sector politics which has been used and studied especially in the realm of development support. Looking at sector transitions through a PEA-lens allows us to see which political factors are at play and how that might determine which outcomes are feasible and which are not.

4.1 POLITICAL WILL AND POLITICAL ECONOMY ANALYSIS

Since the late 1990s, development assistance agencies have been using diagnostic tools to analyse political economy dynamics in their partner countries. Donors realised that technically feasible and properly funded projects were often not leading to the desired reform because of a lack of political will. To understand what is behind this catch-all term of ‘political will’, the first step for the development agencies was to acknowledge that economic development and governance processes are inherently political and that understanding the political dynamics could increase the effectiveness of development interventions and programs (Poole, 2011; Hout and Schakel, 2014; Hudson and Leftwich, 2014).

Political economy is the field of study concerned with the distribution and contestation of power and resources, and can be used to investigate how these affect development outcomes in specific countries and sectors (Poole, 2011). Political economy exists at the intersection between political science, sociology, and economics, and aims to help our understanding of why things change, rather than how. It looks at power and interests, and how dynamics between actors are shaped by incentives and constraints. Political Economy Analysis is a diagnostic approach to find out what is really ‘going on’ in a situation, looking at who influences change, what lies behind the surface, or finding out whether and where competing interests exist. PEA helps to “unpack all the issues previously lumped into the `political will’ box so that we can consider the factors to which we must adapt and those that we can try to influence and change” (Whaites, 2017).Political economy analysis is not based on a single theory but does share a set of concepts to explain how political and economic development occurs (The Policy Practice, 2012).

5 This chapter is based on vanTilburg and Minderhout (2019/forthcoming)
4.2 LOOKING THROUGH A POLITICAL ECONOMY LENS: FOUR AREAS OF INQUIRY

When comparing three widely used frameworks for PEA, we observe that the approaches use similar concepts yet with minor differences in terminology or focus (DFID, 2009; Fritz et al., 2009; USAID, 2016). Conceptual models for PEA frameworks are all centred around actors and designed to analyse how actor behaviour and interaction is shaped by structural factors and the (perceived) rules of the game, and how that affects change processes.

**ACTOR BEHAVIOUR** concerns the motivations, incentives, and relationships that determine the balance of power between actors and shape their responses to events. Each person or group will weigh the ‘pros and cons’ of issues and is seldom driven by material incentives alone: beliefs and ideas can also be powerful motivators (Whaites, 2017). Tools used for analysing actor behaviour include mapping of stakeholders (both individuals and organized groups) and their relative influences, power relations, and positions in proposed reforms.

**INSTITUTIONS** represent formal and informal rules of the game, and organisational structures, that constrain and shape actor behaviour. Institutions are not static and are more susceptible to deliberate change than structural factors. An institutional analysis involves the mapping of government ministries and agencies and their interaction, existing laws and regulations, and policy processes, but also cultural and social norms and traditions that shape how organisations and transactions are structured. (Booth et al., 2016).

**STRUCTURAL FACTORS** can be relevant in shaping and constraining actor behaviour, but these are outside the direct control of the actors, and are fixed, or change only very slowly. Structural factors can include geographical features and natural resource endowments, economic and historical legacies, border arrangements and access to trade routes, demographics, and urbanisation, but also changes in commodity prices or external geopolitical threats. Tools used for mapping of structural factors include analysis of resource availability, patterns of (sectoral) investments, human and technology capacity, social issues and trends, technological and financial barriers, and historical analysis.

**PLAUSIBLE CHANGE** is a concept that relates to the reality of change and what actions can be proposed in support. It is also called ‘dynamics’ or ‘uncertainty in change processes’ (USAID, 2016; Booth et al., 2016). This component links the other three: it considers how actors behave in response to structural factors and institutions, and what this means for the feasibility of change. Tools for analysing plausible change include combining the three previous components and analysing historical legacies and prior experience with reform, social trends and forces, and how these shape stakeholder interaction.
To illustrate how these four areas of inquiry could feature in the findings of a political economy analysis, consider for example a study by Baker et al. (2014) who analyse the struggle over competing energy visions, infrastructures and political agendas in South Africa, with the aim of generating insights into the governance and financing of clean energy transitions. They point to networks of economic political power around provincial government councils (cf. actor behaviour and rules of the game), apartheid as a historical legacy that defines trajectories and lock-ins (plausible change), and the interplay between internal drivers and exogenous factors (actor behaviour and structural factors).

**BOX 5: AGENCY AND INSTITUTIONS**

The two central concepts in PEA are agency and institutions, each of which has a somewhat different meaning in political science than in everyday language. In clarifying these terms, it is good to know that there is a tendency among academics to picture the political space as a game: a bargaining process with participants and different possible outcomes.

The term *agency* is understood as the capacity of actors to act independently and make their own free choices. The term *institution* in common parlance is understood to describe an organisation founded for a specific religious, professional, or educational purpose. In political science, however, the term institution goes beyond organisations and also includes all formal and informal ‘rules of the game’. These rules mediate political and economic interaction and can include, for example, laws and regulations, social and cultural norms and expectations, patronage networks running along social and ethnic ties, budgeting processes, election rules, etc. (Harris, 2013; Poole, 2017; Whaites, 2017).
4.3 USEFULNESS AND LIMITATIONS OF PEA

In the past two decades, political economy analysis has proven to be a useful tool for understanding how to improve development support by taking the political context into account (Fritz et al., 2014; Poole, 2011; Booth, Harris, and Wild, 2016). PEA presents an approach and set of tools to access that additional level of insight into the dynamics of reform and “how political actors interact and jostle not only with each other but also against, around and with the structural and institutional context they operate in” (Hudson and Leftwich, 2014). Starting from actors involved in a transition rather than emissions, technologies, and policies, a political economy analysis could provide a structured way to include political dynamics to complement existing assessment frameworks.

Experience in the field shows that there are limitations to the uptake of PEA and the insights it produces: “While PEA is a useful tool of analysis that can offer a different angle on a problem or issue, it is not meant to be more or less than that. It is not a magic bullet and cannot provide quick fixes or readymade answers to what are essentially complex development problems.” (Rocha Menocal, 2014). One of the practical challenges with conducting a political economy analysis is that effort level and expertise requirements may be considerable. There is a recent move towards more light-weight approaches that promote ‘thinking politically’ rather than simply applying a tool (Hudson, Marquette, and Waldock, 2016; Whaites, 2017). Another challenge involves political sensitivity, especially because PEA analyses consider specific actors (individuals or groups) and the political dynamics between them, which might include failure to adhere to transparent and democratic decision making processes, or corruption. Revealing what is behind ‘political will’ may expose facts that are not popular with some of the actors.

CONCLUSIONS

This chapter looks at political economy analysis as a diagnostic approach to unpack the notion of ‘political will’, in an effort to understand which structural and political factors accelerate or hamper sector transformation. PEA approaches are centred around actors and typically follow four lines of inquiry to explain how actor behaviour and interaction is shaped by structural factors and the (perceived) rules of the game, and how that affects change processes.

Existing political economy analysis approaches are directly applicable to study political dynamics of sector transformation. Political economy analysis has the potential to add value to sector dialogues and processes, by explicitly taking actors and their behaviour into account and building on that to explain why change is more or less likely to happen. Over the years, a body of literature on theory and practice has been built up that can be drawn on.

Understanding the political interests of stakeholders is important for shaping effective policies and programmes to drive Paris-compatible sector transitions. Most examples of PEA are conducted from an external perspective, for example by donors analysing the national and sectoral political dynamics in partner countries, and not by governments as part of their own stakeholder engagement thinking and processes. We are however optimistic that political economy analysis can also be used in support of sector planning (i.e. from inside the process) in one way or another: especially for ‘big decisions’ about technology pathways and for achieving the most difficult (and obviously last) 10-20% of emissions reduction, where political dynamics matter in identifying which actions are feasible and which are not.
This chapter explores full sector decarbonization pathways from the following three perspectives: ‘transparency’, ‘financing’, and ‘governance’. These thematic areas together with ‘sectors’ – which has been extensively discussed in the chapters above – form the foundation of the NDC Support Cluster. Within the Cluster, the areas are each represented by a thematic working group made up of different organisations. The goals of the working groups are to provide a platform for information sharing, coordination of activities, and developing joint outputs as appropriate, among implementing partners. Each working group was invited to provide a short answer to the following sector decarbonization related questions, from the perspective of their thematic area:

1. What challenges does full sector decarbonization pose for the medium term (2025-2030);

2. And which short-term actions can are needed (or best avoided) to anticipate these challenges?

5.1 TRANSPARENCY

By Kelly Levin and Cynthia Elliott (WRI) on behalf of the Transparency Thematic Working Group

INTRODUCTION

Sectoral decarbonization pathways demonstrate how achieving the Paris Agreement’s goals can be achieved, in a way that is technically and economically feasible and aligned with a country’s long-term vision. Transparency can lend credibility to these pathways and enhance their potential to stimulate transformational change. Clear and transparent sectoral pathways may guide domestic implementation, unlock policy barriers, and stimulate domestic action by sending policy signals to businesses and other climate actors. When developing and communicating sectoral pathways, transparency is critical to gain broad stakeholder support and political buy-in. If the Paris Agreement’s goals are to be met, major transformation will be inevitable and achieving decarbonization will require major shifts across economic sectors. Clearly defined pathways will ensure decarbonization responds to domestic needs and priorities. A transparent process with open dialogue about the trade-offs and opportunities of potential pathways provides a channel for an equitable and just transition for impacted communities and businesses.
Transparency of sectoral decarbonization strategies has three facets: transparency of inputs and methodology; transparency of the development process; and transparency of communication.

**TRANSPARENCY OF INPUTS AND METHODOLOGY:**

It’s important that processes to develop sectoral decarbonization pathways are transparent enough to show how the pathways and/or models were built, and not only the output or results. This will support consensus-building, planning, target-setting and implementation. There are several approaches to improve the transparency of inputs and methodology. First, to the extent possible, data and inputs should be publicly available, verifiable and come from reputable sources such as national laboratories, universities and international agencies. This will help validate the outputs and improve accuracy of results. Second, for modelling work, open-source models should be considered as they encourage process transparency, replicability and collaboration. Third, when developing sectoral decarbonization pathways, it is important that all inputs and assumptions are well-documented and recorded. This is important for both transparency of the process but can also be useful when repeating modelling runs or developing new pathways in the future. Finally, to further improve the clarity and understanding of how outputs and results were determined, it is important to note all trade-offs, alternatives, and limitations that were considered.

**TRANSPARENCY OF THE DEVELOPMENT PROCESS:**

As the sectoral decarbonization pathway is being built, it will be critical to ensure a transparent process so that stakeholders and relevant institutions can inform the inputs and design choices, provide feedback, and gain an understanding of how the strategy will impact them. This has several benefits. Transparency of the development process can enhance the legitimacy of the process and improve stakeholder support and buy-in. Given that the sectoral decarbonization pathway will potentially involve difficult choices and trade-offs, taking stakeholders’ concerns seriously will help ensure that the plan is fair. The design of the pathway itself can also be improved as technical experts and other stakeholders will hold critical information that can inform the pathway and its long-term vision. Additionally, the durability of the pathway can be enhanced as the needs of those affected can be addressed from the start, rather than as an afterthought.

A transparent process would establish a timeline with clear roles and responsibilities and information on when and how stakeholders can engage throughout the process. Countries can consider the variety of approaches that have been used for engagement in the development of long-term strategies, including surveys or questionnaires, in-person workshops, public consultations, websites, and open common period (Elliott et al. 2019 forthcoming).

**TRANSPARENCY OF COMMUNICATION:**

It is important to transparently communicate the strategy to stakeholders once designed. The plan will need to be written up in a clear manner that is accessible to the variety of stakeholders. It is accordingly possible that sectoral development pathways may need to be communicated in different ways, to the extent that stakeholders have different needs. The methodology and assumptions will also need to be transparently communicated, although this could be done in a technical annex or accompanying document.

And once the plan is written, the pathway and any plans for implementation will also need to be communicated to those affected. This can be achieved, for example, through a series of in-person workshops to affected communities, webinars, online communications, among other approaches. It may also be advantageous to communicate the plan
internationally, especially to neighbouring countries and trade partners which may be affected by the strategy and can strengthen the prospects of its achievement, as well as to those who may be able to provide support to the extent it is needed.

CONCLUSION
The quality of the sectoral decarbonization strategy, as well as its legitimacy and durability, will be significantly strengthened by transparency. This includes considerations of transparency of inputs and methodology, transparency of the development process, and transparency of communication. Accordingly, transparency should not be seen as a one-off; rather, if countries consider transparency along the entire trajectory of the strategy -- from its development, to finalization and to its eventual implementation and revision -- they will be able to reap its benefits.

5.2 FINANCING
By Charlotte Ellis (SouthSouthNorth) with contributions from Nils May (DIW) and Alexia Kelly (Electric Capital Management) on behalf of the Financing Thematic Working Group

As the previous chapters of this report have stated, it is now clear that achieving long-term carbon neutrality will encompass complex political, social and economic aspects. It will require significant structural shifts in economic sectors that are emission intensive posing challenges for employment and other socioeconomic factors. This will require conditions favourable to mobilising low emission investment and avoiding “carbon lock-in”. Full transformation can only be viewed from a longer term perspective, particularly in developing countries where the issue of a just transition is central to meeting the long term goals of the Paris Agreement. For developing countries the challenge of the medium term period (2030-2050) is that the timeframe may be insufficient to address the structural path dependencies around emissions intensive industries and sectors in many countries.

A large proportion of the world’s financial assets belong to sectors that will be sensitive to the effects of climate policy and the full implementation of the Paris Agreement. For many developing countries these sectors (e.g. fossil fuels, extractive industries, energy and emission intensive activities, etc.) make up the primary resource base for the majority of institutional investors and financial services sector. Any abrupt devaluation of this class of assets could therefore constitute a systemic risk, and create substantial amounts of stranded assets and set back developing countries progress in achieving the SDGs.

The critical challenge is one of means of implementation - in particular, finance. Setting countries on a pathway to low-emissions
Full transformation requires significant enhancement in access to low-carbon, renewable energy technologies, however the associated costs are not always economically viable. Long-term full decarbonization requires that not only low-hanging fruits and current best-available technologies are implemented, but policies need to take into account full long-term decarbonization to prevent lock-in into polluting technologies. Investments must be carbon-neutral in the long run and the market design and policy instruments must facilitate such long-term orientation, for example through sector-specific goals and according policy instruments. To facilitate financing, these include renewable energy remuneration mechanisms that reduce regulatory risks and incentivize integration, investment incentives for energy-efficient housing, carbon pricing and innovation support for a shift to clean industrial production processes and resource efficient material use, and city planning and clear incentive structures around sustainable transport.

To conclude, the process to achieve a shift towards low emissions development and transformation requires detailed planning and the cost-effective deployment of financial resources at the scale needed. This requires short-term adjustments, and multi-stakeholder processes to identify investment opportunities, risks and socioeconomic impacts of a longer-term transition.
5.3 GOVERNANCE

By Katharina Davis (UNDP) on behalf of the Governance Thematic Working Group

The development of the first generation of NDCs, which feature a time horizon of 2025 or 2030, initiated an important process for countries to set emission reduction targets. Moving towards full decarbonization by 2050, however, entails an economy-wide transformation that raises important questions about the underlying drivers of emissions, such as global production and consumption patterns, economic development models, and poverty, among others. While a net-zero emissions economy has a positive impact on development in the medium and long-term, full transformation does pose a number of challenges to address in the medium term (2025-2030).

For one, alignment of short or medium-term policies and priorities, including those of the NDC, with long-term decarbonization milestones has not yet been achieved. Currently, only a handful of countries have developed long-term strategies, and NDCs are not on track with comparable 2050 decarbonization targets. Similarly, the foundations for large-scale transitions have not been laid. Having a clear vision for a decarbonized economy would likely change how sustainable development policies, NDCs and respective investment plans are designed and how measures are prioritized. The attempt to resolve more immediate priorities or “quick fixes” without looking at the benefits of a long-term investment can thus jeopardize the design of more sustainable solutions.

Another challenge arises from the interrelated nature of the sectoral pathways. To effectively identify the potential trade-offs and solutions for society, economy and environment, especially under the uncertainties that long-range planning involves, important questions on sustainability, equality and prosperity for all will have to be answered consistently within and across sectors. Vertical coordination across governance scales poses another challenge. While substantial progress has been made in terms of breaking down governance silos, institutional capacities have not kept pace with the needs for integrated planning at scale. There is thus an urgent need to further strengthen countries’ institutional capacities to lead transformational change.

Considering the urgency for laying the foundations for a global net zero emissions future by 2050 and set in motion the full roll-out of decarbonization by 2025, the following short-term enablers are needed:

Developing a clear long-term vision for a resilient, decarbonized economy by 2050. The vision will outline the magnitude of the transformations, taking into account the country’s development aspirations, socio-economic conditions, sectoral infrastructure and resources. Long-term goals must incorporate considerations for just transitions, including anticipating where they may need to occur and how to leverage policies to create new opportunities for stakeholders connected to the high-emitting sectors of the economy. Uncertainties can be addressed by looking at long-term decarbonization planning as a ‘living’ roadmap that will be adapted as new technologies, information and environmental conditions emerge. ‘No-regret’ measures which combine emission reduction and development priorities, can be pursued regardless of uncertainties.

Upgrading governance capacities for a systemic, whole-of-society approach. The goal is to ensure that all options are being considered, are equitable and are supported by key stakeholders. Governments
play an important role in framing the discourse and normalizing new approaches. The socialization aspect is critical for involving actors including the business community, local governments, and civil society. A supporting set of policies and instruments are key for driving the desired behaviours on both the supply and demand sides. Beyond norm shifting, governance modes need to shift to ‘co-creation’ and partnerships. These measures rely on governments’ capacity to orchestrate transformational change and shift investment patterns in the target sectors, while reconciling complex needs in the societal, economic and environmental arena.

Integrating decarbonization strategies with sustainable development pathways to achieve a resilient, zero carbon economy. Development objectives in health, food and water security, poverty alleviation, and employment, for instance, are highly dependent on the provision of affordable, clean energy. Modelling various options within and across sectoral pathways allows countries to explore the particular mix or composition of technologies and measures that can drive sustainable development. There, identifying early on which scenarios would be technologically feasible, which could face barriers, and which can be translated into socially and politically acceptable solutions is important. Some countries have embarked on dialogues to rethink prevailing economic and social patterns in the context of a resilient, net-zero emissions economy.

Developing clear implementation plans, including short and medium-term goals that clearly stated in revised NDCs and related implementation plans. These need to be supported through a finance strategy and a coherent policy framework that spans all relevant sectors and scales. Large infrastructure projects or changes in industrial structures require large up-front investments and have long implementation time frames. This significantly narrows the window of opportunity for decarbonizing sectors before 2050. Back-casting the transitions and milestones that need to take place within particular time frames, can inform how to sequence various measures. They also provide clear policy signals for shifts in technologies and investment patterns.
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