Transformative climate policies: a conceptual framing of the 4i's

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Abstract

This report sets out the conceptual framing of transformation and transformative climate policies taken in the 4i-TRACTION project. Transformative EU climate policy needs to address the challenge of transforming the European Union to climate neutrality in its entirety – across all sectors, addressing all its technological, economic, political and social implications. The report first sets out four 'hallmarks' that distinguish a transformative approach to climate policy: thinking back from the end; overcoming path-dependencies; developing transformational institutions; and fostering sectoral and technical integration. The report then discusses the four cross-cutting challenges, which EU climate policy needs to address as key vectors for the transformation to climate neutrality: stimulating innovation to transform the material base; rolling out the necessary infrastructure for a resilient, climate-neutral economy; shifting investment and finance; and achieving integration of policies and technologies across sectors. These four key challenges will guide the 4i-TRACTION project in its entirety and serve as lenses to grasp and foster transformation in EU climate policymaking.

Content

Abbreviations

BECCS	Bioenergy with Carbon Capture and Storage
CCUS	Carbon Capture, Utilisation and Storage
CO_2	Carbon Dioxide
CPI	Climate Policy Integration
EBA	European Banking Authority
EEA	European Environment Agency
EIOPA	European Insurance and Occupational Pensions Authority
ESMA	European Securities and Markets Authority
EU ETS	EU Emissions Trading System
GHG	Greenhouse Gas
IEA	International Energy Agency
RES	Renewable Energy Sources

Executive summary

Limiting global warming to well below 2°C, whilst striving to limit it to 1.5°C, means that many sectors of the European economy will need to be transformed over the next three decades. Our existing systems for energy, mobility, industry, food and housing need to change, whilst at the same time making our economies and societies more resilient, resource-efficient and sustainable. Given the long lead times and path dependencies involved, the 2020s are the pivotal decade for this transformation, when major decisions on its design need to be taken, and the associated policy processes initiated – or drastically ramped up.

Traditional EU climate policy was mostly focused on delivering incremental improvements along existing technological trajectories through sector-specific interventions. In some respects, following the adoption of the Paris Agreement, the EU and its Member States have begun to incorporate elements of a more transformative approach to climate governance. Most prominently, the European Green Deal expresses this transformative ambition to make Europe the first carbon-neutral continent. This ambition has been enshrined in the EU Climate Law and is also expressed in the proposed 'Fit for 55' package, a set of legislative proposals to put the EU on track towards its 2030 targets, including, for instance, the extension of emissions trading to most sectors of the economy. Overall, however, the EU's existing set of climate policy instruments have not been sufficient to bring about change at the necessary speed across the economy.

Hallmarks for transformative climate policies

Transformative EU climate policy needs to address the challenge of transforming the European Union to climate neutrality in its entirety – across all sectors, with regard to its technological, economic, political and social implications, and across the different phases of the process. This simple premise has numerous implications for how to think about climate policy, captured in four hallmarks that distinguish a transformative approach to climate policy from an incremental one.

1. Think backwards from the end – climate neutrality by 2050	▪ Develop policies geared towards the long-run objective of climate neutrality, and capable of driving change in the right direction at the necessary speed ▪ Incorporate the current understanding about the technological options and account for different levels of uncertainty ▪ Account for long lead times associated with essential technologies and necessary infrastructure – administrative preparations and securing of resources needs to start early. ▪ Coordinate and sequence measures in different sectors to account for interdependencies and bottlenecks

2. Overcome path-dependency and lock-in risk	▪ Create positive path-dependencies in which trajectories for technology, investment and finance are aligned with carbon neutrality in a self-reinforcing way to lock-in a model of economic development that is commensurate with climate neutrality ▪ Ensure broad understanding of targeted innovation (bringing in new solutions and creating conditions for their deployment at the necessary scale and pace) ▪ Manage the phase-out (exnovation) of existing technologies that have no place in a climate-neutral economy, transition labour, skills, physical assets to new uses.
3. Develop governance mechanisms capable of delivering transformative change	▪ Facilitate active support and participation of stakeholders and the public at large and incorporate participatory and deliberative elements. ▪ Encourage adaptive and learning forms of governance, allowing room for experimentation. ▪ Anchor long-term climate policies that are durable enough to provide predictability to investors/consumers and flexible enough to adapt to changing economic, political and scientific/technological conditions. ▪ Develop future EU climate policy from the current EU climate governance and its political, institutional and legal set-up.
4. Foster integration across sectors and embed technical changes in a political and socio-economic process	▪ Ensure that efforts are coordinated, aligned and consistent across different government departments and units ▪ Stimulate education and training to ensure necessary skills and knowledge is available in the workforce to realise the transition – at all levels from governance to technical installations. ▪ Align strategies and efforts across national boundaries within the EU, where different Member States pursue different strategies or set different priorities in the process of transforming to climate neutrality.

The 4i's as key challenges for transformative climate policy

Transformative climate policy is about initiating and driving forward the systemic changes that are needed to take the economy to climate neutrality. Many of these necessary change processes are no longer confined to individual sectors such as transport or housing but are crosscutting in nature. Sectoral approaches – predominantly the domain of traditional climate policy – are no longer sufficient. In recognition of this, the 4i-TRACTION project is organised around four cross-cutting challenges, which EU climate policy needs to address as key vectors for the transformation to climate neutrality: stimulating **innovation** to transform the material base of the EU economy, rolling out the **infrastructure** for a resilient, climate-neutral economy, shifting **investment and finance** and achieving **integration** of policies and technologies across sectors.

Challenge	Aspects pursued in 4i-TRACTION
Innovation	▪ Focus on technological innovation and business model innovation as sources of solutions for climate neutrality – as well as policy and governance innovation for new governance solutions. ▪ Within technological innovation, focus on innovations at higher levels of technological readiness, for which there is a higher chance that they can be scaled up sufficiently towards commercialisation within the timeframes considered. This also includes market creation for new technologies, products, processes and services. ▪ Adopt a system-wide perspective, including the policy context, to understand how actors active in the field shape innovation outcomes, as well as the role of specific RD&D policies and the broader political framework conditions.
Infrastructure	▪ Assess which new infrastructure is needed for climate neutrality, which needs to be upgraded, which can be converted, and which becomes obsolete. ▪ Develop and assess policy instruments and governance to develop an EU infrastructure compatible with climate neutrality: support the co-evolution of infrastructure and technologies, incorporate uncertainties, and handle the time lags involved. ▪ Analyse the interplay of physical infrastructure with regulations and markets. ▪ Include the role of digitisation of the energy system and (smart) infrastructure.

Investment and Finance	▪ Adopt a more detailed and granular perspective, beyond the sectoral approaches currently pursued in financial regulation, and analyse the implications of such a granular perspective. ▪ Identify specific instruments with a high transformative potential for mainstreaming climate issues in the financial sector. ▪ Propose how the financial sector can contribute to the exnovation/phase-out of incumbent fossil technologies, and the implications of the resulting stranded assets. ▪ Analyse the role of financial regulators and supervisors in Europe and propose steps to better incorporate climate issues. ▪ Develop options to improve the internal procedures, incentives and governance structures of financial institutions for integrating climate issues.
Integration across sectors	Integration across traditional policy areas: ▪ Explore what an "all-of-government" approach to transformative climate policy would entail at EU level. ▪ Ensure the coordination of parallel, interdependent processes in different policy areas. ▪ Extend the established understanding of climate policy integration. Integration across economic sectors / technological trajectories: ▪ Provide tools to respond to the governance challenges arising from the erosion of classical sector distinctions/sector coupling. ▪ Ensure coordination across parallel, interdependent processes of technological change.

1. Introduction

Limiting global warming to well below 2°C, whilst striving to limit it to 1.5°C, means that many sectors of the European economy will need to be transformed over the next three decades. Our existing systems for energy, mobility, industry, food and housing need to change, whilst at the same time making our economies and societies more resilient, resource-efficient and sustainable. Given the long lead times and path dependencies involved, the 2020s are the pivotal decade for this transformation, when major decisions on the design of the transformation need to be taken, and the associated policy processes initiated – or drastically ramped up. Bringing this transformation about requires not only an increase in the ambition of climate policies beyond existing policies and measures, but also a fundamentally different approach to climate policy.

This report seeks to define what constitutes transformative climate policies for the European Union and what transformative climate policy entails for four key vectors of the transformation to climate neutrality.

This report will first provide some background on the concept of transformative climate policy, and what distinguishes transformative from conventional climate policy (chapter 2). It then defines four hallmarks of what constitutes transformative policies (chapter 3). Finally, chapter 4 of this report takes a more detailed look at four crucial and interlinked challenges that transformative climate policy needs to address – the 4i's: stimulating **innovation** to transform the material base of the EU economy, rolling out the **infrastructure** for a resilient, climate-neutral economy, shifting **investment** and finance, and achieving **integration** of policies and technologies across sectors.

2. Background

2.1 The concept of transformation in relation to climate policy

The concept of transformative climate policy has gained in frequency of occurrence, both in the academic discussion on climate policy (Moore et al. 2021), but also in the formulation of political strategies with transformative ambition, such as the European Green Deal (European Commission 2019). While different scholars and policy actors apply different definitions, they generally start from the premise that "policy as usual" is insufficient to bring about the profound changes implied by ambitious decarbonisation objectives. Initiating these profound changes instead requires a different type of climate policy.

Fazey et al. (2018) offer a useful definition of transformative change, which can also be applied to distinguish transformative climate policies from "policy as usual" (Fazey et al. 2018). They maintain that transformative change differs in terms of its depth, breadth and speed:

- **Depth** refers to the intensity or quality of the change: Transformative change disrupts existing practices, and often necessitates a fundamentally different approach – for instance by reconfiguring value chains or finding different ways to address basic human needs such as food or mobility.

- **Breadth** of change refers to the distribution of change: Transformative change refers to changes happening in parallel in different subsystems. This can refer to concomitant changes of lifestyles, social practices, technologies and infrastructure, but also to parallel change processes across economic sectors, across different levels of governance, and across jurisdictions.[1]

- **Speed** of the transformation refers to the timeframe through which a change occurs, where transformation requires change to happen on a much shorter time scale than what would be normal for a change process of comparable magnitude.

All of these entail challenges for the design and implementation of policies: the depth of change means that there is much more uncertainty about possible solutions and their viability – from technological feasibility to social acceptance. Transformative climate policy will necessarily need to deal with these substantial technological, political, socio-economic as well as socio-cultural uncertainties: it requires setting course towards long term goals with little certain knowledge of what this world will look like. The breadth of change constitutes a fundamental challenge for coordination, as it increases both the need for horizontal coordination (across sectors and governance departments) and for vertical coordination (across levels of governance). The greater speed finally means that there is less time to experiment with different approaches, observe their effects, learn from mistakes, and improve over time. This may in turn require that several potential solutions are deployed in parallel, where possible, to ensure that the overall effect is achieved.

A further aspect that is relevant for an understanding of transformative climate policy pertains to the understanding of transformation as a social process. A fundamental change such as the transformation to climate neutrality stands to affect the lives of all citizens and requires not only the acceptance, but in many instances the active support and participation of citizens – not only at the ballot box but also as investors, consumers, and voices in the political discourse. To organise transformation as a social change process thus also requires a deepening of democracy as well as greater participation and inclusion. In parallel, tackling the socio-cultural dimension of the

[1] To this could also be added the broadness of participation in change processes: these will, sooner or later, need to involve all relevant actors in the affected groups, i.e. millions of consumers, or thousands of companies, who are not the object of change, but eventually the subjects driving the change.

change – by changing social norms and lifestyles – also requires a transformation of ideas and knowledge, including education and reskilling both in the labour force and in society more broadly.

2.2 From incremental to transformative policies

Traditional EU climate policy can be largely described as an optimisation approach focused on delivering incremental improvements along existing technological trajectories through sector-specific interventions. Policies that are representative of this approach include:

- The system of CO_2 emission performance standards for cars and vans (European Commission 2021b), which requires a steady improvement of vehicle technology, but does not directly mandate a switch in technology from internal combustion engines to electric mobility – let alone a fundamental overhaul of how mobility is achieved and organised.

- The EU Ecodesign Directive and the associated EU energy label, which seek to improve the energy efficiency and the environmental performance of a broad range of household appliances and information and communication technology devices (European Commission 2009). What it ensures is thus a gradual improvement of appliances along given technological trajectories.

- Sectoral emissions trading, which incentivises marginal improvements of the efficiency of covered installations – but also contains the incentive for change through exemptions and subsidies, as in the case of free allocation to industrial installations under the EU ETS (European Commission 2021a).[2]

Following the adoption of the Paris Agreement, the EU and its Member States have begun to incorporate elements of a more transformative approach to climate governance.[3] Most prominently, the European Green Deal expresses this transformative ambition to make Europe the first carbon-neutral continent. This ambition has been enshrined in the EU Climate Law, and

[2] Arguably, some of these instruments have the potential to instill more disruptive change on the technologies they are regulating. For instance, a tightening of efficiency standards will eventually amount to a ban on certain product types (such as internal combustion engines), and a sufficiently high carbon price in the EU ETS will effectively result in a phase-out for certain processes and technologies (such as coal-fired power plants). In this way, at least regarding the intensity and speed of change, such instruments could also be part of a package with transformative ambition – even though they have not had such transformative effects in the past. What remains, though, is that they are mostly sector-specific and often technology-specific along existing technological trajectories, and as such may be ill-suited to steer systemic changes.

[3] The EU's GHG emission reduction targets over time may serve as one expression how the ambition of EU climate policy has increased over time – from a stabilisation at 1990 levels (0%) for 2000, to a reduction of 8% below 1990 levels for 2010, a 20% reduction for 2020, and now 55% reduction for 2030.

is also expressed in the proposed 'Fit for 55' package, a set of policy proposals to put the EU on track towards its 2030 targets (European Commission 2021c; 2021d).

While the EU's existing set of climate policy instruments have not been sufficient to bring about change at the at the necessary speed across the economy, the proposed Fit for 55 package includes several elements with transformative potential.

For instance, to move from an incremental to a transformative approach, the EU's set of climate policy instruments needs more and stronger mechanisms to deliver mitigation across sectors and coordinate mitigation efforts in different sectors. The Fit for 55 package foresees to extend emissions trading to most sectors of the economy. By placing a cap on the emissions of the covered sectors and allocating reduction efforts across sectors, this can be a step in this direction. Yet it also needs to be ensured that all sectors develop and pursue efforts to reduce emissions, not only easy-to-abate sectors (see below). Furthermore, the expanded innovation fund and envisaged instruments such as Carbon Contracts for Difference have the potential to support industrial decarbonisation – yet to develop disruptive technologies that open up radically new, low-carbon ways of delivering needed services, more tools will be needed, especially in terms of infrastructure and investment (e.g., battery storage, power grids, regulation and infrastructure for green hydrogen).

One reason why EU climate policies are more firmly rooted in an incremental approach is that they largely aim to maximise the (static) efficiency of climate policy. Following this approach, the strategy is to first start with the cheapest options to reduce emissions, while keeping the more expensive ones for a later point in time, when more aggressive reductions are called for. This logic applies not only at the level of individual abatement options (as embodied in the EU Emissions Trading System) but also at the level of economic sectors, where abatement is concentrated on the cheaper, easier-to-abate sectors where cost-efficient alternatives are within reach, while placing lower priority on action in the hard-to-abate sectors, where emission reductions are either more challenging technically or more costly politically.

Yet an economy-wide transformation to climate neutrality requires that ultimately wide-ranging measures will need to be taken in all sectors. An incremental approach that begins with only the cheapest options runs the risk of creating a lock-in situation, in which further action becomes extremely costly (or outright impossible) once all the low-hanging fruits have been harvested. In response to this, there are two interpretations of how a transformative approach could go beyond incrementalism and take the whole set of options into view.

- A first, milder interpretation expands the focus from a static to a dynamic understanding of policy efficiency: efficiency means minimising cost of reaching targets by employing the cheapest option. But while a static view takes the available options as a given, a dynamic perspective would also include expanding the set of options by making them cheaper (Vogt-Schilb, Meunier, and Hallegatte 2018). This includes a whole set of policy options to bring down the cost of the more expensive options and lead them to market maturity through policies that foster innovation of technologies and business models, bringing them to commercial scale, and providing the necessary physical or regulatory infrastructure. Such action needs to be taken in all sectors – postponing action in some sectors on the grounds of higher abatement cost makes little sense if all sectors are to decarbonise eventually. Prioritising action does makes sense where sectoral strategies depend on each other (e.g., electrification of transport, heating, or industrial applications require a sufficient supply of zero-carbon electricity at competitive rates).

- A stronger interpretation maintains that transformative climate policy is not simply more of the same, only quicker. It also entails shifting to different paths, which differ from those that would be seen in an incremental approach: this is expressed in concepts such as disruption or leapfrogging of technological and socio-economic pathways. For instance, a more efficient coal-fired power plant or a more efficient internal combustion engine would represent an incremental improvement over the current technology. A switch from lignite to hard coal, or from coal to gas, likewise represents a way of reducing emissions. Yet to be consistent with goals of transformation, virtually all (unabated) fossil technologies will eventually need to be phased out. Further investments and marginal improvements in fossil-based value chains therefore increase the lock-in risk – even though they may increase efficiency and lower emissions. Instead, one main task of transformative climate policy is to manage the phase-out of fossil technologies and support the reconfiguration of fossil-based value chains.

2.3 Revisiting Criteria for Policy Design

Shifting from an incremental, optimising approach to climate policy towards a transformative understanding also requires a re-evaluation of criteria for good policy design, and a shift of emphasis between different criteria. Typically, climate policies (and other public policies) would be measured against three (types of) criteria (Görlach 2013):

- effectiveness (reliably achieving the desired impact),
- efficiency or cost-effectiveness (achieving the given target with least resource input), where efficiency can be further distinguished into static (minimising cost at a given point in time, with given options) and dynamic (minimising cost over time, by expanding the set of options),
- considerations of feasibility (administrative, legal or political feasibility) can be invoked as criteria for policy design; where political feasibility is crucially linked to public acceptance or support, and by extension distributional impacts.

Moving towards a transformative understanding of climate policy can be seen as placing greater weight on the effectiveness of policies: a key premise is that transformative pathways should be able (with a reasonable degree of certainty) to reach the long-run target of climate neutrality. This means that, at least in terms of the headline target for emission reduction, the target is firmly set – it is thus not part of the policy design to determine an optimal (or efficient) level of mitigation effort. Yet efficiency of course remains relevant:

- A classical economic viewpoint would be to maintain that more efficient policies allow to achieve more mitigation overall. The budget for climate policy is finite – irrespective of whether the resource constraint is monetary (public or private budgets), whether it is conceived as (limited) political capital to make things happen, or as the limited willingness of the electorate and/or key stakeholders to accept burdens and make sacrifices. In this reading, the cheaper a policy is (be it budgetary or in terms of political cost), the more of it can be implemented. It could even be argued that this aspect is bound to become more important: Until now, most climate policy has remained relatively marginal (from an economy-wide perspective), hence inefficiencies could be tolerated, since the total cost remained manageable (Edenhofer et al. 2021). Yet with increasing scale and impact, it becomes imperative to spend the limited resources efficiently.

- An alternative viewpoint would be to argue that we have run out of time to look for efficient solutions and now are at a point where climate policy needs to deliver drastic changes in a very short time: effectiveness must be prioritised over efficiency. Also, the situation that climate policy needs to correct is inefficient to begin with: As a result of compounded market (and policy) failures, the climate change that is already happening means that the world already incurs a welfare loss compared to a situation where more rigorous and consistent climate policies had been applied (Parry, Black, and Vernon 2021). Over time, this welfare loss will increase because of further and more drastic, climate change. Whether this inefficient situation is corrected though more or less efficient instruments is thus a secondary consideration.

The criterion of feasibility also takes a different meaning. In one way or another, transformative change will entail policy interventions that would typically be considered infeasible in a "politics as usual" world, or that would at least appear doubtful from a feasibility perspective. Bringing about transformative change will not be possible with win-win solutions alone – it will entail cases of changing social norms and behavioural routines, it will put an end to certain economic development trajectories (with associated job losses and stranded assets) and although it will create a net benefit to society, it will also involve higher costs or other dis-amenities for certain groups and at certain points in time.

Feasibility is thus less of a trade-off with efficiency or effectiveness, but rather as a constraint that itself can be the subject of policy interventions. One objective of the climate policy mix is therefore to create the conditions for extending the range of feasible options, where this is necessary. This may involve changing the regulatory framework where legal feasibility is a constraint, it may involve the expansion of administrative capacities and allocate budgets where administrative feasibility is the limiting factor – but most importantly, it entails flanking measures that soften distributional impacts and raise public acceptance and support and thereby increase political feasibility.

The decision on which criteria should generally guide climate policy also has implications for instrument choice and instrument design. Economic instruments – in particular carbon pricing – promise a higher degree of (static and dynamic) efficiency, by giving economic actors greater autonomy to respond to the price incentive as they see fit and to stimulate search-processes for more efficient solutions. However, this process of market discovery through trial and error can take time – which is short in the transformation to climate neutrality. Also, the search process does not happen in a void, but depends on many prerequisites – the availability of technologies and the regulatory and physical infrastructure to support the deployment of low-carbon technologies. Many of these would not be provided by the market itself but rely on the regulator to make key choices and provide the framework and incentive for private investment.

Efficiency of regulation is not only a matter of the choice of instruments (economic vs. regulatory), but also affects the level of overlap between instruments that is deemed desirable (Huppes et al. 2017). Efficiency and coherence of the instrument mix are better served if there are fewer instruments with less overlap and clearly defined roles. At the same time, the need for resilience in the light of uncertainties also places a value on redundancy in the policy mix, as an insurance against policy failures or other unforeseen calamities.

Therefore, if a shift from incremental to transformative climate policies goes along with a lower value placed on efficiency, this also suggests a different approach to instrumentation, and a need to revisit the role of carbon pricing and market-based approaches more generally. This is clearly not a matter of either-or – of no markets or markets only – as it is evident that the carbon price will need to play an important role in any scenario for EU climate policy. The question is rather what the function of the carbon price should be: whether it is the main driver for emission reductions and thus the central pillar around which the policy mix is constructed, or one among many important instruments in the mix. Greater emphasis on effectiveness may also affect the choice between different economic instruments and their design: an ETS with a stringent cap can be a very effective tool, whereas design features such as overly generous free allocation may undermine the signal and incentive provided by the carbon price. Likewise, broad sectoral coverage of an ETS is desirable from an efficiency perspective, as it expands the range of abatement options that are addressed by the market – but may also result in a situation where the abatement is concentrated in those sectors that have low-cost abatement options, whereas sectors with higher abatement costs fail to take action. While this is perfectly in line with the economic logic of the instrument, it may exacerbate the lock-in risk in a situation where, eventually, emitters in all sectors need to reduce their emissions to net zero.

A step-change is needed to reach climate neutrality in the EU

The EU-27 has made considerable progress to reduce its GHG emissions over the last three decades, managing to achieve the target of a 20% reduction by 2020 from 1990 levels. The EEA estimated that GHGs in the EU were 34% lower in 2020 than in 1990 (EEA 2021). However, much of the 2020 drop can be attributed to the Covid-19 pandemic and it is expected for emissions to rebound in 2021 (IEA 2021a). Projections indicate that under existing and additional policies proposed by Member States, the trajectory of the EU is not aligned with the goal of reaching net-zero by 2050 – indicating the need for significantly higher political ambition to match the ambition of the emission reduction goals.

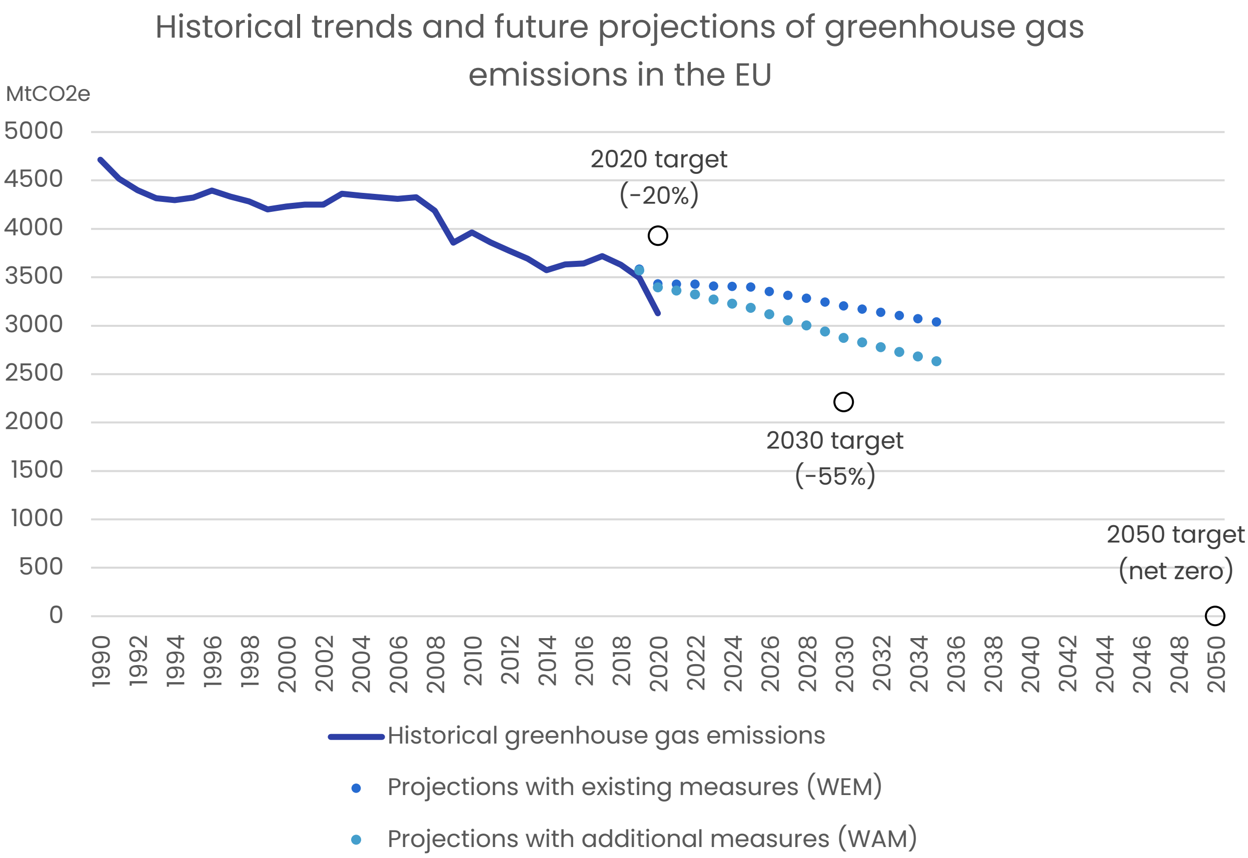

Figure 1: Historical trends and future projections of greenhouse gas emissions for the EU Member States (EU-27) from 1900-2050 - adapted from EEA (2021).

3. Hallmarks of transformative climate policy

Transformative climate policy needs to address the challenge of transforming to climate neutrality in its entirety – across sectors, in its technological, economic, political and social implications, and across the different phases of the process. This simple premise has numerous implications for how to think about climate policy. These can be structured around four dimensions – which can also serve as hallmarks that differentiate a transformative approach to climate policy.

1. Think backward from the end – climate neutrality by mid-century
2. Overcome existing and future path-dependency and lock-in risk
3. Develop institutions capable of delivering transformative change
4. Foster integration across sectors and embed technical changes in a broader political and socio-economic process

These four dimensions are elaborated below.

3.1 Think back from the end: climate neutrality by mid-century

As one distinguishing feature of a transformative (rather than incremental) approach to climate policy, the main yardstick for policies is whether they can take us to the goal that needs to be reached – climate neutrality by mid-century.

To be able to judge whether policies are compatible with the long-run objective requires a shared vision and concept of the transformation to climate neutrality, and (at least in broad terms) a shared understanding what kind of future our current policies should lead to – but at the same time acknowledging the abundant uncertainties, be they technological, political or socio-economic. Such a shared understanding is not about exact predictions, but rather about providing sufficient clarity on core elements that need to happen and being sufficiently open to accommodate unforeseen and unforeseeable developments.

3.1.1 What do we know about technological options?

The exact pathway towards climate neutrality remains uncertain. But within this uncertainty, it is becoming increasingly clear which role several elements need to play in the process, based on a range of modelling efforts, scenarios and other analyses published in recent years (IEA 2021ba; Luderer, Kost, and Sörgel 2021; Auer et al. 2020; Capros et al. 2019). To reflect this, technological options can be distinguished into three broad categories:

- **The obvious**: This comprises the technological options for which it is certain that they will need to be part of the solution and thus need to be tackled and scaled quickly. This includes the expansion of renewable power generation to achieve a fully decarbonised power sector well ahead of 2050 and the phase-out of coal much sooner; an increasing role for storage and flexibility of demand in the electricity system (including power-to-X and some use cases for green hydrogen); much greater emphasis on energy efficiency, above all in buildings (renovation wave and phase-out of fossil-based heating), but also for appliances in households and industry; exploiting the potential of a circular economy for emission reductions and decarbonisation; and a push toward electrification in industry, land transport and buildings, based on much expanded renewable electricity.

- **The likely**: This comprises elements that can play a role and/or feature in some scenarios, but which are not a foregone conclusion – for instance since they require significant additional support and overcoming barriers, be they economic, technological or in terms of public acceptance, or because options only make sense in some scenarios, but not in others. This includes, for instance, many use cases for green hydrogen and synthetic fuels, carbon capture and utilisation (CCUS) and other technologies for negative emissions, and possibly nuclear power.

- **The (known) unknowns**: This includes elements for which technological options cannot (yet) be foreseen – or for which technological options have been proposed but cannot yet be reliably evaluated. This includes, for instance, climate-neutral aviation or long-distance freight transport, where the choice between biobased fuels, direct electrification or indirect electrification via synthetic fuels remains open.

3.1.2 What do we know about how to get there?

The technological options that are available in the different sectors are interdependent. Such interdependencies can create bottlenecks and incur delays, if mitigation options only become feasible once conditions are met in other sectors. They also introduce coordination needs (be it market-based, or through regulatory intervention, or a mix of both), if mitigation options in different sectors compete for the same scarce resources.

- **Renewable electricity** plays a pivotal role in all scenarios: the electrification of transport, space heating and industrial heat, but also the production of green hydrogen and other power-to-X technologies requires abundant and affordable renewable electricity, and an electricity system capable of absorbing, storing and transmitting this electricity.

- Likewise, **(green) hydrogen and CCUS** will have a role to play. But to do so at competitive cost, they require physical infrastructure, regulatory frameworks, public acceptance etc., all of which take time to build.

- Many aspects involve **new construction work** – thermal insulation of buildings, installation of renewable energy technologies and energy infrastructure, etc. The capacity of staff with necessary skills and expertise for planning, installation and maintenance already sets a limit to the renovation rate.

Planning from the end thus requires careful sequencing of measures in the different sectors, in order to anticipate and account for interdependencies and bottlenecks.[4]

However, whatever its shape will be, future EU climate policy and its climate governance more broadly will need to evolve, including the policy instruments applicable at EU level and in the Member States, as well as the associated political, institutional, and legal set-up. At the same time, the EU's future climate governance will most likely continue to be based on established principles of EU (environmental) law, such as the polluter pays principle, the precautionary principle and the principles of subsidiarity and proportionality (Jordan and Gravey 2021, 175), and be informed by the experience of EU climate policy governance over the last decade. And it will be assessed against criteria embodied in the EU's better regulation agenda (efficiency, effectiveness, feasibility – possibly extended to include aspects of resilience/robustness) (Jordan and Gravey 2021, 247; Görlach 2013). Above all, it should also embody a clearly recognisable regulatory philosophy: this pertains to the role of and reliance on market in contrast to public provision and public investment, as well as the sharing of risks and benefits between public and private actors.

3.2 Overcome path-dependency and lock-in risk

Another hallmark of transformative climate policies is that they need to bend the current socio-economic and technological trajectories and thereby overcome existing path-dependencies, which lock the economy into a high-carbon model of economic development.

For the last 150 years, European economies have developed around a fossil-based and high-carbon model of economic development. Their technologies, value chains, infrastructure and governance systems have all co-evolved around fossil-based technologies (Unruh 2000). As a result, fossil technologies and the value chains they support are deeply embedded in the global economy. As a result, the fossil-based model of economic development is locked in at different levels, which are mutually reinforcing: through technologies and infrastructures (techno-economic lock-in); through political institutions and decision-making (political-institutional lock-in), and through individual behaviour and social structures (behavioural lock-in) (Seto et al. 2016).

[4] Sequencing, in this context, refers to planning the timing of parallel processes. It does not mean that one step can only be taken after another one has been concluded – which simply would not be feasible in the timeframes involved. Thus, for instance, electrification of transport and heating only generates the full climate benefit when it uses renewable heat – but steps towards electrification also make sense beforehand. Likewise, industrial uses that rely on green hydrogen for climate neutrality may be operated with hydrogen of other provenience (grey, blue or turquoise) as a transitional arrangement.

Overcoming this situation is therefore not only a matter of replacing an individual technology, or even a specific fuel, but requires reconfiguring the whole economy. Instead of the current fossil lock-in, climate policy needs to create the socio-economic framework conditions that lock-in a model of economic development that is commensurate with climate neutrality and create a positive path-dependency in which trajectories in technology, investment and finance are aligned with carbon neutrality in a self-reinforcing way.

To bring this about, transformative climate policy needs to combine two elements: policies targeting innovation broadly understood (i.e., bringing in new solutions and creating conditions for their deployment the necessary scale and pace) and exnovation policies (i.e., managing the phase-out of technologies that have no place in a climate-neutral economy, where possible realising a transition of labour, skills and physical assets to new uses).

3.2.1 Innovation policies

Innovation goes beyond the invention of new technological solutions: to function, to be adopted, and to scale up at the necessary pace. New solutions need to be taken up by different actors to integrate them into new business models and new social practices. For this, they need to have the right, enabling framework conditions – in terms of regulation, public acceptance, infrastructure etc. As elaborated further in chapter 4.1 below, innovation policies as part of transformative climate governance therefore need to simulate different types of innovation that work towards the same direction as part of an innovation (eco-)system – technological innovation as well as social, organisational and business model innovation, but also fostering innovative forms of governance.

To be able to function technically and economically, innovations must be conceived along the entire value chain. The transformation to climate neutrality is not only a matter of exchanging fossil with renewable fuels – in many instances it will also involve reconfiguration of value chains. For instance, the electrification of transport implies that parts of the automotive value chain will decline and eventually disappear – the manufacturing and maintenance of elements that are no longer needed, such as gearboxes, but also the supply infrastructure for transport fuels from refineries to gas stations. Some of these will be replaced by new industries and new types of infrastructure, such as charging points and associated services, in other instances electrification will come along with entirely new products and services (such as mobility as a service/shared mobility, battery swapping schemes, or grid stabilisation through flexible use of car batteries). In other instances, materials and products that are now part of fossil value chains may no longer be economically viable if the associated fossil energy use is discontinued – such as lignite wax that is a by-product of lignite mining, gypsum plasterboard that uses gypsum from flue gas desulphurisation, but also the use of mineral oil as a feedstock for the petrochemical industry will change if less oil is needed for production of mineral fuels. Innovation (and exnovation) policies therefore need to anticipate and address such interdependencies along the value chain.

3.2.2 Exnovation policies

For a systemic change towards climate neutrality to happen, it is not enough to introduce new elements – such as renewable energy sources and fossil-free value chains – in the expectation that the new, climate-neutral elements will eventually displace the old, fossil-based technologies and business models. There are several reasons why a systemic approach to transformative climate policy also needs to actively address the phase-out of incumbent, fossil technologies (and supporting infrastructure and business models):

- **The necessary pace of the transformation:** Transformation in the 2020s means that building up the new and phasing down the old technologies needs to happen in parallel.
- **Lock-in of incumbent technologies:** The sunk costs of fossil assets mean that incumbents have a strong interest in extending the economic and physical lifetime of these assets, and also a business advantage over newcomers, if their assets have been written off. It is therefore in the interest of incumbents to delay or slow any change processes that would undermine their business model, creating both a physical and a political lock-in risk.
- **Certainty of planning:** To preserve the chance of reaching climate targets, certain change processes (such as a phase-out of fossil fuels in electricity generation) are inevitable. Others (such as the phase-out of internal combustion engines) are highly likely. Translating these likelihoods into phase-out mandates creates certainty for businesses, investors, consumers and employees in the affected sectors to adjust their plans accordingly.
- **Containing political backlash through managed decline:** Accepting the reality of a phase-out allows the political management of the phase-out process, e.g., through re-training.

There are different ways to conceive of the intentional decline of fossil technologies (Rosenbloom and Rinscheid 2020): Phase-out refers to the managed process of retiring fossil-intensive technologies and infrastructures. In a similar vein, exnovation can be understood to refer to policy interventions that intentionally discontinue fossil-based and carbon-intensive technological trajectories (David 2017). Disinvestment is a related, but different concept that refers to diminishing both the financial resources and the political legitimacy of fossil-based businesses. As a broader concept, destabilisation describes the intentional disruption of entire carbon-intensive systems, including interests, institutions, markets and practices.

To support a managed decline and eventual phase-out of fossil technologies, different policy approaches are available.

- **Explicit phaseout policies** fix a termination date for technologies, substances, or processes. Technically, these can take the form of a regulatory ban on production, import or sale/purchase that applies after an announced end date. In the field of climate policy, examples include the phaseout of coal in electricity generation, of cars with internal combustion engines, or of oil heating in buildings.

- A phaseout can also be the result of a **gradual tightening of standards** (for energy efficiency, fuel consumption), which makes conventional technologies and processes less and less attractive or economically viable. Similarly, the phaseout of a technology, substance or process can also be the (implicit) result of **market-based instruments**, such as an increasing carbon price or the discontinuation of subsidies. While these approaches would not amount to an explicit prohibition, they can create conditions where using the technology, substance or process in question becomes economically prohibitive.

In practice, the two approaches can – and typically do – work in combination: the phase-out announcement defines the political target and sends a clear signal to investors, consumers and other stakeholders. Standards or pricing can then serve as the instrument to do the actual phaseout work by eroding the business model of the technology, substance, or process, rendering them unattractive.

In either case, a managed decline process will typically also involve some form of transition assistance for groups or stakeholders that are most affected – be it because they lack the resources or capacity to adjust themselves, as a matter of solidarity, or to overcome resistance by pivotal actors and win support. Such assistance may involve transitioning and reskilling labour, but also compensation for stranded assets. While the economic justification and the fairness of such assistance can be debated – for instance if it compensates bad investment decisions – it may still be warranted simply as a matter of political expedience.

3.3 Develop governance mechanisms capable of delivering transformative change

A transformative climate governance also requires new mechanisms that can deliver transformative change with the active support and participation of stakeholders and the public at large. These mechanisms need to provide clear direction to investors and consumers, retain the necessary space for experimentation, be able to adapt to inevitable setbacks and provide a robust long-term perspective – within the confines set by political systems.

Transformative climate governance encompasses both policies (discussed above) and governance mechanisms. The latter include institutions and requirements for agenda setting, legislative decision-making, stakeholder/citizen/expert participation, planning, monitoring, reporting, and enforcement that help to catalyse and steer the transformative changes needed to achieve the goal of climate neutrality in 2050. In some cases, these mechanisms take the form of requirements set in legislation on individual climate policies. For example, many existing EU climate policies include requirements for monitoring, reporting, and regular review and revision (European Court of Auditors 2018; Schoenefeld, Hildén, and Jordan 2018). An important type of mechanism are governance frameworks, which include climate-focused frameworks such as the 2018 Governance Regulation on the Energy Union and Climate Action, the National Energy and Climate Plans required under that regulation, and the 2021 European Climate Law. In addition, frameworks that are not specifically focused on climate change can also play an important role in climate governance, such as the European Semester and the Multiannual Financial Framework (Rietig 2021; Duwe 2018).

Along with the number and ambition of EU climate targets, the extent of EU climate governance mechanisms has increased, as well as their degree of formalisation. As the EU aims for a 55% reduction in greenhouse gas emissions by 2030 and climate neutrality by 2050, the existing landscape of climate-related governance mechanisms needs to evolve further, to be able to deliver the coordination needed in the transformation process, and to do so in an inclusive and participatory way (Duwe 2022). Possible approaches include the creation or modification of climate-related mechanisms across and within a broad set of relevant sectors, such as coordination units to deliver the needed oversight across sectors (see also following section), sectoral carbon budgets, and independent advisory bodies of scientists, citizens, and/or other stakeholders (e.g., the European Scientific Advisory Board on Climate Change established under the European Climate Law).

A key area of focus for the 4i-TRACTION project is to examine the criteria for effective and transformative EU climate governance. Initially, three potentially important criteria have been identified.

1. First, climate governance should enable the active support and participation of stakeholders and the public at large and should incorporate participatory and deliberative elements (Torney 2021).
2. Second, adaptive and learning forms of governance are needed to steer through the transformation process, providing room for experimentation (Kivimaa et al. 2017; Laakso, Berg, and Annala 2017) – coupled with ex-ante assessment and ex-post evaluation to ensure that the experiments lead to more effective and efficient policies.
3. Finally, governance mechanisms should aid in the long-term anchoring of climate policies that are both durable enough to provide predictability to investors/consumers and credible commitment to climate targets and flexible enough to adapt to changing economic, political and scientific/technological conditions (Jordan and Moore 2020).

This approach should lead to the evolution of diversified policy mixes, balancing the trade-offs between long-term stability and short-term responsiveness.

3.4 Foster integration across sectoral systems

A further hallmark of transformative climate governance is that it needs to initiate and coordinate parallel – and interdependent – change processes in all economic sectors, and therefore also in all policy domains. In the transformation to climate neutrality, "all policy is climate policy" – transformative climate governance thus requires an all-of-government approach. The overlap between climate and energy policy will remain strong, and the decarbonisation of electricity remains pivotal as an enabler for transformations in other sectors. But transformative climate governance requires that other sectoral policies are aligned with the transformation agenda. This includes the sectors accounting for the largest emission sources – transport, industry, buildings, and agriculture – as well as the cross-cutting domains such as fiscal policy, trade policy etc.

One feature of the transformation to climate neutrality is that interdependent change processes happen in parallel across economic sectors, and across political departments. This creates a whole new set of coordination needs, which transformative climate governance needs to address:

- Ensuring that efforts are coordinated, aligned and consistent across different government departments and units.
- Coordinating across levels of governance (international, EU, national, regional and local), where efforts and strategies pursued at different levels need to be consistent, if not aligned.
- Aligning strategies and efforts across national boundaries within the EU, where different Member States pursue different strategies or set different priorities in the process of transforming to climate neutrality.

Beyond the coordination and integration of governance (across departments, sectors and levels), there are also a number of instances where there are material interdependencies between the transformation strategies pursued and the mitigation measures applied in different sectors. These in turn create further coordination needs, to which a governance framework geared at transformative change needs to respond:

- The most obvious case is **sector coupling**. One feature common to many technologies for deep decarbonisation is that they extend across traditional sector boundaries. This is most notable for electrification – be it in the form of direct electrification of transport (electric mobility), space heating (heat pumps), industrial heat, etc., or as indirect electrification (via green hydrogen, synthetic fuels, etc.). This means that the success of a mitigation strategy for the transport, buildings or industry sectors will partly depend on the expansion of renewable capacity, which falls under the remit of the energy sector. Likewise, the economic viability of an expansion of renewables depends, among others, on flexible uses that can absorb surplus electricity also in times of peak production and thus on various sector coupling technologies (power-to-X) applied in other sectors.

- Likewise, coordination needs arise where transformation strategies pursued in different sectors draw on the same set of **scarce resources**. A case in point would be the (limited) supplies of renewable electricity and, by extension, green hydrogen. Another is the limited potential for sustainable biomass or CCS capacity. But scarcity may also be a factor when it comes to land (where biomass, solar and wind may compete with other land uses).[5]

- A related issue concerns the **availability of skilled labour** – for instance in planning and constructing the infrastructure for low-carbon technologies. In this case, however, the challenge is less about accepting that resources are scarce and managing the scarcity, but rather about alleviating scarcity – through education and vocational training. This could help to diffuse what could otherwise become one main constraint for the transformation to climate neutrality.

3.5 Broader aspects of the transformation

The four hallmarks described above define what transformative governance needs to achieve from a socio-economic and policy point of view. In addition, there are also further-reaching interpretations that place the transformation to climate neutrality as a broader, societal project. In this understanding, several other aspects are relevant – which are, however, not the focus of the 4i-TRACTION project:[6]

- **Changes in norms and values**: This includes both changes of habits, routines and behaviour at the individual level to make e.g., consumption choices compatible with climate goals, but also the process through which new social norms emerge. If successful, this can help to overcome inertia, address concerns, resolve fears and thereby reduce barriers to change.

- **Social momentum and societal coalitions for change**: Clearly, a process that is as profound as the transformation to climate neutrality will require not only the acceptance of the public, but rather needs to be carried by a groundswell of social momentum and societal coalitions for change.[7]

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[5] To some extent, such competition for scarce resources can be resolved via markets. In some instances, however, market coordination may be seen as inappropriate (in the case of land use, where economic and other objectives need to be weighed), or as ineffective (in the case of skilled labour shortages, where market coordination would run the risk of delivering too little too late). And even where market coordination is possible in principle, the resulting price uncertainty could be a deterrent for investors – e.g., in the case of CCS or green hydrogen as young and immature markets.

[6] The choice of focus is not related to the importance of these aspects, but rather responded to the research call – where for instance behavioural changes and changes in norms and values are addressed in several other EU-funded research projects, such as FULFILL, CAMPAIGNers or 1.5 LIFESTYLES.

[7] This is relevant for the 4i-TRACTION research to the extent that this translates into participatory and deliberative forms of governance and civic engagement in the policy process.

- **System change**: As the transformation to climate neutrality involves a *systemic* change from a fossil-based to a renewable, circular economy, it seems but a small change to also see it as a system change, with more or less profound changes to how the European economy is set up. This is captured in discourses on sufficiency and degrowth (van den Bergh 2010; Keyßer and Lenzen 2021), but also extends to positions that view the market-based economy as a part of the problem and question whether a transformation to climate neutrality will be feasible in a capitalist system (Fournier 2008).

- **Political power and vested interests:** As a fundamental change process, the transformation to climate neutrality will see winners and losers, even though it provides a net benefit overall. The political economy of this process means that incumbents, if they expect to be on the losing side, will defend the status quo and may thus seek to slow or undermine the change process. This clearly has effects on the policy formulation – from lobbying and regulatory capture, to the intentional spreading of misinformation (Oreskes and Conway 2010) and as such is a relevant consideration for many of the change processes described above (e.g., in the case of innovation vs. exnovation policies).

4. The 4i's as key challenges for transformative climate policy

Transformative climate policy is not only about reducing emissions but about initiating and driving forward the systemic changes that are needed to take the economy to climate neutrality. Many of these necessary change processes are no longer confined to individual sectors, such as transport or housing, but are crosscutting in nature. Sectoral approaches – predominantly the domain of traditional climate policy – are no longer sufficient, as change needs to happen in all sectors at once. Many of the required solutions extend across sectors, creating interdependencies and bottlenecks. Climate policy therefore needs to anticipate conflicts and coordinate accordingly.

The 4i-TRACTION project is organised around four challenges, which were identified as central for the transformation to climate neutrality: stimulating innovation to transform the material base of our economy; shifting investment and finance; rolling out the infrastructure for a resilient, climate-neutral economy; and achieving integration of sectoral systems. Whereas the previous chapter defined general hallmarks for what constitutes a transformative approach to climate policy, and what distinguishes it from traditional "policy-as-usual", the following chapter formulates four concrete challenges that EU climate policy needs to address in the coming decade – and specifies how these are understood for the purposes of the project.

4.1 The innovation challenge: developing and deploying solutions for climate neutrality

The innovation challenge considers different types of innovation and how they could contribute to achieve EU climate neutrality by 2050. As the transformation to climate neutrality is a systemic challenge, this also means looking beyond mere technological innovation but also considering both business model innovation and policy/governance innovation:

- **Technological innovation** is the use of new technologies, techniques and combinations thereof to bring emissions down in line with climate neutrality/net-zero
- **Business model innovation** is the introduction of new business models that can scale up emission-reducing activities and technologies.
- **Policy and governance innovation** is the use of new policy instruments/governance mechanisms or the modification of existing instruments/mechanisms to enable the transformation of the (sectoral) scope covered by the policies.

4.1.1 Technological innovation challenges

Innovation challenges are seen here as challenges/barriers to meet the goal of climate neutrality by 2050. There are several technological innovation challenges:

- Inventing new technologies (techniques, products, systems, etc.) – this applies to technologies at a low technological readiness level, i.e., at an earlier stage of the development from invention to market maturity.
- Piloting and demonstrating new technologies and techniques – this applies to technologies at a higher technological readiness level.
- Preparing new technologies for market deployment and uptake.
- Improving new technologies to enhance competitiveness with incumbent technologies.
- Making new technologies affordable during their development and deployment.

An important element of the transformative innovation challenge is the limited time in which it needs to deliver – given that the transformation to climate neutrality will need to be completed by 2050. This limits the potential for some radical or early-stage inventions, as there is simply not enough time for extensive search and selection processes. Instead, a focus on the following areas is warranted:

- Focus on demonstration and deployment of technologies, for which there is high confidence that they will reach maturity.
- Focus on creating markets for innovative technologies, techniques, systems, and products to enable their market entry (and public acceptance).
- Focus on accelerating learning curves of technologies to make them affordable.

There are different types of policy instruments that can foster technological innovation. These apply at different stages of the process from invention to commercialisation, and will function differently, because they address different challenges and bottlenecks at these stages. Typical categories of policy instruments include:[8]

- Policy instruments aimed at stimulating and enabling inventions (e.g., research and development finance, real-world laboratories, intellectual property protection),
- Policy instruments that scale up innovations and lead them to market maturity (e.g., carbon contracts for difference, green lead markets, public procurement),
- Policy instruments that (sometimes indirectly) induce innovation (e.g., a carbon price, regulatory standards), but do not have innovation as their unique or even main goal.

The governance of technological innovation can be seen from different perspectives:

- From the perspective of innovation systems (e.g., the actors involved in innovation).
- From the perspective of society, witnessing the impact of innovation.
- From the perspective of policymakers trying to steer innovation via policy instruments.

For the scope of 4i-TRACTION and the transformational challenge on innovation, the innovation system perspective will be analysed in combination with the policy context. This also means that innovation policies are considered beyond the sector where technology will be deployed.

4.1.2 Business model innovation challenges

Achieving climate neutrality will not only require technological changes in processes or products, but also adapting existing business models and introducing new ones (European Commission -

[8] Policies and governance for technological innovation should not be confused with policy and governance innovation. The former seeks to address the technological innovation challenges through the use of policy instruments and governance (systems). The latter concerns the innovation of policy and governance itself (see Section 4.1.3).

DG RTD 2018). *Business model innovation* refers to new ways that companies can create, deliver, or capture value. Examples include:

- Changes to the production process that radically **alter supply chains or extend producer responsibility** (e.g., towards a circular economy, such as through closed-loop supply chains) (Carra and Magdani 2017).
- **Capitalising on flexibility:** The intermittent nature of renewable electricity generation places a higher premium on flexibility of demand. Using flexibility potentials can lower cost for transmission and backup. This flexibility premium gives rise to new business models (e.g., in the fields of (distributed) storage, pooling and flexibilisation of demand)
- Changing the product in such a way that **materials/GHG intensity is dramatically reduced** but the same consumer benefit is achieved. This includes instances where the physical production and delivery of a product is instead replaced with a service (e.g., materials as a service, mobility as a service, energy service companies), but also cases where pooling and sharing of goods can deliver the same benefit with less resource use.

Business model innovation is often linked to enabling technological innovation, where new technological solutions enable new business models (e.g., battery technology and IT enabling shared electrical mobility and mobility-as-a-service more generally). This will often build on technological advances outside of the direct scope of the production system, for instance digitisation to enhance the circular economy along the value chain. Business model innovation may also coincide with social innovation – as, for instance, in the case of peer-to-peer distributed energy trading, bringing together consumers and prosumers.

4.1.3 Policy and governance innovation

Policy/governance innovation is the process of modifying existing – or developing new – policies or governance mechanisms (adapted from Jordan and Huitema 2014a, 915; see also Bellinson and Chu 2019; Patterson and Huitema 2019). This innovation can involve the creation of new policy instruments/mechanisms or changes in the design of existing policies and mechanisms (e.g., through increasing the percentage of energy coming from renewable sources in existing EU renewables policy). Innovation can happen via *diffusion* (the spreading of a novel policy instrument or governance mechanism from one jurisdiction to another) or via *invention* – the creation of an entirely novel instrument/mechanism (Jordan and Huitema 2014b).

The three types of innovation will interact in important ways. Technological innovation – such as cost reductions in renewable energy technologies – can open up new opportunities for policy/governance innovation or alternatively make policy changes necessary. On the other hand, policy/governance innovation can be directed to better support technological and business model changes, e.g., by increasing financial incentives and support (see Section 4.1.1).

4.1.4 Focus of the innovation challenge in 4i-TRACTION

Building on the above, the focus of the innovation challenge in the 4i-TRACTION project can be summarised as follows:

- **Focus on technological innovation and business model innovation** as sources of solutions for climate neutrality – as well as **policy and governance innovation** for new governance solutions. Other types of innovation (e.g., social innovation) are not a focus of the project.

- Within technological innovation, the focus will be on **innovations at higher levels of technological readiness**, for which there is a higher chance that they can be scaled up sufficiently towards commercialisation within the timeframes considered (before 2030). This also includes elements such as market creation for new technologies, products, processes and services.

- The research will adopt an **innovation system perspective**, including the policy context, to understand how actors active in the field shape innovation outcomes. For the policy context, this angle investigates not only classical innovation policies (e.g., RD&D policy), but also the broader framework conditions set in other fields of public policy.

4.2 The infrastructure challenge: rolling out the infrastructure for a climate-neutral economy

The infrastructure challenge is fundamental to meeting the EU's long-term climate goals, as well as other key EU objectives such as ensuring security of energy supply. This challenge needs to straddle several trends: changes in energy production, changes in energy demand and, for transport infrastructure (roads, railways, waterways), changing patterns in transport and mobility.

Firstly, **infrastructure needs are driven by the transition from fossil to renewable energy production**. Renewable energy production has a number of characteristics that differ from fossil energy production, which has significant implications for the infrastructure needs of the future. In a climate-neutral economy, wind and solar energy are expected to dominate the total energy mix. These are two energy sources that produce electricity only (although that can be converted to a gas or liquids), with strongly fluctuating production levels over time. This is quite different from the fossil energy system which is based on largely centralised electricity production in power plants that can adapt production levels to demand, and extensive use of natural gas and oil-based liquid fuels for heat, industry feedstock and transport. The geographical aspects of RES production are also different from the current system: There are many more production locations, in different areas than the current power plants. Wind and solar energy production sites need to be connected to the electricity grid, and the electricity generated then needs to be transported to the end-users. Peak loads can be high due to the fluctuating production levels, which requires an adequately sized grid to avoid grid congestion, as well as a combination of storage and flexible load to absorb such peaks. Part of the electricity produced is likely to be converted to hydrogen, to allow for large-scale storage of the energy for times with lower production, and for cost-effective transport of large amounts of renewable energy. A hydrogen infrastructure needs to be developed for this, which may in part be based on the existing gas grids but will also require new pipelines.

Secondly, **infrastructure is a key enabler for decarbonisation of end-uses**. Without the right infrastructure in place, the industry, transport and building sectors cannot decarbonise sufficiently to meet their climate goals. Some examples illustrate this:

- Widespread electrification of transport requires an extensive charging infrastructure network throughout Europe.
- The vast majority of the current production processes in industry are based on natural gas. These will need to be replaced by processes based on renewable energy. This requires new infrastructure to supply large amounts of renewable electricity and/or green hydrogen to the site.
- Climate-neutral heating of the EU's buildings will be achieved with technologies such as electrification (heat pumps), solar thermal energy, biogas, geothermal heat, etc. This transition can only be achieved if there is sufficient transport capacity in place for the energy needed (electricity, biogas, heat, etc.)

And finally, future **transport infrastructure will need to facilitate climate-neutral mobility.** This relates to energy (there will be a need for charging infrastructure, perhaps also with overhead wires to power heavy transport) but also to the availability and characteristics of roads, railways and waterways.

4.2.1 Infrastructure for the future

Part of the future infrastructure requirements will be determined by the strong increase in renewable electricity production from wind and solar, as well as increasing electricity demand due to electrification in all sectors. In addition, there will also be significant demand for carbon-neutral gases (green hydrogen, biomethane, etc) and liquid fuels (synfuels, biofuels). These will be the most attractive option for applications that cannot be electrified,[9] such as aviation, maritime shipping, some heavy-duty road transport and the high-temperature heat demand from industry. Many scenarios also rely on CCUS to meet climate goals, based on fossil CO_2 or, in the longer

[9] Typically due to their high energy consumption and/or need for high energy density.

term, CO_2 from biomass (BECCS). The energy mix and demand and supply volumes are uncertain and vary between scenarios.

With these key features of the future energy and transport system in mind, we can draw a rough sketch of infrastructure in a climate-neutral EU.

- **Electricity grid**: The power grid needs to be expanded and strengthened to provide sufficient capacity to transport the electricity produced to the consumers, with special attention for cross-border connections as these are still weak in some regions within the EU. These end-users may provide demand flexibility and there will be storage capacity for grid balancing and temporary storage. Electrolysers will be integrated in the system to produce green hydrogen.

- **Hydrogen pipelines**: A hydrogen grid will be needed throughout the EU, to connect electrolyser locations with end-users. Hydrogen storage will be integrated into this system. Hydrogen produced from renewable electricity is likely to become a key pillar of the energy system. It causes significant additional electricity demand due to conversion losses but allows long-term storage of the energy produced. In addition, hydrogen (or further processed products, e.g., ammonia) is an energy carrier that can be used to transport large amounts of renewable energy at lower cost than electricity, as a feedstock for carbon-neutral synthetic fuels, or as an input into low-carbon industrial production processes.

- **Gas pipelines**: Some parts of the existing EU gas network will become obsolete over time, other parts may be used to transport renewable gases such as biomethane, hydrogen or synthetic gas based on green hydrogen. Natural gas use may still increase in parts of the EU (until 2030), as coal is phased out, but eventually will decline strongly.

- **Heat networks**: District heating systems may be a cost-efficient option in part of the EU's densely populated municipalities. However, their use may be limited as energy efficiency measures will lower heat demand (e.g., building renovation and insulation) and a large part of low-temperature heat demand will be provided with electricity (heat pumps).

- **CO_2 pipelines**: CO_2 infrastructure is needed to transport large volumes of captured CO_2 to subsurface storage sites (CCS and BECCS) and to other industries that may use the CO_2 for their production processes (CCU).

- **Transport infrastructure**: The future transport sector requires a charging network for electric vehicles (passenger cars, busses and light duty vehicles but also an increasing share of heavy-duty trucks), and for the remaining share of -heavy-duty vehicles perhaps a network for hydrogen (or hydrogen-based synthetic fuels) or overhead charging. It also needs infrastructure for synthetic (liquid) fuels for aviation and maritime shipping, which is likely to be based on the current fuel infrastructure. Rail transport may increase, requiring expansion of the EU rail network (incl. for high-speed passenger and for goods transport) and reducing current barriers associated with border crossings due to different national material and safety standards. Spatial and urban planning may facilitate walking, cycling and public transport, reducing the role of cars for mobility.

Infrastructure is needed on different levels, from local to trans-European. Furthermore, each type of infrastructure needs market regulation adjusted to its specific characteristics, regulating issues such as access, ownership, financing and security of supply.

4.2.2 Path dependency and lock-in risks

Infrastructure, technology developments and the demand and supply of the various energy carriers and CO_2 are all interdependent. Having the right infrastructure in place is a crucial pre-requisite for many technological options for climate mitigation such as electrification, renewable energy integration, hydrogen economy, CCS, etc. Whether such solutions become economically viable options depends, among others, on the availability and capacity of the infrastructure. However, infrastructure is not technology-neutral – hydrogen cannot be transported via the power grid or heat network, electricity cannot flow through a pipeline. This creates a path dependency and risk of technology lock-in. This risk is likely to be most significant for investments in natural gas and CO_2 infrastructure, since these may incentivise the prolonged use of fossil energy and delay the scale-up of alternatives, unless effective policies are in place to counter that effect.

Furthermore, infrastructure development has a long lead time, with often at least 5-10 years from plan to investment decision to realisation. This requires an early decision on infrastructure investments, at a point in time when the most cost-effective decarbonisation technology for that location or region may still be uncertain. This creates a risk that demand for the infrastructure may turn out to be much lower or higher than anticipated by the time the grid or pipeline is operational.

Finally, current regulation can create a lock-in in current technologies and form barriers for developments needed to create the infrastructure required for the future. For example, network operators (TSOs and DSOs) are granted monopolies on the condition that their investments are worthwhile for the clients, which in practice means that they invest only given signed contracts for new connections.

The result is that in case the investment decision process leans towards limiting financial risks, the roll out of the infrastructure may be too slow. This can severely hamper decarbonisation of end use sectors and may lead to high costs in the future and risks to the security of supply. To achieve climate neutrality by 2050, the decisions need to be targeted more towards ensuring that sufficient infrastructure is available in the future. This requires more government involvement but also accepting the risk that some of the investments may not prove to be economical in the end.

4.2.3 Institutions and governance

The challenges result in several governance issues and questions that need to be resolved:

- **Technological openness versus technology-specific infrastructure needs.** How to ensure that there is some degree of technological openness and competition between different solutions, with the knowledge that infrastructure has such a strong effect on determining the outcome?
- **Coordination across Member States versus room for experimentation at Member State level.** Many solutions will be more efficient when implemented across borders, requiring provision systems (combination of physical infrastructure, regulatory frameworks and markets) that work across borders. However, other aspects of these provision systems may best be addressed at national or even regional/lower lever, where specific solutions can be found that match the specific circumstances on the ground.
- **Coordination of the different (sectoral) strategies.** For instance, hydrogen versus direct electrification of different end-uses each have very different infrastructural implications. These strategies are in part determined at EU level, and implemented through climate and energy directives and regulations, but national implementation of directives may vary significantly across the EU. Coordination is necessary particularly where countries share transboundary provision systems.
- **Public acceptance of infrastructure projects.** Given the already long time-leads for infrastructure projects, public acceptance is crucial to avoid delays. Sharing in the benefits of infrastructure investment can be one remedy (see following point).
- **Sharing of risks and benefits from infrastructure** (and connected to this the question of public or private ownership). Infrastructure construction will often require at least some public support, and since infrastructure networks often create a natural monopoly, this raises the question how risks and benefits can be shared adequately – providing a sufficient incentive for private infrastructure investment, while avoiding situations where risks are borne by the public, and benefits accrue to private investors.

4.2.4 Focus of the infrastructure challenge in 4i-TRACTION

A climate-neutral EU is not possible without taking the infrastructure transition into account: Throughout the EU the energy system needs new electricity connections and pipelines, strengthening and upgrading of existing power grids, conversion of existing pipelines to hydrogen or synthetic fuels and roll-out of an infrastructure for CCUS. Furthermore, some of the existing infrastructure may become stranded assets in the future. Lastly, a large part of the current infrastructure may remain operational in the future.

4i-TRACTION will develop and assess policy options that contribute to this development of an EU infrastructure compatible with climate neutrality. Ensuring that the right infrastructure is in place at the right time requires effective policy instruments and governance. These need to take into account cost-effectiveness but also the interdependency with other developments, the uncertainties in future demand and supply of energy carriers and transport, and the long timeline of infrastructure development. They include energy market regulations that are adjusted and optimized for the future energy system, as well as regulations for the digitisation of the energy system and (smart) infrastructure. Without this, lack of infrastructure may prove a significant barrier to meeting the climate goals in the various sectors of the economy. In the opposite direction, the availability of suitable infrastructure can be one main factor which locations (inside or outside the EU) manage to attract major investments in low-carbon infrastructure.

4.3 The investment and finance challenge: mobilising financial resources for the transformation

The integration of climate issues into investment and finance has long focussed on the identification and increase of climate-friendly investments. The main policy instruments were labelling (green bonds, benchmarks, taxonomy, etc.) and disclosure frameworks for the financial sector (risk and alignment disclosures). However, this approach has not been sufficient to trigger transformative changes in the finance sector itself, nor has it had significant impacts in the real economy. There are two reasons for this, first, this approach confined itself to the niche of green finance, and second, it lacked focus on its actual impact on the structure of the real economy.

All of the identified hallmarks for transformative policies are relevant in order to ensure that the finance sector effectively acts as an enabler for transformative changes in the real economy.

4.3.1 Thinking back from the end and overcoming path dependencies

To achieve transformative outcomes, there is an urgent need to enlarge the view from the niche of green finance to overall finance and investment flows. This means continuing to cover purely green investment flows, but also finance to carbon-intensive companies that seek to invest in their transformation. This, however, is more difficult to identify and track, as there can be wide variety within the same sector, as companies vary deeply in how far they have accepted and embraced the transformation challenge. Financial actors have traditionally approached climate issues with a sectoral approach. But they need to build up a more granular perspective, that enables them to analyse transition, adaptation abilities and willingness for each company. Recently the idea of company-level transition plans has been gaining traction.[10] While the idea

[10] https://www.spglobal.com/platts/en/market-insights/latest-news/energy-transition/110321-cop26-uk-to-make-corporate-net-zero-planning-mandatory

still needs clarification, it could provide the missing information to financial institutions eager to finance companies that have a convincing strategy to align their business with a transformation pathway compatible with climate goals. Explaining what role innovation (technological and business model) and exnovation will play would need to be an integral part of these transition plans. In addition, such plans could also aim to situate the company's development in a transition pathway that is built on backward planning (think back from the end) and thus make the link with national and sectoral transition plans.

The often-cited case of divestment is not necessarily a good solution with regard to overcoming path dependencies. As the assets are sold, they disappear from a specific financial institution's balance sheet, but their activity in the real economy is not always negatively affected.

However, the simple existence of better data on company strategies is unlikely to be enough to overcome the path dependencies within financial institutions themselves. Finance is a highly regulated space where financial risk management is the key concern. Internal procedures, incentives and governance structures of financial institutions are strongly influenced by existing financial regulation and need to be reconsidered if these path dependencies are to be overcome.

4.3.2 Institutions and governance

In recent years, the interpretation of the existing mandates of financial regulators and supervisors in Europe has shifted in revolutionary ways regarding the integration of climate concerns into their operations. The European Central Bank's Governing Board decided in July 2021 that tackling climate change was indeed compatible with its current mandate and has set itself an ambitious roadmap and action plan.[11] The Commission, through its 2018 Action Plan on Financing Sustainable Growth and the 2021 Renewed Sustainable Finance Strategy has effectively extended the mandates of the European Supervisory Authorities' (EBA, ESMA and EIOPA) to work on climate-related issues and integrate them in their operations.

At the international level, the Network for Greening the Financial System, set up in 2017, has become the driving force on how to mainstream climate issues across central banks' and supervisors' operations, mobilising experimentations and sharing lessons.

Therefore, the role of 4i-TRACTION regarding finance and investment is rather to provide input on specific instruments with high transformative potential than to reflect on more general institutional mainstreaming needs.

4.3.3 Integration

As the financial sector is in large parts a reflection of the real economy, decarbonisation of the real economy must go hand in hand with corresponding changes in the financial sector.

[11] https://www.ecb.europa.eu/press/pr/date/2021/html/ecb.pr210708_1~f104919225.en.html

Regulatory approaches therefore need to be cross-checked to examine whether they help or hinder coordination, be it in terms of cross-sectoral analysis or in terms of internal integration of governance and processes. Taking climate-related disclosure of financial institutions as an example, descriptions of how financial institutions integrate climate-related analysis into their internal processes is more helpful than simply publishing carbon exposure data, which was initially the standard practice. While the latter can be a transparency exercise that only requires action from ESG/communication teams, the former potentially requires actual changes in decision making.

The trend towards increased sector integration in the real economy also presents a challenge for the mainstreaming of climate issues in the financial sector. With sector coupling, the traditional sector distinctions become blurred, and the transformation of one sector becomes dependent on the progress achieved in another. For instance, electrification of space heating, mobility and industrial application depends on the availability of sufficient electricity from renewable sources. Such interdependencies, however, are difficult to reflect in an approach that is based on a binary distinction between green or non-green sectors, or investments that are or are not Paris-aligned.

Another aspect that requires an integrative approach is the question of burden sharing between public and private finance actors, especially with regard to the sharing of risks (and opportunities) of the transition. The project will seek to integrate this question in its outputs.

4.3.4 Focus of the investment and finance challenge in 4i-TRACTION

Based on the explanations above, the investment and finance challenge in 4i-TRACTION will have the following focus:

- Adopt a more detailed and granular perspective, beyond sectoral approaches currently pursued in financial regulation, and analysis of the implications of such a granular perspective.
- Identify specific instruments with high transformative potential for mainstreaming climate issues in the financial sector.
- Propose how the financial sector can contribute to the exnovation/phase-out of incumbent fossil technologies, and how exnovation and the stranding of assets may affect the financial sector.
- Analyse to what extent financial regulators and supervisors in Europe have already incorporated climate issues under their existing mandates, and where mandates would need to be revised/extended.

- Develop options to improve the internal procedures, incentives and governance structures of financial institutions for integrating climate issues into their operations, how these are shaped by financial sector regulation, and how they may perpetuate existing path dependencies.

4.4 The integration challenge: integrating technologies and policies for the transformation

In the 4i-TRACTION project, 'integration' is understood both as *sector integration* – the linking of different sectors through technological solutions – and as *climate policy integration* – the systematic integration of climate policy objectives across different sectors.

Integration in both senses is crucial for the EU's climate neutrality transition but poses important challenges. An earlier study on EU climate and energy policy concluded that "even in the best cases, CPI [climate policy integration] is insufficient" from the perspective of the EU's previous long-term goal of reducing greenhouse gas emissions by 80 to 95 per cent by 2050 (Dupont 2015, 152). This implies that a lot more needs to happen for climate policy integration to reach the breadth and depth required for the EU's 2050 climate neutrality transition. For sector integration, then, the linking of technological developments in different sectors creates a range of technological, governance, regulatory and market challenges. For example, in the energy sector, different ways of producing energy must be linked with different sources of energy demand. Increased electrification means that different electricity-uses must be coordinated.

4.4.1 'Integration' as sector coupling

A key example of sector integration is energy system integration, also known as sector coupling. This, according to the Commission's definition, means "the coordinated planning and operation of the energy system 'as a whole', across multiple energy carriers, infrastructures and consumption sectors" (European Commission 2020). Energy system integration hence means the linking of energy consuming sectors – such as buildings, industry and transport – with the power producing sector and also linking different energy sources. This will require significant changes to the energy system in the EU (Olczak and Piebalgs 2018).

The EU Strategy for Energy System Integration highlights the importance of the energy-efficiency-first principle and identifies the need to build a more circular energy system (European Commission 2020). It emphasizes the importance of the *electrification of energy demand* and stresses that renewable energy must play a major role in responding to the increased demand. The 4i-TRACTION project will look, for example, at how different countries are tackling sector integration as a vehicle of change, starting from progress achieved in connecting electricity generation with storage, but also considering the effects of increased electrification in end uses such as mobility, space heating or industrial processes.

Sector integration involves several governance and policy issues. In the literature, four key requirements have been identified for energy system integration in the EU, namely: infrastructure planning especially with respect to electricity and gas infrastructure; reviewing system operation and market rules; development of coherent regulation; as well as research, development, demonstration and deployment (Olczak & Piebalgs, 2018). The EU Strategy for Energy System Integration, in turn, identifies the need for policies to promote a level-playing field across all energy carriers (European Commission 2020). The strategies also emphasize improved consumer information as well as the role of digitalization and innovation.

Sector integration will also require collaboration between the public and private sectors, and between different levels of government, from the EU to the national and local levels. Energy system integration will follow different pathways in different Member States, depending on their respective starting points and policy choices. National Energy and Climate Plans under the Governance Regulation can provide one governance tool to link the EU and national levels. In the context of energy system integration, increased reliance on electricity may lead to competition between different users, thereby surfacing the question of how different electricity uses can be coordinated.

4.4.2 'Integration' as climate policy mainstreaming

'Integration' in the sense of **mainstreaming climate policy objectives** relates to the need to systematically integrate climate considerations into different policies across various sectors at multiple levels of governance. Integration of different policies towards a holistic vision is one of the rationales of the European Green Deal (van Nuffel et al. 2018).

Examples of non-climate policy sectors that are key to transformative change include trade and industry, finance and investment, land and agriculture, as well as buildings, energy and transport. To achieve climate neutrality and subsequently net negative GHG emissions, all EU policy sectors will need to play a part in reducing greenhouse gas emissions and sectoral policies must be on the same track towards climate neutrality. The aim of integration is therefore to change the dominant paradigm at multiple levels of governance (Wamsler and Pauleit 2016).

Climate policy integration can be advanced through different means. At the procedural level, it is important that climate policy considerations be taken up during the policymaking process (van Asselt, Rayner, and Persson 2015), for example through climate impact assessments. Climate policy integration may also require that substantive balance be struck between climate and other sectoral policy objectives (van Asselt, Rayner, and Persson 2015). In its most advanced form, climate policy integration means that climate policy is given principled priority over other sectoral goals in all stages of the policy process (Dupont 2016). Challenges to climate policy mainstreaming include the lack of sustained political commitment to such mainstreaming in non-climate policy sectors, the lack of expertise and lack of resources (Runhaar et al. 2018).

While there has been progress, climate policy integration in EU energy policy has been found to be insufficient (Dupont 2015). Much deeper integration will therefore be needed to bridge the existing gap and ensure the transformational change required for the EU to implement the European Green Deal and achieve climate neutrality. Climate policy must penetrate deep into policies related to finance and investment, budget, trade and economic policy, industrial and competition policy, energy policy and so on – deep transformation will not be possible if core objectives of these policy fields remain at odds with the climate neutrality transition.

4.4.3 Focus of the integration challenge in 4i-TRACTION

As explained above, the integration challenge in 4i-TRACTION will have the following focus:

- Integration across traditional policy areas, integrating climate policy into other policy fields: exploring what an "all-of-government" approach to transformative climate policy would entail, how it can ensure the coordination of parallel, interdependent processes in different policy areas, and how it can build on the established understanding of climate policy integration.

- Integration across economic sectors/different technological trajectories: providing tools to respond to the governance challenges arising from the erosion of classical sector distinctions/sector coupling, and ensuring coordination across parallel, interdependent processes of technological change.

4.5 Overlap and interrelations between the 4i's: the role of technological specificity and openness

The 4i's are distinct challenges that the EU faces in the transformation to climate neutrality, which all require a distinct policy response. At the same time, they are interrelated in many ways, for instance:

- Innovations will only scale up from the laboratory scale to widespread commercialisation if there is sufficient private and public financing available, and if the infrastructure is in place to make the new technologies practically feasible and commercially viable.

- Infrastructure is not technology-neutral: The decision on which infrastructure is built will (partly) determine which new technologies will be able to develop to commercial scale. Likewise, the availability of seed funding and risk capital influences which new technologies and business models will emerge and grow. As a result, technological and business model innovation need to co-evolve with infrastructure and financing.

- Policy innovation is closely linked to the integration of sectoral policies – the erosion of typical sector delineations, but also the parallel nature of the transformation in different sectors, requires new types of coordination mechanisms across traditional sectoral policies.

- Integration across sectors in the form of sector coupling is, among other things, also an infrastructure issue: Electrification of transport and heating requires an electricity grid that is capable of handling the additional load down to the household level and charging points or other infrastructure to get electricity to the vehicles.

A common theme that is relevant for all four challenges, and their interactions, relates to the relationship between market and state in shaping and directing the transformation process. This concerns the questions of which technological choices are taken centrally based on political deliberation, and which are taken in a decentralised way through the market; it concerns the blend between public and private funding for technology development and infrastructure investments; and the sharing of risks and benefits of transformative investments between public and private actors. In this process, to some degree, regulations need to make explicit choices between technologies.

To deliver a cost-effective outcome, a transformation process should be technologically open, i.e., based on undistorted competition between different emission reduction technologies on the basis of their merits and costs. If this is true, then efficient regulation ought to be technologically neutral, and leave the selection of technologies to the market. Yet this is an abstraction that is rarely observed in reality (Agora Verkehrswende 2020). In practice, multiple distortions exist, including transaction costs, non-market barriers, policy failures, and technological and institutional path dependencies. These distortions mean that such openness is rarely ever a given. In the absence of openness, technology-specific interventions are warranted and can be efficient.

For the transformation to climate neutrality, technology-neutral regulation will not be a feasible strategy in most instances – neither in light of the technological and socio-economic path dependencies involved, nor given the short timeframe for the transformation and the long lead times for changes in technological regimes. Since some degree of technological specificity cannot be avoided, there is an even greater need for both sectoral and integrated, cross-sectoral roadmaps and scenarios that map possible technological pathways, highlight choices to be taken, and present interdependencies across sectors. This also supports a combined approach where the broad lines of techno-economic development are determined in a deliberative political process – but delivery and implementation are organised as a parallel market-based process, allowing for competition and cost minimisation.

A separate, related question is to what extent technology-specific regulation needs to be harmonised across Europe. On the one hand, there are powerful reasons and drivers for a harmonised approach: these include the common market, common EU policy framework for climate and energy policy, and the scale and efficiency advantages of implementing transformative projects in transboundary cooperation. On the other hand, Member States have historically made very different choices regarding their energy supply, resulting in different path dependencies, acceptance of different energy technologies, endowment of resources, technologies, and knowledge. In acknowledgement of these differences, the right of Member States to choose their energy sources is enshrined in the European Treaties. Thus, an approach aimed at partial harmonisation is needed – where Member States are free to pursue different pathways toward the same goal. This raises the challenge of ensuring coherence and consistency where it is needed, but also promises the benefit of allowing for experimentation and mutual learning.

5. Conclusions

With the transformation to climate neutrality, the EU has set itself a substantial governance challenge in terms of the breadth, depth and speed of the process. Crucially, the necessary transformation goes far beyond "policy as usual" and requires a fundamental overhaul of European climate governance. Moreover, transformation involves parallel change processes in different sectors that are interdependent and interwoven and will become more so over time. The timing of these processes is critical – change needs to happen more quickly than before. Yet at the same time, rolling out the necessary infrastructure and scaling up innovation takes time, as well as sufficient public support. To add to this, steps taken in different areas are interdependent – delays in one field will inhibit progress in other areas.

The EU has several climate policy instruments and other governance mechanisms in place – which, however, are predominantly geared at incremental improvements rather than transformative change. With the European Green Deal and the Fit for 55 Packages, the EU has outlined its ambition and taken first steps towards crafting a new climate policy with much greater transformative ambition.

Central to its success will be addressing four key challenges. Irrespective of the specific approach chosen, an approach to European climate governance that is fit for net zero will need to (1) stimulate low-carbon innovations that can be scaled up quickly enough; (2) roll out the infrastructure to support the scaling up of low-carbon solutions; (3) mobilise the necessary financial resources to fund low-carbon investments, and (4) ensure that the change processes in different sectors and at different levels of governance are integrated with each other, and aligned with the goal of climate neutrality.

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About the project

4i-TRACTION – innovation, investment, infrastructure and sector integration:
TRAnsformative policies for a ClimaTe-neutral European UnION

To achieve climate neutrality by 2050, EU policy will have to be reoriented – from incremental towards structural change. As expressed in the European Green Deal, the challenge is to initiate the necessary transformation to climate neutrality in the coming years, while enhancing competitiveness, productivity, employment.

To mobilise the creative, financial and political resources, the EU also needs a governance framework that facilitates cross-sectoral policy integration and that allows citizens, public and private stakeholders to participate in the process and to own the results. The 4i-TRACTION project analyses how this can be done.

Project partners

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