Integrated assessment of the policy avenues for transformative climate policies

Deliverable 4.3

Benjamin Görlach, Leon Martini, Flora Dicke (Ecologic Institute)

Maarten de Vries, Bettina Kampman, Nina Voulis, Marieke Nauta, Joeri Vendrik (CE Delft)

Pol Fontanet Perez (U Vigo)

Kati Kulovesi, Sara Lehtilä, Niklas Löther, Tatu Hocksell (UEF)

Clara Calipel, Anuschka Hilke (I4CE)

Brendan Moore (VUB)

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Responsible author(s):	Benjamin Görlach, Leon Martini, Flora Dicke (all Ecologic Institute) Maarten de Vries, Bettina Kampman, Nina Voulis, Marieke Nauta, Joeri Vendrik (all CE Delft) Pol Fontanet Perez (U Vigo) Kati Kulovesi, Sara Lehtilä, Niklas Löther, Tatu Hocksell (UEF) Clara Calipel, Anuschka Hilke (all I4CE) Brendan Moore (VUB)
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Abbreviations

AFIR	Alternative Fuels Infrastructure Regulation
CAP	Common Agricultural Policy
CBAM	Carbon Border Adjustment Mechanism
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilization
CCUS	Carbon Capture, Utilization, and Storage
CO2	Carbon Dioxide
COP28	28th Conference of the Parties
CPI	Climate Policy Integration
DG	Directorate-General
DSOs	Distribution System Operator
DT	Directed Transition
EGD	European Green Deal
EIB	European Investment Bank
EIT	European Institute of Innovation and Technology
EMD	Electricity Market Design
ENTSO-e	European Network of Transmission System Operators for Electricity
ENTSO-g	European Network of Transmission System Operators for Gas
ENTSOs	European Network of Transmission System Operators
EPBD	Energy Performance of Buildings Directive
ESABCC	European Scientific Advisory Board on Climate Change
ETS	Emissions Trading System
EU	European Union
EV	Electric Vehicle
GDIP	Green Deal Industrial Plan
GDP	Gross Domestic Product
GEL	Green Economic Liberalism
GHG	Greenhouse Gas
GIP	General Industrial Policy
GW	Gigawatt
HSR	High-Speed Rail
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change

MCB	Mission Coordination Board
MS	Member State
Mt	Megaton
NECPs	National Energy and Climate Plans
OECD	Organisation for Economic Co-operation and Development
PA	Policy Avenue
PCI	Project of Common Interest
PV	Photovoltaic
RD&D	Research and Development and Deployment
RED	Renewable Energy Directive
RRF	Recovery and Resilience Facility
SET	Strategic Energy Technology Plan
SWOT	Strengths, Weaknesses, Opportunities, Threats
TEN-E	Trans-European Networks for Energy
TEN-T	Trans-European Transport Network
TRL	Technology Readiness Level
TSO	Transmission System Operator
TYNDP	Ten-Year Network Development Plan
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America

Executive summary

There are diverse approaches to climate policy that are based on different perceptions of the nature of the problem that needs to be solved and that rely on different policy instruments and governance frameworks to do so. This report presents an integrated assessment of four "policy avenues" (PA) – different combinations of policy instruments that reflect such distinct approaches to the design of climate policy. They are all geared at achieving climate neutrality in the EU, but differ in the choice of instruments, but also in the underlying regulatory philosophy. The aim of the report is to understand the respective PA's ability to address the transformation challenges of innovation, investment, infrastructure, and integration – the 4 i's (Görlach, Hilke, et al., 2022) – and derive insights for the EU's climate policy mix going forward.

Gaps still exist in the EU's climate policy for addressing the transformation challenges of innovation, investment, infrastructure, and integration on the way to climate neutrality. Summarised in the table below, Chapter 2 describes the gaps that still exist in policy and action across the 4i challenges.

Table ES 1. Transformation gaps towards climate-neutrality

Challenge	Transformation Gap
Innovation	▪ The EU faces primarily a deployment gap for mature and key energy technologies. ▪ Gaps exist across the full innovation chain for power storage, alternative fuels and feedstocks, Carbon Capture and Storage (CCS), and renewable process heat. ▪ Policy gaps exist in EU innovation funding and financing mechanisms; policy certainty and directionality; as well as dedicated exnovation policies.
Investment	▪ The climate investment gap is in the order of €406 billion a year until 2030. ▪ Gaps exist in the coherence of EU funding instruments and the alignment of fiscal policy with the climate neutrality goal. ▪ The overall funding volume for climate investments is insufficient and must increase at EU and Member-State (MS) level, also to crowd-in more private investments.
Infrastructure	▪ There are substantial transformation gaps in energy and transport infrastructure, inter alia in transmission grids, hydrogen pipelines, district heating, and the transformation of existing pipelines. ▪ There is no comprehensive EU-wide approach to transnational energy or transport infrastructure in the EU. ▪ Other gaps relate to funding, lead times, and lack of transnational planning.

Integration	▪ Progress with Climate Policy Integration in the EU is uneven across sectors – most advanced for energy, with room for improvement for transport and buildings, and most deficient in land use and agriculture. ▪ Climate Policy Integration must be equipped to address challenges of sector coupling, e.g. through the electrification of end uses. ▪ Policies and frameworks are needed that support the integration of innovation, investment, and infrastructure based on a long-term view of the transformation. ▪ Climate objectives need to be continuously balanced with and re-calibrated against other political priorities, in particular geopolitical objectives, social objectives, competitiveness, as well as the need to protect biodiversity and adapt to the unfolding climate change.

EU climate policy has been influenced by different paradigms of policymaking. The influence of ideas on the evolution of EU climate policy is detailed in Chapter 3. Developing out of a command-and-control EU environmental policy, EU policy has been prominently influenced by economic liberalism resulting in the dominance of market-based policy instruments. However, the EU's climate policy mix continues to also rely on planning and direct regulatory instruments. Increasingly, the EU employs elements of industrial policy to transform its economy, such as technology support tools and incentives for investment. Largely absent from the EU's policy are instruments that explicitly address sufficiency and lifestyle changes, instruments most associated with the policy paradigm of sufficiency and degrowth.

Chapter 4 presents an integrated assessment of the four policy avenues that were developed in Görlach, Martini, et al. (2022). An overview of the results is presented in Table ES 2 below. While the results are mixed and should be interpreted with caution, some general patters become evident:

- The assessment of the different PA's and their suitability for transformative climate policy finds that neither of the four avenues would offer a superior approach to address the combined transformation challenges of innovation, investment, infrastructure, and integration. The assessment reveals strengths and weaknesses of the different policy avenues and suggests aspects where some avenues are better suited than others.

- Overall, Green Industrial Policy shows comparative strengths, especially due to its relatively strong performance on tackling innovation, investment, and infrastructure. This is primarily because of the policy avenue's explicit focus on directing and supporting technological change through different mechanisms (economic incentives, planning, and regulation). However, the approach is assessed as weak on political attainability, given its reliance on public investments and high demands for state capacity.

- The PA of Green Economic Liberalism is strong in the deployment of market-ready innovations and disincentivising fossil-based technologies. While it is less strong on tackling the infrastructure challenge, its relatively low demands for state capacity and planning may be a comparative strength. The Directed Transition policy avenue is strong in providing directionality and planning, but weak when it comes to mobilising investments and dynamic incentives.

Table ES 2. Overview of results of integrated assessment of policy avenues

	Green Economic Liberalism	Green Industrial Policy	Directed Transition	Sufficiency & Degrowth
Innovation	Strong on deployment of mature technologies and disincentivising fossil technologies	Strong across full innovation chain with focus on investment in RD&D, deployment, and providing directionality	Strong across full innovation chain with focus on standards, RD&D funding, and exnovation.	Strong in providing directionality and exnovation of fossil technologies
	Weak on providing certainty and directionality as well as sufficient R&D funding.			Weak on demonstration and deployment of innovations.
Investment	Strong in preventing investments in climate-forcing assets and correcting information-related market failures.	Very strong in mobilising public and private climate investments to close investment gap. Strong in preventing investments in climate-forcing assets.	Very strong in preventing investments in climate-forcing assets.	Strong in preventing investments in climate-forcing assets.
	Weak in committing public climate investments.		Weak in mobilising public and private climate investments	Weak in mobilising public and private climate investments
Infra-structure	Blindspot in approach. Weak on planning and making explicit infrastructure / technology choices.	Very strong due to integrated planning of infrastructure along industrial policy priorities.	Very strong due to integrated planning of infrastructure and clear directionality.	Weak due to adversity towards new energy infrastructure demands
Integration	Strong in mainstreaming climate through ETS.	Strong in coordination of industrial policy priorities.	Strong on mainstreaming climate and coordinating sectors through planning.	Strong on mainstreaming climate and enviro. through new policy priorities.
	Weak in coordinating sectors and decision-making (infrastructure and investment).	Weak in mainstreaming climate in all areas (such as agriculture). High admin demands.	Weak on providing adequate administrative capacity.	Weak on administrative capacity; coupling of sectors; and integrating investment with innov. & infra.
Politics	Mixed: Continuation of dominant approach but difficulty of high carbon prices.	Difficult: high demands for state capacity and public investments	Difficult: high demands for state capacity; strong break w/ status quo	Very difficult: Fundamental departure from existing approach

Key conclusions and recommendations for EU climate policy:

- **Evolution instead of revolution:** A "pure" policy mix that is exclusively organised around a single policy paradigm would require a fundamental overhaul of EU climate policy. This seems politically unrealistic, risky, and would take several years to agree and implement. Moreover, while following a single policy paradigm may be more consistent, it is unclear if it will be more effective and efficient. Therefore, the more promising route is evolving the current mix by incorporating elements of the different PA's.

- Green industrial policy will be necessary to drive the development of new technological solutions and lead them to market maturity, to close the investment gap, to facilitate the emergence of business models, and to coordinate the joint deployment of the infrastructure that is needed to support the emerging innovations.

- Elements of economic liberalism, such as the ETS and other market-based instruments, are essential for the efficient deployment of climate-neutral alternatives when technologies have become market-ready and when other non-price barriers have been addressed. The EU must stay course in their emissions trading policy.

- Elements of direct regulation are important for providing directionality throughout the process and clarity where possible. Such policies serve to provide strategic planning and overarching coordination. This also relates to determining which types of infrastructure will become available where, and thereby enables or precludes certain mitigation options.

- Sufficiency and lifestyle changes will be needed to address those decarbonisation challenges where no suitable (technological) alternatives can be foreseen, or where rebound effects threaten to erode technological gains. For some emission sources, for which technological solutions are unlikely to materialise (such as meat consumption or long-distance travel), it seems inevitable that a part of the solution would involve changing lifestyles and consumption behaviour.

- **The mix of these approaches will evolve over time, emphasising different elements in different stages.** A sequence of the policy avenues could look like this: In the near term, given the time lags involved in developing technological alternatives, leading them to market maturity, and allowing new markets and business models to emerge, greater efforts are needed for innovation support and removal of barriers. Likewise, regulation can provide guidance and certainty, in particular to coordinate the deployment of infrastructure that is necessary for a climate-neutral economy. Given the considerable lead times involved in planning, permitting, and building infrastructure, the integrated planning and deployment of infrastructure must be ramped up. Economic instruments, already firmly established in the EU's toolbox, will continue to play a role. Yet this role will change over time, from optimising existing systems towards driving the phase-out of fossil-based technologies and value chains in the 2030s and 2040s. Sufficiency and lifestyle changes are currently still underdeveloped as a policy tool, due to their controversial nature, and lacking a footing in the existing EU climate policy architecture. But when the shift away from fossil fuels and towards renewable-based solutions is (nearly) concluded in energy or road transport, political attention will need to also take those reduction potentials where technological alternatives are not available, and may not be forthcoming at the needed pace, scale, cost, and convenience.

Reading guide

- **Chapter 2** describes the transformation gaps between current EU climate policy and what would be required to address the respective transformation challenge of innovation, investment, infrastructure, and integration.

- **Chapter 3** analyses the EU climate policy acquis and describe its evolution over time from the lens of four different paradigms of climate policymaking.

- **Chapter 4** assesses the four policy avenues in an integrated way, focusing on their theoretical ability to address the four transformation gaps.

- **Chapter 5** draws some overarching conclusions from the integrated assessment and discusses what they mean for EU climate policy, including whether a "purer" policy mix is desirable.

1. Introduction

Nearing the middle of the 2020s – often described as the "decisive decade" to avert the most severe consequences from climate change – the EU is not on track to contribute its fair share to the 1,5°C set through the Paris Agreement (Climate Action Tracker, 2024). Although the EU has ramped up its ambition with the European Green Deal and the European Climate Law, and upgraded its climate policy instrumentation with the Fit for 55 package, the EU's policies and actions are rated to be insufficient (Climate Action Tracker, 2024). And while, on many accounts, the EU is moving in the right direction, the pace of the transition remains too slow (Velten et al., 2023).

The 4i-TRACTION project analyses how to reorient EU policy towards transformative change so that the EU achieves the climate targets it has committed itself to and reaches climate neutrality by 2050. To do so, in previous work we identified four policy avenues (PA's): different combinations of policy instruments, reflecting distinct approaches that guide the design and instrumentation of climate policy, geared at achieving climate neutrality in the EU (Görlach, Martini, et al., 2022). These include Green Economic Liberalism (GEL), Green Industrial Policy (GIP), Directed Transition (DT), and Sufficiency and Degrowth (S&D), each with its own set of policy instruments, governance frameworks, and challenges, reflecting varying degrees of market intervention and state control.

This report aims to conduct an integrated assessment of the four avenues to understand the impacts of the different possible pathways on challenges of innovation, investment, infrastructure and integration – the "4i challenges".

For this assessment, we first outline the gap for each of the 4i challenges between existing EU climate policy and what would be required to address the transformation challenge. These so-called "transformation gaps" will be addressed in Chapter 2. To establish the point of departure, we analyse the current EU policy mix, including imminent changes through revisions that are part of the Fit for 55 packages, and cluster the different elements that correspond to the different PAs and their underlying regulatory philosophy (Chapter 3). The transformation gap is the yardstick against which the four policy avenues are analysed and evaluated in Chapter 4. There, we assess all four policy avenues through a customised assessment framework, in order to determine to what extent they are fit to bridge the transformation gap identified in Chapter 2. Our assessment framework identified relevant aspects for the 4i challenges and assesses how each policy avenues addresses performs on these. It addresses various aspects, for example, whether the PAs can be expected to deliver the necessary innovative technologies, mobilise sufficient investment, or are likely to be politically attainable. Based on these elements we develop recommendations for the current EU policy-mix, discussing how the insights from the policy avenue analysis are relevant for upcoming EU climate policymaking (Chapter 5).

2. The transformation gap

The chapter aims to describe the transformation gap for each of the four challenges that define the project – innovation, investment, infrastructure, and integration. It does so by providing a detailed description of the gap between current EU climate policy and what would be required to address the respective transformation challenge.

2.1 Innovation

Reaching climate neutrality in the European Union (EU) and pursuing the goals of the Paris Agreement will require broad, rapid transformations in how society operates (European Commission, 2019b, p. 4; Intergovernmental Panel on Climate Change [IPCC, 2018]; Moore et al., 2021). Some of these transformations can be achieved with existing technologies and business models, such as existing solar and wind energy technologies. But given the urgent need to reduce emissions, new technologies will also be needed, and existing inventions will need to be demonstrated and then scaled up (Blanco et al., 2022). The International Energy Agency has estimated that "…almost half of the emissions savings needed in 2050 to reach net-zero emissions rely on technologies that are not yet commercially available" (International Energy Agency, 2021, p. 30; see also European Commission, 2021b, p. 20).

In the 4i-TRACTION project, three types of innovation have been identified (Görlach, Hilke, et al., 2022, p. 29)

- **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.

In this analysis, we focus on **technological innovation** and **policy instruments aimed at stimulating and enabling as well as scaling up innovations and leading them to market maturity.** The successful commercialisation and deployment partially include business model innovation. Policy and governance innovation is thus not directly part of the analysis. Below, we describe the innovation gap, briefly analyse existing policy, and then examine three areas where policy action is needed: policy certainty; technology R&D, demonstration, and deployment; and exnovation.

2.1.1 Assessing the innovation gap to 2030 for EU climate neutrality

In the following we will assess the technological innovation gap, focusing on the disparity between the current development stage of emerging low-carbon technologies and the level required for their widespread adoption in pursuit of climate neutrality. This technology gap can be estimated by identifying technologies that will likely play an important role in the transformation to climate neutrality and comparing their current development level with what is needed. To do so, we draw on the International Energy Agency (IEA) Energy Technology Perspectives – Clean Energy Technology Guide (IEA, 2022b), which classifies 551 technologies based on their importance to climate neutrality and their Technology Readiness Level (TRL) at a global level. The TRL "[provides] a snapshot in time of the level of maturity of a given technology within a defined scale" 67; see also: Mankins, 1995). This approach gives an estimate of the extent to which a technology is ready for commercialisation, diffusion, and deployment (see Table 1 for an overview of the IEA's TRL typology).

Table 1. Technology Readiness Levels

TRL	Description	Innovation Gap
1	**Initial idea:** Basic principles have been defined.	Research & Development Gap
2	**Application formulated:** Concept and application of solution have been formulated.	
3	**Concept needs validation:** Solution needs to be prototyped and applied.	
4	**Early prototype:** Prototype proven in test conditions.	
5	**Large prototype:** Components proven in conditions to be deployed.	
6	**Full prototype at scale:** Prototype proven at scale in conditions to be deployed.	
7	**Pre-commercial demonstration:** Prototype working in expected conditions.	Demonstration Gap
8	**First of a kind commercial:** Commercial demonstration, full-scale deployment in final conditions.	
9	**Commercial operation in relevant environment:** Solution is commercially available, needs evolutionary improvement to stay competitive.	Deployment Gap
10	**Integration needed at scale:** Solution is commercial and competitive but needs further integration efforts.	
11	**Proof of stability reached:** Predictable growth.	Mature Technology

Source: Based on IEA (2022b)

Technologies at TRLs 1-6 (from initial idea to full prototype) face a **research & development gap**, in that further research is needed to reach the stage where they can be fully demonstrated. Technologies at TRLs 7-8 face a **demonstration gap**: they must be demonstrated in real-world conditions (including first-of-a-kind commercial demonstration) to prove that investment in their deployment is warranted. Finally, technologies at TRLs 9-10 face a **deployment gap**: they are commercially operating but need further support for wider deployment in the market.

2.1.2 How big is the challenge? The innovation gap

From the IEA database, we identified 24 high-priority technology categories relevant to the EU that the IEA classified as either important or very important for reaching net-zero emissions. Each of these technologies was analysed according to the current innovation gaps it faced, its qualitative challenges, and the EU-level policy which is most relevant to its development (the full results can be found in Annex 1). Table 2 below gives an overview of the innovation gaps that each technology category currently faces.

Table 2. Technology gaps for key categories in energy, transport, buildings, and industry

Sector	Technology	TRL	Importance to net zero (IEA)	R&D	Demo	Deploy
Energy	Solar thermal	9-10	Moderate / High			
Energy	Solar Photovoltaic	10	Very High			
Energy	Onshore wind	9-10	Very High			
Energy	Offshore wind	8-9	Very High			
Energy	Green/blue hydrogen	7-9	Very High			
Energy	Advanced geothermal	6-8	Moderate			
Energy	Power storage: Heat	5-9	High			
Energy	Power storage: Battery	5-9	High / Very High			
Energy	Demand response techniques	5-10	High / Very High			
Energy	Advanced nuclear	3-8	Moderate / High			
Transport	Battery electric vehicles	8-10	Very High			
Transport	Electrification of road transport	8-9	Very High			
Transport	Aviation (alt. fuels/electric)	3-8	Very High			
Transport	Shipping (alt. fuels/electric)	4-8	Very High			
Buildings	Electrification: Heat pumps	9	Very High			
Buildings	Energy efficiency	10-11	Very High			
Industry	Low/med.-temp. elec. heating	9	High / Very High			
Industry	High-temp. elec. heating	3-7	High / Very High			
Industry	Industrial CCS	5-8	High			
Industry	Industrial Carbon Capture and Utilization (CCU)	2-8	High / Very High			
Industry	Bio-based feedstock	5-8	Moderate / High			

Industry	Hydrogen (green) feedstock	5-8	High			
Industry	Circular plastics	3-9	Very High			
Industry	Circular metals	9-10	Very High			

Source: Own illustration

The analysis illustrates that the technologies that are deemed most relevant for the transition towards climate neutrality, key energy technologies (such as solar photovoltaic (PV) and onshore wind) have high TRLs. However, a notable deployment gap still exists for these technologically mature innovations. Moreover, there is a critical need for enhanced R&D and demonstration activities in the fields of power storage and demand response techniques as well as in the transport sector. There, alternative fuels – especially for aviation and shipping – remain in the early stages of development and require substantial support in R&D and demonstration. Likewise, in the industry sector there is still a gap across all stages of the innovation chain, with more progress needed in the development of industrial CCS, alternative feedstocks, and renewable process heat technologies.

This indicates there are significant gaps across nearly the entire range of TRLs and across technologies, suggesting that policy support at both EU and national level will be important to support these technologies' further development.

2.1.3 Current EU policies are not enough to close the climate innovation gap

Currently, Horizon Europe, the follow-up programme to Horizon 2020, is the EU's key funding programme for research and innovation in the 2021 – 2027 financial cycle. With a budget of around €95 billion it aims to tackle climate change and pollution, issues of ageing and health, mobility, food, security, and energy through supporting research and innovation in these areas and aiming to ensure the EU's prosperity and growth in the future. Horizon Europe primarily supports early innovation stages (European Council, 2023).

At the demonstration and deployment stage, along with Horizon Europe especially the European Innovation Council, the EU's Innovation Fund ranks among the most substantial funding programmes to support innovative net-zero technologies with a volume of about €40 billion until 2030. Designed to facilitate the large-scale development and implementation of advanced technologies aimed at reducing greenhouse gas (GHG) emissions, the fund prioritises breakthrough innovations in several of the identified areas and technologies that are deemed to be key in the transformation to climate neutrality. These include energy-intensive industries, renewable energy, energy storage, and carbon capture, utilisation, and storage projects. By allocating revenues generated from the auctioning of emission allowances under the EU ETS, it provides financial backing to bridge the gap from pilot to scalable projects (European Commission, 2023n).

Additional to Horizon Europe and the Innovation Fund, the LIFE programme complements with funding that supports environmental and climate action projects across the EU. It aims to contribute to sustainable development and the achievement of the EU's environmental and climate objectives. The programme supports projects in areas such as nature and biodiversity, circular economy and quality of life, climate change mitigation and adaptation, and the clean energy transition. By offering financial support to projects that focus on innovation, among other areas, it serves as a relevant element of innovation policy.

However, the EU does not only support innovation through funding. Carbon pricing, regulation, and coordination also play a role. The EU ETS provides an economic incentive for companies to switch to clean production processes and energy carriers[1], although it is debated to what extent it has encouraged innovation (Lilliestam et al., 2021). Standards such as those of the Ecodesign Directive can drive technological change. Finally, different bodies and initiatives coordinate actors. For example, the European Institute of Innovation & Technology (EIT), a body of the EU contributing to the Horizon Europe objectives, aims to enhance the EU's capacity for innovation and technology deployment. The EIT aims to fosters collaboration between leading companies, research institutions, and higher education entities through its Knowledge and Innovation Communities. These communities aim to build a connection between research and market and through that, tackle societal challenges by driving research, innovation, and the commercialisation of new technologies in different areas such as climate change, digital transformation, and sustainable energy (EIT, 2024). In addition, there are several sector specific initiatives such as industry alliances initiated by the EU Commission, such as the European Batteries Alliance or the European Clean Hydrogen Alliance, that aim to coordinate public and private players.

Overall, the EU currently has a range of programmes to support climate-related innovation that cover the full innovation cycle (Humphreys, 2023b, p. 10). However, the analysis presented in Table 2 suggests that there are still large gaps for various technologies deemed (very) important to reach climate neutrality. The European Climate Neutrality Observatory (Humphreys, 2023a) suggests that while there is significant research and development in cleantech within the EU, the translation of this research into market-ready innovations is not proceeding at a pace sufficient to meet the 1.5°C target, especially due to financial constraints (see also Rienks & Moore, 2023, p. 35).

2.1.4 What is required to close the innovation gap

Supporting innovation throughout different TRLs

Cervantes et al. (2023) and Humphreys (2023a) emphasise that to accelerate progress, there is a need for increased investment in technological innovation, suggesting that current financing

[1] Although we should note that it is debated to what extent the ETS has encouraged innovation (see, for example, Lilliestam et al., 2021).

levels are inadequate for the scale of transformation required for the EU to achieve climate neutrality by 2050. This is especially relevant for the **R&D phase** of innovations. Here, public support to basic and applied research, in addition to fiscal incentives for R&D and direct support to firm R&D are important levers (Edler and Fagerberg, 2017). Additionally, pre-commercial procurement policies and innovation inducement prizes can support private research and development.

To support the **demonstration phase** of innovation, a multifaceted approach can bridge the gap between research and market entry in the EU. According to Humphreys (2023a), increasing the number of cleantech demonstration projects is pivotal for showcasing the viability of new technologies and facilitating their transition to market readiness. This can be done through a strengthened Innovation Fund. Edler and Fagerberg (2017) list further policies which can be especially supportive in the demonstration phase, namely technical services and advice and innovation network policies as well as pre-commercial procurement. Furthermore, (Rienks & Miłobędzka, unpublished) highlight the importance of leveraging local expertise and facilitating experimentation in the development of industry standards to facilitate demonstration.

For the **deployment phase**, a comprehensive policy mix is crucial for market diffusion and price competitiveness. The EU ETS provides an economic incentive to adopt low-emission options when they become available. Green lead markets can provide important demand signals when innovations become commercially available. For the adoption of novel production processes, instruments such as Carbon Contracts for Difference through the Innovation Fund can play a role to bridge the cost gap between conventional and low-emission processes. Moreover, public procurement policies are not used systematically across the EU yet but can provide a reliable market for new products (Mähönen et al., 2023). Additionally, establishing appropriate regulatory frameworks is essential for fostering an environment conducive to the adoption and widespread deployment of new technologies. Product standards through an enforced Ecodesign Directive as well as ambitious product labelling can support the deployment of innovative products. Humphreys (2023a) also underscores the significance of coordinating and targeting EU and Member State public funds to support the manufacturing and deployment of mature technologies, ensuring a smooth transition from innovation to market presence.

Overall, a more streamlined and unified innovation strategy is needed to expedite the market introduction of innovative technologies within the EU. A policy framework consisting of supply-side policies – sufficient funding especially for Research and Development and Deployment (RD&D) and deployment – and demand-side policies, including carbon pricing, green public procurement, and regulation, can enhance market uptake and scaling.

Exnovation and carbon lock-in

In addition to supporting innovation for low-carbon technologies, a growing literature has called for policy support for exnovation: "attempts to end fossil-based technological trajectories in a deliberate fashion" (David, 2017, p. 138; see also Görlach, Hilke, et al., 2022) and the related concept of deliberate decline, "the managed erosion of lock-ins that perpetuate the production and consumption of fossil fuels" (Rosenbloom & Rinscheid, 2020, p. 12; see also: Davidson, 2019). Three key policy levers for exnovation are carbon pricing, technology bans (Rosenbloom & Rinscheid, 2020, p. 6), and the phase out of high-carbon subsidies, especially fossil fuel subsidies (Skovgaard & van Asselt, 2018). The EU is involved in all these approaches, but many of the policy competences, and therefore much of the policy action, remain at the national level.

In the past decade, increasing attention has been paid to technology bans related to incandescent light bulbs, coal-fired power plants, and internal combustion engines (Blondeel et al., 2020; Howarth & Rosenow, 2014; Meckling & Nahm, 2019). At the EU level, the most prominent recent technology ban is the revision of the CO_2 Regulation for Cars and Vans, which bans the sale of new vehicles with internal combustion engines by 2035 (with an opt-out for carbon-neutral e-fuels). At the national level, coal phase-out dates have proliferated. All member states except Poland have announced a phase-out date, eight had stopped using coal by 2023, and a further ten set a phase-out date by 2030 (Beyond Fossil Fuels, 2023).

Regarding fossil fuel subsides, the EU set an objective to phase out these subsidies in its Eighth Environmental Action Programme in 2022 (Article 3). However, monitoring under the Governance Regulation shows that from 2015 to 2021 these fossil fuel subsidies stayed steady and then rose dramatically in 2022 in the wake of the full-scale Russian invasion of Ukraine (European Commission, 2023a, p. 6). Around half (52%) of these reported subsidies have planned end dates after 2030 or no planned end date (p. 15).

What both these examples highlight is that explicit technology bans or phase-outs of carbon-intensive subsidies exist at EU level but are relatively rare when compared to other policy approaches such as emission-oriented regulations and market-based instruments. The fact that EU coal phase-outs are set out at the national level – and that the EU has not made headway on reducing fossil fuel subsidies – illustrates the challenge that its multilevel governance structure and strong national competences related to energy pose to exnovation-oriented policy approaches. However, the case of the internal combustion engine ban (e-fuel opt-out notwithstanding) shows that EU-wide action is indeed possible in certain areas.

Prioritisation and policy certainty

Policy certainty and clear priorities are important for directing innovation and innovation funding in the most effective way. There is a tension between widely distributing funding to a broad range of low-carbon technologies (in partly to address the inherent uncertainty of technological change) or, as an alternate strategy, to focus on a smaller number of high-priority areas to concentrate funding and policy attention. This policy challenge is made more difficult by the complex nature of EU innovation policy, divided between 27 national funding systems and an EU-level landscape that includes a multitude of funding programmes and initiatives (Humphreys, 2023b; Skjærseth & Eikeland, 2023, p. 260). Geopolitical uncertainties and crises further add to these existing political as well as the inherent uncertainties of innovation. In light of this, policy is needed to provide direction to innovation.

There has been long-standing discussion at the EU-level about approaches to better focus climate-related innovation funding. In 2004, Energy Technology Platforms were created to coordinate specific technology areas, initially hydrogen/fuel cells and photovoltaics (Eikeland & Skjærseth, 2020, p. 21). In 2008, the European Commission put forward the EU Strategic Energy Technology Plan (SET Plan) to coordinate innovation funding related to energy-related technologies (Eikeland & Skjærseth, 2020, p. 34). One of the stated reasons for the SET Plan was to better focus support on a smaller number of technologies, and the plan put forward six priority technology areas: wind, solar, bioenergy, CCS, electricity grid, and nuclear fission. However, as Skjærseth and Eikeland note, this attempt to focus on a small number of technologies was largely unsuccessful. Between 2008 and 2014, the SET Plan's own priority areas grew from six to fourteen, in large part to acknowledge the de facto dispersed focus across a wider range of technologies found in EU funding programmes such as Horizon 2020/Horizon Europe and the Innovation Fund (Eikeland & Skjærseth, 2020, p. 34; Skjærseth & Eikeland, 2023, p. 263).

In recent years, there has also been a growth in sectoral strategies that include a strong innovation component. These strategies include the Hydrogen Strategy, the Renovation Wave Strategy, and the Offshore Wind Strategy. However, while they and the Energy Technology Platforms can address further focusing of funding within technology categories, they are not designed to do so when it comes to creating priorities between totally different technologies.

Overall, to bridge the innovation gap, a more coordinated, strategic, and sustained policy approach to fostering innovation at the EU level is essential. Such an approach should encompass support across all TRLs and provide more certainty for long-term planning to both the industrial and research sectors.

2.2 Investment

Redirecting financial flows towards clean technologies and services is essential to put the EU on track to achieve climate neutrality by 2050 (IPCC, 2022). With many past and current investments locking-in future GHG emissions, the transition to a climate-neutral economy will require both increasing climate-friendly investments and decreasing climate-hostile investments and spendings (Velten et al., 2023). Emission intensive capital stock must be replaced with climate-friendly capital stock. This will most likely require a net increase in investments and result in an overall rise in the investment-to-GDP (Gross Domestic Product) ratio, i.e., a shift from consumption to investment (European Commission, 2024c; IEA, 2021; Pisani-Ferry, 2021).[2] Given that most

[2] In its Net-Zero Economy Scenario, the IEA (2021) estimates that global climate neutrality by 2050 would imply increasing global investment in energy from 2.5% of world GDP in 2016–20 to 4.5% by 2030, after which it would gradually return to 2.5% by 2050. The investment needs in transport and housing are even larger. The European Commission (2023l) assumes a similar *increase* for the EU, with an increase in annual energy system

transformative investments are frontloaded, this shift is more pronounced in the coming decades, before it moderates again, in what can be referred to as an investment lump. The gross investments in the transition will likely be even larger, given that current climate-hostile investments must be reallocated to climate-friendly ends. The "investment gap" should therefore be considered in two complementary ways: additional investments needed for climate-friendly investments on the one hand and the decrease – and eventual end – of investments that perpetuate an economy based on fossil fuel use.

These investments involve both public and private investments and related financial flows. Regarding the public side, these can concern direct public investments, e.g., in infrastructure or financial flows from and to public authorities that can directly influence decision making for private investments. Fossil fuel subsidies or environmental taxation, for instance, have a potentially strong impact on private investment choices, e.g., regarding the type of vehicle purchased or the decision to invest or not in efficient heating devices or energy refurbishment works. On the private side, investment flows include, for example, bank loans, household purchases and business capital expenditure. These changes all depend on investments now and in the coming decades until we reach climate-neutrality.

2.2.1 What would transformative investments look like?

A transformative investment is an investment that helps the EU achieve its climate neutrality targets. More specifically, these are investments in assets that enable the EU to reduce its GHG emissions and include, for instance, investments in new renewable energy capacity, in electric vehicles or in buildings renovation.

To achieve its climate objectives, the European Union has implemented several legislative measures, in particular the directives and regulations resulting from the Fit for 55 legislative package and REPowerEU plan. For each sector, these different directives and regulations have set specific sub-targets that would require significant investments.

In the power sector, for example, the REPowerEU plan has set major targets for the deployment of renewable energy capacity, particularly in solar and wind power (European Commission, 2022d). About 306 Gigawatt (GW) of additional wind capacity and 394 GW of additional solar capacity need to be installed by 2030. Transformative investments are those that will make it possible to reach these capacity additions by 2030. Further investments will also be needed to modernise and expand electricity grids as new renewable energy generation capacities will be added.

In terms of energy renovation of buildings, the European Union plans to double the rate of renovation and foster deep renovation, as foreseen in its revision of the Energy Performance of Buildings Directive. Investing in deep renovations could represent a significant financial burden

investments in the order of 1.9% in GDP for 2021-2030 compared to 2011-2020. Including the transport sector, this would increase to 3.3% of GDP in additional investment.

for households. A survey carried out by Ipsos and Navigant for the European Commission estimated the cost of deep renovation at €219/m² for residential buildings, while the cost of energy renovations below energy efficiency thresholds, which are currently the norm, is about €56/m² (IPSOS et al., 2019).

Several transformative investments should also be made in other sectors, to enable for instance the shift of the fleet from internal combustion engines to electric vehicles, the modernisation of railways infrastructures or in industrial low-carbon installations.

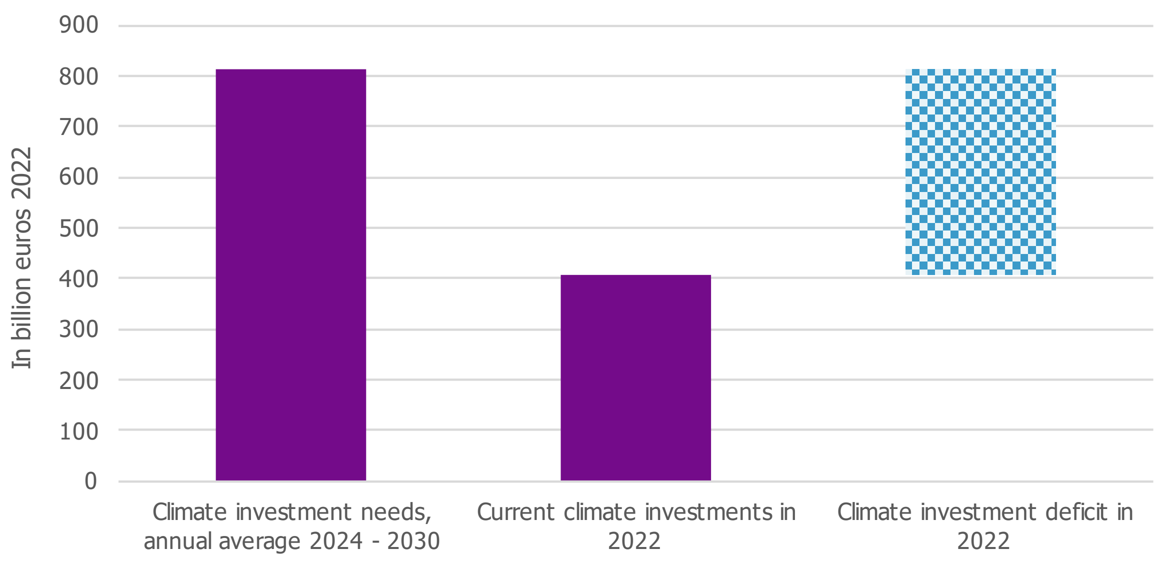
2.2.2 How big is the challenge? The climate investment gap

Initial estimates of the EU climate investment gap put it at €406 billion a year until 2030.

As mentioned above, the efforts required for the EU to achieve its climate objectives will require very large amounts of investments. Several assessments show that the climate investment gap – the difference between what is required from what is done today is significant.

The Institute for Climate Economics (I4CE) estimates that reaching EU 2030 targets requires at least 813 billion euros per year – or 5.1% of EU GDP (Eurostat, 2024a)– in the energy, transport and buildings sectors for both public and private investments. As climate investments reached 407 billion euros in 2022 for the same perimeter, this results in a climate investment gap of 406 billion euros. In other words, the EU needs to double its current levels of investments every year from now on if it wants to reach its 2030 climate goals (Calipel et al., 2024) (see Figure 1).

Figure 1. The 2022 climate investment gap in the energy, buildings, and transport sector



Source: Own illustration reproduced from Calipel et al., 2024. *Note: All figures are in billion euros 2022.*

Climate investments needs are significant in all sectors. The building sector accounts for the largest share of investment needs (41%), followed by transport (31%), and energy (28%).[3] The climate investment gap is approximately evenly distributed across all those three sectors. However, at a more granular level, the different sub-sectors studied can present varying proportions of investment gap. For example, wind power 2022 investments only represent 17% of total wind power investments needs. Conversely, investments in solar panels represent already 78% of their investment needs (Calipel et al., 2024).

Other estimates of climate investment needs have been made by EU institutions and international institutions. The European Investment Bank, based on European Commission calculations, estimates that €1.04 trillion would be needed, for all the sector of the EU economy, from now and every year, for the EU to achieve its goal of reducing net GHG emissions by 55% by 2030 . For the period from 2031-2040, the Commission estimates annual investments of €1.53 trillion to reach the 90% net emissions reduction target (European Commission, 2024d). A recent Staff Working Document from the European Commission (2023l) estimated the climate investment gap at around €477 billion per year between 2020 and 2030. The International Energy Agency estimates that $5 trillion would be needed annually by 2030 for the EU to reach climate neutrality by 2050. The International Renewable Energy Agency estimates this amount at $5.7 trillion (€5.1 trillion) and the Bloomberg New Energy Finance at $3.1 trillion (€2.8 trillion) (Lenaerts et al., 2022). These estimations vary on methodology and scope, explaining the main differences.

The public share of these investment needs will be significant in the next decade. According to recent research, the public share could cover an average of 54% of total climate investment needs between now and 2030, including 45% of investment needs in the buildings sector, and up to 95% in the rail and public transport infrastructures sector (Baccianti, 2022).

Closing the climate investment gap is not enough for the EU to reach its climate objectives. The EU must also stop climate-hostile investments. For now, there is no EU-wide aggregated data available on EU financial flows that contribute to significant GHG emissions. However, a number of indicators suggest that these investments are likely to be increasing (Velten et al., 2023)

In 2022, the IEA estimated that 118 billion dollars had been invested in fossil-fuels based power generation and in fossil fuel supply (mainly oil, gas and coal-fired power and oil, gas and coal supply) in the European continent (International Energy Agency, 2023).[4] This figure is 6% higher than in 2021. Over the last five years, these fossil-fuel investments flows have increased overall by 5.1% per year. To assess the EU's evolution of all climate-hostile investment flows, it would be necessary to complement these fossil-fuel investments with other investments into fossil-based

[3] The EU Commission (2023l) has similar estimates: the transport sector accounts for the largest share of the investment gap, representing 43% of the gap, followed by the building sector (32%). The power sector accounts for 19% of the gap, while industry only represents 5%.

[4] The data includes the EU, as well as the UK, Iceland, Switzerland, Norway, the Balkan countries, Ukraine, Belarus, Turkey, and Israel.

value chains, such as investments in technologies and infrastructure for combustion engines, or in sectors with high GHG emissions, such as aviation or coal-powered blast furnaces.

2.2.3 What is required to close the climate investment gap?

Closing the climate investment gap and phasing-out investments in fossil fuel value chains will require effective and efficient public intervention, and sector-specific policy action which is currently not sufficiently the case.

The EU's climate neutrality objective and the measures in its Fit for 55 and REPowerEU legislative packages imply significant investments needs. However, there is no mechanism in place to finance these needs in their entirety in a coordinated way that mobilises both public and private finance. The EU and its Member States are helping to finance the transition through various direct and indirect measures. Public institutions can invest through public spending, investment in public companies, but also through grants and subsidies. Public subsidies furthermore crowd-in private finance, by incentivising specific private sector spending choices. Fiscal policy and financial regulation can also play an indirect role in redirecting financial flows through taxation, carbon pricing or regulation. It is this different mix of policy instruments that can close the climate investment gap.

From the analysis above, it becomes clear that the EU must mobilise additional investments. A large part of this will need to be public investments, through both more and better coordinated EU-level funding as well as investments at MS level. But private investments play an equally large role. To mobilise these, carbon pricing and other fiscal policies must be aligned with climate neutrality to correct market prices and provide a stable investment framework. Likewise, financial regulation must be aligned with the climate-neutrality objective.

Better coordinated EU-level funding

The EU has a broad and complex architecture of supranational funds and financial instruments which are variously used to publicly fund climate action. Depending on the fund, these can either be channelled directly to projects or companies or disbursed via Member state or subnational institutions. Direct funds include those mentioned under innovation above, namely the EU Innovation Fund (for the financing of green technologies) and Horizon Europe (targeted at R&D, including climate-targeted projects), but also funds managed by the European Investment Bank such as InvestEU (Humphreys, 2023b). Beyond these, many EU public climate funds are disbursed through other institutions, be they national governments or regional administrations, which design implementation plans as to their use (with respect to common guidelines or minimum standards). This category includes the Recovery and Resilience Facility (RRF, the pandemic recovery fund, which mandates a 37% green spending minimum) the Connecting Europe Facility (for energy infrastructure) (International Energy Agency, 2022a) and the Just Transition Fund (to support citizens in the transition). Some few instruments, such as the Social Climate Fund, can be disbursed to both citizens, companies, and administrations (Kambli & Dufour, 2023). Finally, Member State revenues from the Emissions Trading System can play a significant role in closing the climate investment gap (Haase et al., 2022).

This range of funds means that the EU arsenal for closing the climate investment gap is a fractured and fragmented one, often with overlapping objectives and a lack of coordination between them. Furthermore, it is not a given that funds earmarked for climate action are truly deployed to that aim, and impact on the ground is often not incorporated into any assessment regime (Darvas et al., 2023). One clear example of this is in the RRF, in which funds which Member States reported as being used in green investments were later found to not have been used as such (Heilmann & Lehne, 2021).

More climate-friendly public investments on EU and at MS level

While the coherence and coordination of EU funds is one matter, the overall funding volume is another. Because public investment needs remain large, it will be important that EU level climate investments increase or at least remain stable. However, there is a risk that EU level climate funding will even decrease after 2026, which is when the RRF will run out (Pisani-Ferry et al., 2023). So far, there is no alternative funding source to the RRF in sight. Likewise, the funding volumes for other EU level funds that are part of the Multiannual Financial Framework remain uncertain after 2027.

In addition, the reform of the Stability and Growth Pact did not reduce the risks that strict debt reduction obligations will result in decreasing climate investments. Experience has shown that budget consolidations tend to disproportionately come at the cost of public investments, rather than other spending choices (Blesse et al., 2023; Mühlenweg & Gerling, 2023). In addition, there is no mechanism in place that aligns MS budgets with the EU's climate objectives. In sum, the insufficient and uncertain EU and MS public climate investments must be addressed to close the investment gap.

More direction and certainty for private investments

The challenge is to coordinate the investments in different sectors and activities. Transformative investments are not only viewed as riskier because they involve novel technologies – but also because they depend on other things being in place, such as the physical infrastructure and regulatory framework. This affects not only the technical feasibility of novel solutions, but also their economic viability – and with this the perceived risk and the capital costs of transformative investments. This dependence can also result in a first mover disadvantage, where it is more attractive to be the second (or third, ...) investor in a given field. To overcome this conundrum requires either very meticulous planning of the enabling conditions, and/or public guarantees in case the conditions are not in place. Public guarantees can increase the payoff for climate-neutral investments – or steps to reduce the attractiveness of conventional investments, including through subsidy reform and a strong carbon price signal.

Aligning subsidies, taxation, and fiscal policy: providing a clear price signal for private investments.

Government's fiscal policies are very relevant for closing the investment gap. Through subsidies and taxes, government can influence the relative prices of goods and services. Subsidies granted to renewable energies have increased overall by 3.0% per year since 2015, to reach a total amount of €87 billion granted in 2022 (European Commission et al., 2023) . However, so have also fossil-fuel subsidies. Fossil fuel subsidies remained relatively stable at about €56 billion, over the period 2015-2021, but have skyrocketed to €123 billion in 2022 (European Commission et al., 2023). This rise in fossil-fuel subsidies is a result of solutions implemented by member states to fight the rise in energy prices related to post-COVID recovery and Russia's invasion of Ukraine. If the EU committed itself to stop fossil-fuel subsidies by 2025 (European Parliament & European Council, n.d.), a resolution, reiterated by Members of the European Parliament at COP28 (European Parliament, 2023d), most EU Member States have no strategy for phasing out these subsidies (European Commission et al., 2023). Yet, subsidising fossil fuels discourages economic players from investing in low-carbon technologies.

In the EU, different forms of taxation and carbon pricing tools play a significant role in the policy mix, such as the EU Emissions Trading System or energy taxation. By choosing where and how those taxes are levied, European public authorities, including the EU, Member States, and local authorities, do affect the market price paid by businesses and households. This can be used to increase or decrease the purchase costs of products and services that have a negative impact on the climate (Velten et al., 2023). While carbon prices have risen in recent years, the share of environmental taxes in the total government revenues has declined since 2015(Eurostat, 2024b). Moreover, the EU has failed to revise the Energy Taxation Directive to align MS's energy taxation with the EU's climate targets.

The role of financial regulation

Finally, the EU can help redirect private financial flows towards a low-carbon economy through financial regulation. Financial regulation is key to bring up the necessary changes in the financial system. Private finance, primarily banks, has a great deal of influence on the strategic choices of the real economy through the companies it finances and which operate in the fields of energy, mobility or agri-food for example. Financial regulation has an even more important role to play here, since the limitations of voluntary commitments are becoming clear (Cardona, 2023).

Financial regulation instruments should support increasing green investments. But mostly, it should contribute to the phase-out of incumbent fossil technologies, while managing the effects that exnovation and the stranding of assets may have on the financial sector and the economy as a whole.

EU Regulators and supervisors mostly favoured a niche approach, by developing green finance tools. Secondly, they limited financial regulation policies to increasing transparency. To change this, climate finance policies must broaden their focus from the niche of green finance to overall finance and investment flows and be more stringent than disclosure policies.

2.3 Infrastructure

2.3.1 Definition and scope: Which types of infrastructure do we assess?

The 4i-TRACTION project focuses on energy and transport infrastructure. In this realm, we assess the infrastructure transformation gap. Within energy infrastructure, we can distinguish different types of infrastructure by what it can transport: electricity, heat, natural gas, oil, hydrogen and hydrogen-based products (such as methanol, ammonia, etc). Transport infrastructure can also be differentiated, into roads (for cars, trucks, bicycles, etc.), railways and waterways. Charging and fuelling infrastructure marks the intersection between energy and transport infrastructure.

The 4i-TRACTION project applies a narrow definition of infrastructure, understood as a grid connecting (usually many) locations, allowing something to be transported from A to B. Related assets such as associated installations such as power plants and electrolysers are not included in our definition. While being aware the digitalisation also plays a key role in to the optimal functioning of a future system, we focus on changes to the physical infrastructure of both the energy and the transport system and integration of the different energy carriers.

Thus, in this assessment we will limit ourselves to the narrow (grid-related) understanding of energy and transport infrastructure, distinguishing different sub-types (e.g. electricity, hydrogen, rail, road) where necessary and relevant.

2.3.2 What would a Transformative Infrastructure look like? A brief glimpse towards 2050

In both the transport and energy sector, the infrastructure in a climate-neutral future looks significantly different from the current situation. Some of the changes that are needed are drastic – ranging from local power grid reinforcements, district heating networks and bicycle lanes to an expansion of the EU-wide interconnection of the power grid and the creation of a hydrogen grid that extends to different regions and end users.

Energy system

To achieve climate neutrality, the energy system needs to transform significantly, from a system largely based on fossil fuels (coal, oil, gas) to one based on renewable energy sources such as wind, solar, hydropower, geothermal and biomass. This requires significant changes in energy generation, but also in end use. Many energy users that now use oil, fuels derived from oil (petrol, diesel), natural gas (in industry and buildings) or coal (in certain industries) will switch to electricity directly or indirectly in the form of (green) hydrogen and hydrogen derivatives. The future energy infrastructure for a resilient and cost-effective energy system will look very different from the current grids: electricity infrastructure will need to accommodate more electricity generated more flexibly in many decentralised locations; new infrastructure will be needed for hydrogen and its derivatives, and at the same time parts of the existing fossil infrastructure will become obsolete. As was concluded in the infrastructure case study of WP4.2 (Vendrik et al., 2023) considerable investments in energy infrastructure are necessary to facilitate these changes and meet the EU's climate policy objectives.

Transport sector

In the transport sector, transformative changes are mainly needed on the fuel and energy side: electric vehicles require significant power grid expansion and reinforcement. Transport modes that are difficult to electrify – long-haul heavy-duty vehicles, maritime shipping, airplanes – are likely to switch to green hydrogen, synfuels derived from hydrogen, and biofuels. In some cases, the existing distribution and fuelling infrastructure may be re-used for these new energy carriers but in other cases, these energy carriers may require a totally different fuelling infrastructure.

In addition to the transformation of the distribution, fuelling and charging infrastructure, a climate neutral transport sector is also likely to need more infrastructure for walking and cycling as zero-carbon transport modes, and for public transport, which is energy efficient and either already largely electrified (rail) or electrified relatively easy (buses). Railways could play a stronger role as an alternative to air traffic and long-haul road transport, which are both more difficult to make climate neutral.

For all these different types of infrastructure, a key element of a transformative outcome is that the infrastructure needs to facilitate the drastic changes towards a climate neutral energy and transport system. If the right infrastructure is not in place at the right time and location, the future energy and transport systems may not become climate neutral in time, or only at much higher cost (Longoria et al., 2022).

How big is the challenge? Infrastructure in 2030 and beyond

The exact number of kilometres and location of power grid, hydrogen pipelines or rail infrastructure that needs to be built for the EU to become climate neutral cannot be established with certainty, as there are different pathways towards climate neutrality, which would make use of certain types of infrastructure to a different extent. For instance, some industrial processes could be decarbonised using green hydrogen or may be electrified instead. Road mobility could be electrified but also partially be replaced by other modes of transport such as rail, and these two solutions could materialise in different ratios. How the final path towards climate neutrality will look like depends on political choices that need to be made on a short term, to be able to actually achieve climate neutrality in time. Notwithstanding the above, some indications on infrastructural needs can be drawn from existing scenarios and modelling exercises. Below, we look in more detail into energy infrastructure and transport infrastructure, respectively, to establish what needs are already relatively certain and where more certainty needs to be provided through political and policy processes.

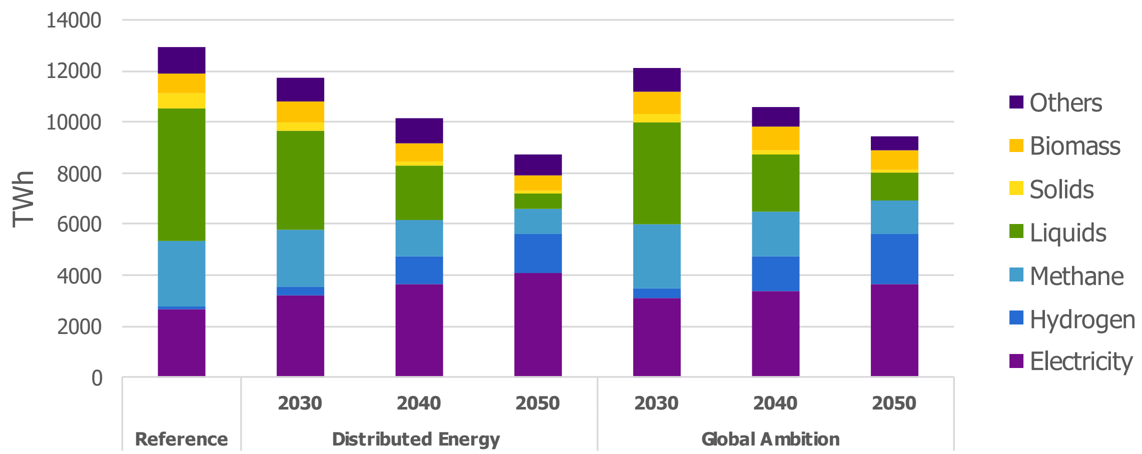
In any case, the necessary changes require action coordinated across different government levels and jurisdictions. All Member States of the EU grapple with a transformation of energy and transport infrastructure, but they differ not only in terms of which transformation strategy they pursue, but also in where they stand in the process of defining their strategies (see for example Amber Grid et al., 2022) his makes it harder to align the infrastructure planning, which, being interconnected, must eventually happen.

Energy infrastructure

The EU energy infrastructure needs to change quite drastically to transform the energy system from a largely fossil-based system to one powered by renewable energy only. This is demonstrated in the figure below, where the development of future EU energy demand is shown for two scenarios from the European Network of Transmission System Operators for Electricity (ENTSO-e) and European Network of Transmission System Operators for Gas (ENTSO-g) Ten Year Development Plan (ENTSO-e & ENTSO-g, 2022).

Main trends of this energy transition likely include a lower overall energy demand, through more energy efficient technologies and products, and behavioural changes. Moreover, a large share renewable energy production is expected and a changing roles of energy carriers, including a strongly increasing role of both electricity (from current 20% of total energy demand to 40-50% in 2050) and green hydrogen (from virtually zero to appr. 20% in 2050). Additionally, strong system integration and fewer energy imports from outside the EU are key trends (Vendrik et al., 2023).

Figure 2. Final energy demand per carrier for the EU 27, energy and non-energy use for feedstock, for two different scenarios (Distributed Energy and Global Ambition).



Source: Own illustration reproduced from ENTSO-e & ENTSO-g, 2022

From this, the following main impacts on the energy infrastructure can be derived:

- The **power grid** needs to be expanded and enforced significantly, due to the changing composition in electricity production and the growth of electricity demand because of electrification. These changes affect the grid on all levels, from the high voltage transmission grid to local distribution grids and connections to the end users, offshore and onshore.

- A **hydrogen grid** needs to be developed, since part of the (surplus) electricity from wind and solar power generation will be converted to green hydrogen. The extent and granularity of the hydrogen grid is still uncertain, as for some sectors it is not clear yet whether they will make use of green hydrogen or alternatives, such as electricity.

- **Heating grids** are common in some parts of Europe but need to be developed in many more districts and municipalities.

- Part of the **natural gas pipelines** may be used for biomethane or transformed to pipelines for green hydrogen. Part of the existing pipelines may not be of use anymore in the future energy system and need to be decommissioned. The same is true for oil pipelines.

In addition, a need may also develop for an infrastructure for synfuels such as ammonia or methanol (synfuels are produced from green hydrogen). However, whether or not this will be needed is still very uncertain.

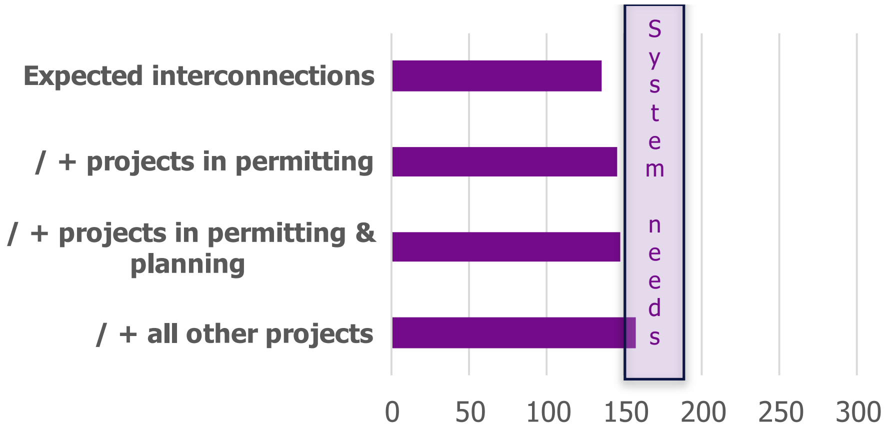
To give an indication of the infrastructure challenge, we provide some illustrative data and insights from a number of recent studies and publications in the following.

Electricity

The IEA recently concluded that globally, investment in electricity grids needs to nearly double until 2030 to correspond with the Net Zero Scenario (IEA, 2023). This amounts to an annual average of $600 billion of investments, about double of current infrastructure investment levels - which have been quite constant in recent years. This study covered grids on all levels, i.e. from local to transnational.

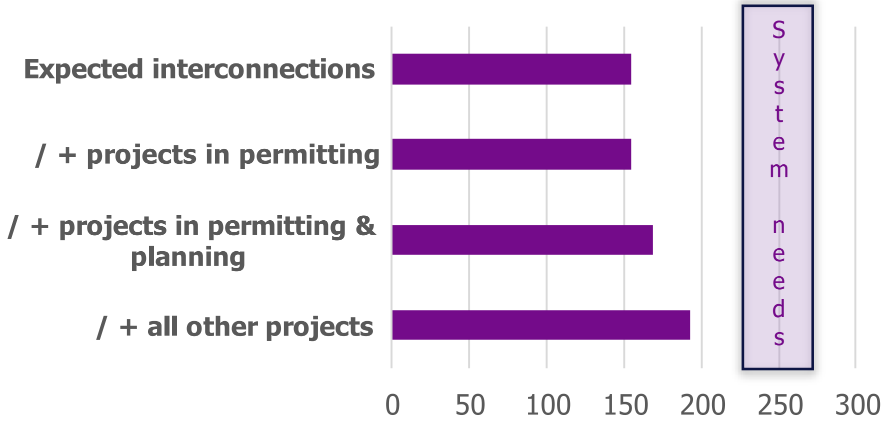
The latest EU-wide Ten-Year Network Development Plan (TYNDP) by the European transmission system operators identified the system needs for the future transmission power grid (in 2030 and 2040). This TYNDP 2022 finds that cross-border transmission capacity would need to increase by 64 GW by 2030 on over 50 borders, increasing to 88 GW over 64 borders by 2040 (compared to 2025; ENTSO-e, 2023). A recent paper by Ember (2023) concluded from these plans that Europe must double its current interconnection capacity over the next ten to fifteen years to meet its energy targets and the climate neutrality objective. Current plans do not yet achieve this, as illustrated in the figure below. As the graph shows, the gap between system needs and expected capacity widens further between 2030 and 2040. The paper also identifies specific priority regions and links that are identified as critical but are not yet on their way towards realisation.

Figure 3. Expected interconnection capacity in 2030 falls short of Europe's future power system needs.



Source: Own illustration reproduced from Ember, 2023

Figure 4. Expected interconnection capacity in 2040 falls short of Europe's future power system needs.



Source: Own illustration reproduced from Ember, 2023

Hydrogen

The role of green hydrogen[5] as an energy carrier and a feedstock for industry is expected to increase in the future, with hydrogen becoming a key energy carrier in many scenarios. The total amount of future green hydrogen production, its origin (domestic vs. imports), demand and infrastructure needs are still very uncertain, but network operators, governments and industry develop scenarios to better understand what may be necessary.

The hydrogen demand in the EU in 2030, 2040 and 2050 has been projected in a number of recent scenario studies (Tarvydas, 2022). Tarvydas, 2022 concludes that even though the scenarios are unanimous that there will be a role for molecules in 2050, they do not agree on the role hydrogen and its derivatives (synfuels, e-fuels) will play (next to bioenergy or, in some cases, fossil fuels). Some scenarios expect an increasing demand for hydrogen and its derivatives from the transport sector already by 2030, but many do not. By 2050, the majority of these scenarios see more than 30 Megatons (Mt) used in final energy demand, reaching 43 Mt in Fit for 55 (21% of end use energy), or even 51 Mt in the McKinsey scenario (Tarvydas, 2022).

Since current hydrogen demand is mostly from specific industry (such as refineries, fertilizer production, etc), hydrogen infrastructure is currently limited to specific and typically relatively short pipelines from a hydrogen production site to the industry location. If hydrogen use is expanded to more types of industry, to transport and perhaps also buildings, a more expansive hydrogen distribution network will be needed (Tarvydas, 2022). A future hydrogen grid will likely consist in part of new pipelines, but the existing natural gas grid may also offer opportunities for hydrogen repurposing. However, it should be noted that it is not expected that the hydrogen network will have to be as expansive as the current natural gas grid, since electrification will be

[5] Green hydrogen is hydrogen produced with electrolysis using renewable electricity

the main technology to replace natural gas in many applications, including heat in the built environment and part of industry, and in a large part of the transport sector.

Transport infrastructure

Looking at the transformative changes needed in transport, the main implications for transport infrastructure have not yet been defined as clearly as in the energy sector. Decarbonisation of this sector is expected to be achieved mainly by switching from fossil fuels either directly to renewable electricity, indirectly to synthetic fuels produced with renewable electricity, or to fuels derived from biomass (biofuels). This also involves a shift to different transport modes that are inherently more efficient (rail, shipping), and which are already largely electrified (rail). All this requires different transport infrastructure, but also different infrastructure to distribute the energy needed for transport activities (fuels, charging).

Specifically for road transport, sufficient charging points for electric vehicles need to be available not only on the main highways but also in both urban areas and countryside, throughout the EU. This should be in a far stage of completion in 2030, as in 2035 newly sold cars are 100% emission-free. If pure hydrogen or hydrogen-based synthetic fuels are to play a role in the future transport energy mix, adequate infrastructure (distribution networks, fuelling stations) is required for these as well.

For passenger transport over longer distances, the main infrastructural implication beyond electrification of road transport would be the strengthening of high-speed railways. Recently, the rail sector itself developed a proposal to expand the high-speed rail network (HSR) throughout the EU, the so-called "Metropolitan Network" (Deutsche Bahn, 2023), with the aim to contribute to the targets of the EU Green Deal. Key elements of this proposal are to double the current EU HSR infrastructure by 2030, and triple by 2050[6]. For freight transport, the infrastructural need is less related to the realisation of new infrastructure but rather to a more frequent and efficient use of existing rail and waterways.

Beyond the provision of decarbonised transport infrastructure itself, a key element for transport sector decarbonisation is the modal shift, i.e. the shift of passenger and goods transport to transport modes with inherently greater energy efficiency and lower CO_2-emissions per km (e.g. by shifting individual transport in cars to rail, ridesharing, bus, rail or to walking and cycling, or goods transport from truck to inland shipping or railways). The modal shift also contributes to decarbonisation because some modes are already largely electrified (e.g. railway), whereas decarbonised alternatives are less available for others (e.g. aviation). Despite long-standing EU strategies and targets for modal shift, as indicated by a 2011 EU White Paper, progress towards less carbon-intensive transport modes has been minimal (Pastori et al., 2018), with projections

[6] For reference: the current HSR network spans approximately 11.300 km, and would then expand to 32.000 km in 2050.

suggesting the continued dominance of road transport and increasing shares for railways and aviation by 2050 (European Commission, 2020a).

According to the EU's Sustainable and Smart Mobility Strategy (European Commission, 2021c) people are mainly willing to switch to a more sustainable mode of transport in their daily mobility, for instance commuting. This implies that especially urban infrastructure, such as tramways or bicycle lanes, should be enhanced. Also, mobility hubs around urban centres could ease the shift from one mode to another, enabling for instance commuters from outside the cities to change from road transport to a more sustainable mode for the last part of their itinerary (Intertraffic, 2021).

2.3.3 Current EU policies addressing infrastructure

In the assessment of past EU policies (2005-2020, analysed in WP2 of 4i-TRACTION), it was concluded that the infrastructure policies were not yet aligned with the decarbonisation of energy or transport. EU policy has mainly been supportive and not very directive in both energy and transport infrastructure. Nevertheless, in recent initiatives, such as the European Green Deal, the Fit for 55 policy package and RePowerEU Plan, some elements do address infrastructural needs.

Energy infrastructure policies

EU legislation in the field of green energy, such as the revised Renewable Energy Directive (RED), implies the realisation of the necessary infrastructure but does not mandate it directly. However, the establishment of ENTSO-E and ENTSO-G provides a coordination structure at EU level for both electricity and gas, respectively. These entities develop 10-year scenarios for infrastructure based on projected needs and identify gaps for cross-border connections, although they do not have a mandate to coerce TSOs to address these gaps (Vendrik et al., 2023).

The Trans-European Networks for Energy (TEN-E) regulation stipulates the development of key corridors for different energy carriers, including electricity and hydrogen. Its recent revision renders the regulation more fit for facilitating the transition to a renewable energy system. Within the TEN-E framework, key infrastructural projects can be granted the status of Project of Common Interest (PCI), which allows for advantages in terms of permitting times and eligibility for grants from the Connecting Europe Facility. It is important to note, however, that investment decisions still need to be made at the level of (mostly nationally organised) TSOs and there is no (EU-level) mechanism that guarantees the actual realisation of the network laid down in the TEN-E regulation. Also, the TEN-E network is mostly addressed at filling current gaps in the European energy infrastructure, not necessarily at providing the infrastructure that is needed (and is sufficient) for the transition to a climate neutral energy system in 2050 (Vendrik et al., 2023).

The RePowerEU Plan envisaged an increase of the RED's overall renewable energy target and a strengthening of the EU's use of solar photovoltaics (PV), wind energy and heat pumps (European Commission, 2022d). Also, it facilitates the increase of liquid natural gas and hydrogen imports, besides the domestic production of 10 million tons of green hydrogen in 2030 that was already announced in the Hydrogen Strategy. Hydrogen infrastructure has been included in the recent revision of the TEN-E regulation. For both electricity and hydrogen, key cross-border interconnections are included in the 5^{th} list of PCIs and additional projects. A network of hydrogen network coordinators at EU level, comparable to ENTSO-E and ENTSO-G, has been announced but has not been installed so far.

The WP4.2 energy infrastructure case study (Vendrik et al., 2023) highlights that current EU policies lack a comprehensive, EU-wide approach to energy infrastructure, with national interests leading to fragmented, incremental changes, suggesting that a more centralised approach creating a responsible institution at EU level, may improve the EU-wide viewpoint and planning backwards.

Transport infrastructure policies

For transport infrastructure limited dedicated EU policies currently exist. The Fit for 55 piece of legislation that most explicitly addresses infrastructural needs in the context of the transition is the Alternative Fuels Infrastructure Regulation (AFIR)[7], which stipulates the required density of road charging stations for alternative fuels (electricity and hydrogen) along the EU's Trans-European Transport Network (TEN-T). Within this framework, the EU identified key corridors (for both road transport and rail freight), but the core network for road, conventional and high-speed rail is still far from completed. Like with the TEN-E network, even though it includes deadlines, there is no mechanism that guarantees the realisation of the necessary infrastructure within a certain timeframe. This is up to Member States, who need to cooperate to bring about cross-border connections. For prioritised connections, funding is available through the Connecting Europe Facility (€23 billion for transport projects within the period of 2021-2027).

In railways, there is little EU competence at the central level. The overall aim of EU railway policy is to create a Single European Railway Area, but this is still far from completion. Four railway policy packages have created some progress on opening the railway market for competition and increasing the interoperability of national railway systems, but significant political and technical barriers remain. Also, these policy packages are mostly inspired by the wish to create a single market for railways, rather than by climate considerations. In 2021, the Commission published an Action Plan to boost long-distance and cross-border passenger rail services, including an initiative to improve online ticketing and a European Investment Bank platform to increase the availability of rolling stock. More recently, the Commission announced it will support 10 concrete pilot projects establishing new cross-border railway connections or improving existing ones.

On modal shift there has not been much progress since the White Paper that was mentioned above. Apart from stimulating a shift to more climate friendly modes of transport, there are no concrete policies such as targets to bring about a modal shift, and the strategy of the European

[7] A revision of the Alternative Fuels Infrastructure Directive of 2014

Commission seems to focus on decarbonising all transport modes to the extent possible rather than enforcing a modal shift.

2.3.4 Breaking down the challenge

From the above, it is clear that for both energy and transport infrastructure there is a considerable gap between what is currently in place and what is needed in 2030 to enable the transition to be completed in time. This is true for the physical infrastructure itself, but also for the policies needed to realise this infrastructure, which is our focus in this gap analysis exercise.

In the following we structure our analysis around four major policy aspects that apply across the different types of infrastructure and that would need to be strengthened to be able to deliver the transformation for infrastructure.

Insufficient funding

Although the infrastructural gap is not always about *more* infrastructure – think of the potential of repurposing existing natural gas pipelines to transport hydrogen – an extension of the network is in many cases necessary. This is particularly true for the electricity network, were more cross-border connections as well as larger-scale international connections will have to be realised, and for (high-speed) railways. The hydrogen network is almost non-existent at the moment, so even though there are more uncertainties there as for the necessary scale of the network, an increase is imperative in any case.

Apart from bicycle lanes in cities and the like, many types of infrastructure are relatively expensive. The RePowerEU Plan estimates investment needs for key hydrogen infrastructure to be in the range of €28-38 billion for EU-internal pipelines and €6-11 billion for storage (European Commission, 2022d). According to a study by Investigate Europe, trains remain significantly underfunded in the EU, particularly in comparison to investments in road infrastructure, showing a difference of almost €500 billion between 2000 and 2019 (Investigate Europe, 2021).

Large infrastructure investments often require substantial upfront funding before benefits can be reaped, with private companies typically unable or unwilling to shoulder such risks, necessitating public financing through direct investment or targeted loans. The lengthy time frame from investment decision to completion, often exceeding a decade, can challenge political support, yet timely infrastructure development is crucial for enabling decarbonisation well before 2050.

For these reasons, safeguarding the necessary investments – in time – is a particular challenge across the different types of infrastructure.

Complex coordination

Lack of infrastructure hinders the expansion of renewable energy production and its integration into the energy system, leading to a "chicken-and-egg" dilemma: large investments in infrastructure require guaranteed demand, while end users delay transitioning to renewables without assured infrastructure. This coordination problem necessitates decisive infrastructural choices to ensure timely decarbonisation, despite uncertainties about cost-effectiveness and future needs, as inaction poses a greater risk to achieving climate neutrality.

Long lead times

Infrastructure projects typically have long lead times of 5-10 years from inception to actual realisation. As infrastructure often is a condition for further decarbonisation (see previous paragraph), it is key that these lead times are kept as short as possible in the coming years and decades. Planning, permitting and spatial planning take time, and manpower is limited – especially considering the many infrastructure projects that need to be developed in the coming decades throughout the EU. Also, participation and public support (or at least acceptance) from the communities in the vicinity is necessary, as is the avoidance of negative (environmental) impacts. Therefore, timely coordination and planning in order to bring down lead times is essential for realising the infrastructure needed for the transition in time. To effectively move infrastructure projects from planning to roll-out, by 2030, the institutional capacity is needed at all governance levels involved (Vendrik et al., 2023).

Insufficient transnational planning

Since the energy system becomes more complex and integrated, we also conclude that integrated energy infrastructure planning at supranational level is essential to design a cost-efficient infrastructure network in 2050. This applies to different levels and types of infrastructure. For energy infrastructure, on the one hand it means that cross-border integration should be carried out as part of a pan-European view on the energy system in the EU in 2050, as incremental changes, based on local cross-border capacity needs, may lead to a fragmented approach that is not sufficient to timely realise a decarbonised energy network at European scale (Vendrik et al., 2023). At the level of energy carrier integration, an EU-wide approach is needed as well, to make sure that needs for electricity and hydrogen (including their conversion via electrolysis and storage) and the replacement of natural gas by hydrogen are well-coordinated and match demand. For transport infrastructure, EU-level planning may be slightly less complex, but also in this case it is important that needs are derived from realistic scenarios for a climate neutral economy in 2050 (backcasting) rather than inspired by current infrastructural gaps, which would again risk a fragmented and incremental approach.

Priorities given uncertainties and lead times

Concluding from the above, there is a pressing need for a comprehensive and expedited strategy for infrastructure transformation by 2030 across all governance levels in the EU, balancing firm decisions and flexible planning in the face of uncertainties. Prioritising urgent and no-regret options, especially those with long lead times, is crucial, leading to a selective focus on key energy and transport infrastructure projects for EU policymakers and stakeholders.

Based on these considerations we suggest this non-exhaustive selection of a number of key priorities in energy and transport infrastructure that EU policy makers and stakeholders may focus on for the time being:

- The expansion of **electricity transmission infrastructure**, particularly transboundary interconnectors, is urgently needed in the EU due to the shift from fossil to renewable energy, increasing electricity demand for heating and transport, and existing network congestion. Strengthening both the existing transmission network and transborder interconnection capacity is both urgent and certain for supporting decarbonisation and delocalised renewable energy generation.

- **Rail infrastructure**, especially high-speed and long-distance connections, can be a key enabler of a model shift from transport modes that are difficult to decarbonise (e.g. aviation, long distance goods transport by road) to electric railways. However, since there are more barriers to this type of modal shift than the infrastructure, this has to be accompanied by a broader policy framework for modal shift. Given long lead times, investment decisions taken today will probably not result in physical infrastructure before 2030.

- **District heating** is likely to be a cost-effective means to decarbonise heating in many more cities and municipalities throughout the EU and could be considered a no-regret option as long as a renewable source of heating is available (excluding process heat from industry).

- Developing a **hydrogen (or hydrogen derivative) network** is potentially important for specific regions and corridors, but uncertainties remain regarding the volumes, future users, and the need for an extensive EU-wide grid. While hydrogen's role as an industrial feedstock is more certain, its comparison with electrification for industry and heavy road transport is still undecided. Given the uncertainty of different development scenarios, it seems advisable to start with developing the infrastructure in regional clusters with more certain hydrogen demand, deferring a decision on a broader grid until future demand becomes clearer.

- **Charging infrastructure** is also a key aspect of the energy transition in the transport sector, but there seems little need for a stronger role of governments in these developments, also given the AFIR that is already in place. With the EU focussing on driving the shift from fossil to electric vehicles (and other zero-emission solutions), the market will eventually ensure that the charging infrastructure is being developed.

2.4 Integration

Transformative change in the EU requires all relevant policy areas being aligned with, and contributing to, the climate neutrality objective (Görlach, Hilke, et al., 2022). Integration as understood here is composed of two related elements, *climate policy integration* and *sector integration*.

Climate policy integration needs to reflect that transformation processes in different sectors and policy areas are becoming increasingly interdependent, for instance due to the pivotal role that (direct or indirect) electrification plays for the decarbonisation of energy-uses like transport and buildings. Climate policy integration also needs to address common, cross-cutting challenges, such as the need for innovation, investment and infrastructure. Climate policy integration thereby draws attention to interconnections between transformation processes, linking the efforts of different economic sectors and policy areas to advance towards climate neutrality.

2.4.1 Climate policy integration in the EU: current status and remaining gaps

Climate policy integration (also known as climate mainstreaming; hereinafter CPI) refers to the systematic incorporation of climate change considerations and objectives into various policy areas and decision-making processes at different levels of government. CPI aims to ensure that climate change is not treated as an isolated issue; otherwise climate policy cannot be effective. Instead, climate policy must be integrated across sectors and policies to promote synergies and holistic approaches. To achieve this, CPI requires collaboration and coordination between different government departments and agencies.

While CPI is a relatively recent concept that entered academic and policy discussions in the 2000s, it builds on extensive body of literature on policy integration and environmental integration (Rietig, 2021). Policy integration is often understood as an *objective or outcome*, for example, the goal of ensuring that the EU's climate objectives are effectively integrated into various sectors and policy areas. However, policy integration has also been conceived as a dynamic, multidimensional *process* (Candel & Biesbroek, 2016). In this sense, it is linked to the policymaking processes, requiring the consideration of climate policy objectives to ensure that various policies are aligned with the climate objectives and do not lead to results that contradict them. This, finally, relates *to institutional arrangements and coordination*, discussed in more detail below.

The procedural understanding looks at how and why integration happens; what its constituent elements are; what prevents it; and why policy disintegration can also happen (Candel & Biesbroek, 2016). Against this background, CPI is understood here both as a policy objective and the policy process through which the objective is achieved. The next section describes its transformation from a theoretical concept into a specific legal requirement under the 2021 European Climate Law (European Parliament & Council of the European Union, 2021).

From at idea to a legal obligation: status of CPI in the EU

Environmental integration is a longstanding policy objective of the EU, first translated into a legal requirement to integrate environmental considerations into the design and implementation of all EU policies and activities in 1986.[8] Regardless of its long history, the implementation of the environmental integration principle in the EU remains "rather disappointing" (Kingston et al., 2017, p. 104). The main cross-cutting practical effort towards its implementation is the requirement for the Commission to carry out an impact assessment when proposing major policy measures (Kingston et al., 2017). This has not, however, been able to ensure that EU policies in all relevant sectors and policy areas are compatible with environmental objectives, including those related to climate change mitigation.[9]

Prior to the European Green Deal and the 2021 European Climate Law, the status of CPI in the EU was significantly weaker than that of environmental integration. The European Climate Law changed this by introducing new legal obligations concerning CPI in particular. Article 6.4 requires the Commission to review ex-ante the compatibility of all its policy and budgetary proposals with the EU's climate neutrality and climate change adaptation objectives (European Parliament & Council of the European Union, 2021, art. 6.4). Article 6.2 requires the Commission to periodically review the consistency of the acquis with the climate neutrality and adaptation objectives. Article 7 establishes a similar consistency check for national measures pursued by the Member States. These new legal requirements have translated CPI from a "merely a theoretical idea" to a concrete legal obligation in the EU.

The ex-ante requirement that the Commission evaluate its budget and policy proposals in light of climate policy objectives is well aligned with the procedural view of policy integration and the idea that climate policy consideration should be taken up during the policymaking process (van Asselt et al., 2015). Yet the European Climate Law merely stipulates that climate policy objectives must be considered in sectoral decision-making; it does not mandate their reflection in relevant outputs and outcomes. This may be criticised as inadequate (Oberthür & von Homeyer, 2023). Indeed, one weakness of the European Climate Law is that it does not *prevent* the Commission from making proposals that it finds problematic in light of the EU's climate policy objectives (Kulovesi et al., 2024). A further weakness is that the European Climate Law does not define the methods and indicators that the Commission should use to assess CPI. Also, while requiring the Commission to publish its assessments of the compatibility of its policy and budget proposals with the climate neutrality objective, no stakeholder input is solicited before the Commission has published its proposal. This significantly restricts possibilities for effective public participation and critical assessment of the Commission's proposals while still at the planning stage (Kulovesi et al., 2024).

[8] Currently included in Article 111 of the Treaty on the Functioning of the European Union and Article 37 of the Charter of Fundamental Rights of the European Union. The environmental integration principle was first included in the Single European Act in 1986 and in its present, strengthened form in the Treaty of Amsterdam of 1999.

[9] Even if some long-term attempts have been made in context of EU climate policy-making, see Kulovesi et al., 2011

Also relevant for CPI in context of the European Green Deal is the "do no significant harm principle", which entails that activities creating significant harm from the perspective of the EU's climate change objectives should not be supported or carried out. The principle is included in the EU Taxonomy Regulation aiming to promote sustainable investments (see below). Otherwise, the principle as included in the European Green Deal has been described as "ambiguous" and as a "concept [that] is to be translated at the level of particular legislative proposals" (Sikora, 2021, p. 689). Hence, it has been recommended that further strengthening CPI in the EU requires strengthening the status of the "do no harm" principle, anchoring it firmly in EU law and complementing it by a "maximise synergy" principle (Kulovesi & Oberthür, 2023).

EU-level institutional arrangements to promote CPI

A key aim of CPI is to ensure that climate policy is not considered as an isolated issue. Achieving this requires collaboration and coordination between different government departments (ministries or, in the EU context, Directorate-Generals (DG's)). Academic literature has developed different concepts with a view to expanding "the traditional 'silo' approach in public sector organisations, which typically does not consider issues across traditional responsibilities" (Tosun & Lang, 2017, p. 560). The main conceptual approaches include the ideas of holistic government, joined-up government as well as the whole-of-government approach (Tosun & Lang, 2017, p. 557). Instruments commonly recommended to advance policy integration include inter-departmental plans, task-forces, regulatory impact assessments, mission statements, interaction guidelines and so on (Tosun & Lang, 2017, p. 562).

Looking at CPI from the perspective of EU-level institutional developments, two trends are relevant. The first relates to the distribution of powers between the EU and its Member States, and the second to arrangements within EU institutions, most notably in the Commission, which plays an important role in the EU's climate policy process.

Regarding the first aspect, EU climate policy has seen a gradually transfer of powers from the Member States to the Commission. Notably, the 2009 climate and energy package shifted power towards the EU institutions, for instance, by setting an EU-wide emissions cap for the ETS that replaced national allocation plans drawn up by each Member State (Kulovesi & Van Asselt, 2020). The Governance Regulation has given the Commission the authority to review and propose revisions to climate plans prepared by the Member States and issue recommendations to Member States making insufficient progress towards the EU's 2030 targets. The European Climate Law has given the Commission similar powers with respect to assessing consistency of Member-State and EU policies with the 2050 climate neutrality objective.

Looking at arrangements within EU institutions, especially within the Commission, the Directorate-General for Climate Action (DG CLIMA) was created in 2010 by separating climate issues from the Directorate-General for the Environment. While this, on one hand, strengthened the status of climate policy, it also increased the risk of creating a climate-policy silo.

The Juncker Commission (2014-2019) improved the institutional design from the perspective of climate policy mainstreaming, including by having a joint Commissioner for Energy and Climate. It introduced a stronger role for vice presidents and centralised decision-making toward the political leadership of the European Commission at the level of the president and vice presidents of the European Commission, as well as the European Commissioners and their cabinets (Rietig, 2021).

During by the Ursula von der Leyen Commission (2019-2024), the status of climate change on the Commission agenda has been stronger than ever before and the relevant institutional arrangements have been described as follows:

> " (…) the Commission's capacity to promote coherent climate policy has certainly been strengthened through organizational reforms, including the stronger hierarchical steering of the President, the special role of an Executive Vice President and Climate Commissioner, stronger levels of horizontal coordination, and the more interventionist coordinating role of the Secretariat General." (Rayner et al., 2023b, p. 385)

Progress towards climate policy integration in the EU

In general, EU climate policy has evolved mainly through target-setting by the European Council, followed by Commission proposals for large packages of implementing measures (Dupont et al., 2023). The first package in 2001 related to the EU's 8% emission reduction target during the first commitment period under the Kyoto Protocol in 2008-2012. These targeted mainly the energy, industry and transport sectors (European Commission, 2001). The establishment of the EU Emissions Trading System (EU ETS) was the main vehicle to advance CPI in this stage. The 2009 Climate and Energy Package was adopted before the United Nations Climate Change Conference in Copenhagen with the key objective was to implement the EU's 20% emission reduction target by 2020 along with the 20% targets for energy efficiency and renewable energy. It strengthened CPI, *inter alia*, through the stronger alignment of the EU's climate and energy policies as well as climate and transport policies.[10] Through the 2030 Climate and Energy Framework, finalised in 2018-2019, the EU sought to achieve an at least 40% emission reduction by 2030, strengthening climate policies in various sectors and policy areas, also strengthening the EU's framework for procedural climate governance (Kulovesi & Oberthür, 2020).

While the first three packages took steps towards CPI in certain key sectors, the Commission's 2018 Clean Planet for All communication, which examined possible pathways for the EU to reach climate neutrality by 2050, was the first to formulate the need for *comprehensive and deep integration of climate policy with all relevant sectors and policy areas* (European Commission,

[10] For a comprehensive overview, see Kulovesi et al., 2011.

2016). This, and the underlying impact assessment, paved the way for the 2019 European Green Deal (EGD), a blueprint for the EU's fundamental economic and societal transformation by 2050.

The EGD clearly spells out that all sectors and policy areas will need to play a role in the climate neutrality transformation and this requires "deeply transformative policies":

> "To deliver the European Green Deal, there is a need to rethink policies for clean energy supply across the economy, industry, production and consumption, large-scale infrastructure, transport, food and agriculture, construction, taxation and social benefits." (European Commission, 2019b, p. 4)

The Commission's EGD communication also stresses that all areas "are strongly interlinked and mutually reinforcing" and that the EGD's implementation would "make consistent use of all policy levers: regulation and standardisation, investment and innovation, national reforms, dialogue with social partners and international cooperation" (European Commission, 2019b, p. 4).

The key policies to implement the EGD include the European Climate Law as well as the Fit for 55 package finalised in 2023 and *de facto* increasing the EU's 2030 net emission reduction target to at least 57%.[11] The EGD implementation also includes various other measures, such as the Sustainable Finance Framework and a new Circular Economy Action Plan. Overall, the EGD has accelerated the speed of legal and policy change in the EU, and put in place a set of instruments intended to deliver a comprehensive transformation of the European economies and societies in a way that would also strengthen CPI in the EU.

2.4.2 What approaches are there to deliver CPI in the EU?

The EU applies different approaches in its efforts to align sectoral policies with the climate objectives. These include procedural requirements (fitness checks) to assess whether new policy proposals and initiatives are aligned with climate neutrality, as required by the EU Climate Law; requiring Member States to develop an integrated plan for the transformation to climate neutrality (the National Energy and Climate Plans, NECPs), and to regularly report on their efforts in implementing them; they include institutional arrangements to support the mainstreaming of climate policy objectives within the structures and processes of EU policy formulation. They also include *ex post* checks by the European Commission on whether EU-level and Member State policies are aligned with the EU climate policy objectives. While it is not strictly speaking a policy integration mechanism, the market-based coordination of emission reduction efforts delivered by the EU Emissions Trading System (EU ETS) and the future ETS 2 for buildings and road transport effectively also has function of distributing and coordinating mitigation efforts across emitters, sectors and countries.

[11] See Kulovesi et al., 2024 for a discussion on how the net target effectively increased to 57% through amendments to the EU climate targets in the land use, land-use change and forestry sector.

Advancing CPI through climate targets

Target-setting and planning are important tools to advance CPI. They provide direction for policymakers and investors, making it easier to align and coordinate efforts across different sectors and levels of government (ex-ante) – and to assess whether the outcomes of sectoral policies are compatible with climate goals (ex-post). Setting clear goals and targets can also advance crucial aspects of the transformation, such as stimulating innovation and promoting investment in clean technologies as well as deploying the necessary infrastructure.

In this regard, the 2021 European Climate Law, enshrining in legislation the EU's 2050 climate neutrality target, constituted and important step towards a clearer long-term perspective for EU climate policymaking.[12] In addition, the European Climate Law indicates a process for defining the EU's 2040 climate target as well as an indicative greenhouse gas emissions budget for 2030-2050.[13] Along with the climate targets, an indicative GHG emissions budget can strengthen CPI in the EU, for example, by making it easier to assess infrastructure and investment plans in light of the EU's remaining carbon budget (Matthews et al., 2020).

However, unlike some national climate laws of EU Member States, the EU climate law targets are not further differentiated into specific sectoral targets or sectoral carbon budgets, which would allow a more granular assessment whether sectors are on track to climate neutrality, or whether additional policies may be warranted (Evans et al., 2023).

Advancing CPI through planning requirements

To advance CPI, the EU has also taken steps to strengthen its *procedural climate governance* (Kulovesi et al., 2024). A key example are the more holistic planning requirements in the form of National Energy and Climate Plans (NECPs) that each Member State must prepare every ten years and update at five-year intervals (European Parliament & Council of the European Union, 2018).[14]

NECPs are supposed to detail the policies and measures that each Member States plans to implement to achieve its national targets for greenhouse gas emissions reduction, renewable energy deployment, and energy efficiency improvements.[15] The plans cover a range of sectors, defining specific actions related to their decarbonization. NECPs are expected to be in line with other EU policies and strategies, such as the European Green Deal, the Energy Efficiency Directive, and the Renewable Energy Directive. This holds important potential to strengthen CPI at both, national and EU levels through a roadmap for national energy and climate policies and actions,

[12] For more detail, see Kulovesi et al. (2024).
[13] The European Scientific Advisory Body on Climate Change published its recommendations in June 2023, suggesting that the EU adopt a net emission reduction target of 90-95% by 2040 (European Scientific Advisory Board on Climate Change [ESABCC], 2023). In February 2024, the EU Commission proposed a target of 90% emission reductions below 1990 levels by 2040 (European Commission, 2024a).
[14] The Governance Regulation also requires the Member States to develop long-term climate plans with a 30-year horizon at 10-year intervals.
[15] For detailed discussion, see Kulovesi & Oberthür, 2020.

which is regularly assessed by the Commission in terms of its alignment with EU targets and legislation.

Obligations to assess the conformity of policy proposals with climate neutrality

Article 6.4 of the European Climate Law obliges the Commission to review the compatibility of all its policy and budgetary proposals with the EU's climate neutrality and climate change adaptation objectives and has thereby elevated the formal status of CPI to a firm legal requirement (European Parliament & Council of the European Union, 2021).

Notwithstanding this, the requirement formulates in the European Climate Law is still limited in that it merely requires that climate policy objectives must be considered in sectoral decision-making but does not mandate their reflection in relevant outputs and outcomes (Oberthür & von Homeyer, 2023). Likewise, the European Climate Law does not *prevent* the Commission from making proposals that it finds problematic in light of the EU's climate policy objectives (Kulovesi et al., 2024).

Institutional arrangements to advance CPI

Advancing CPI requires overcoming the traditional "silo" approach in public sector organisations, where political responsibilities and incentives are organised around clear sectoral boundaries, often with competing priorities. To overcome this, different approaches have been proposed, such as the notion of holistic government, joined-up government as well as the whole-of-government approach. Instruments commonly recommended to advance policy integration include inter-departmental plans, task-forces, regulatory impact assessments, mission statements, interaction guidelines and so on.

As elaborated above, the EU has undergone several rounds of reorganising competencies for climate policy and aligning efforts across different branches of government, in this case the DGs of the European Commission. With the establishment of a Commission Vice President in charge of implementing the Green Deal and the EU Climate Law, climate policy was elevated to a higher status in the von der Leyen Commission than before. In addition, the establishment of the EU Scientific Advisory Board on Climate Change, as mandated by the EU Climate Law, further strengthens the institutional anchoring of climate policy in the EU, as well as its integration across different policy areas.

Advancing CPI through Emissions Trading

The EU's flagship climate policy instrument, the ETS, was launched in 2005, covering initially the energy sector as well as carbon-intensive industry sectors (iron and steel, glass, cement, pulp and paper) (Kulovesi & Van Asselt, 2020). Subsequently, its scope has expanded to new sectors and greenhouse gases. In 2023, legislation to create a second ETS was adopted for emissions from buildings and road transport. Emissions trading has also covered aviation emissions since 2012 and in 2024, it will be extended to maritime transport.

In principle, emissions trading as policy instrument holds important potential to advance CPI. By setting an overall cap on emissions and providing an economic incentive for the covered emitters to reduce greenhouse gas emissions, the system distributes the mitigation effort across all sectors in the most cost-effective manner. In this way, an ETS reduces – or, as some would argue, obliterates – the need for other mechanisms to distribute the mitigation effort across sectors, countries and emitters. If the ETS cap is set in accordance with a pathway to climate neutrality, it automatically ensures that the emissions of covered entities are aligned with climate neutrality.

However, in practice, the EU ETS has not always delivered these high expectations. While it has ensured that covered emissions remain below the cap, it has gone through a period of very low carbon prices, mainly caused by an oversupply of emission allowances on the market. A key reform to address this has been the Market Stability Reserve created in 2019, which has removed excess allowances from the market and thereby stabilised the carbon price.

Also relevant from the perspective of CPI is that emissions trading has played an increasing role as a source of revenue, via the auctioning of EU emission allowances. The auctioning revenue has been used to promote innovation and investment in clean technologies through the Modernization and Innovation Funds. For example, the Innovation Fund was created in 2018 and linked with the ETS[16] with a current size of 530 million ETS allowances, to provide funding for the demonstration of innovative low-carbon technologies. Going forward, the Social Climate Fund is intended to address some of the distributional effects of carbon pricing, by channelling back part of the revenue to vulnerable groups. While the volume of the Social Climate Fund remains limited, it represents one of the first instances where EU policy addresses the social impacts of climate policies, thus extending climate policy integration beyond the traditional domain of the main energy-using / emitting sectors.

2.4.3 What is required for a more integrated EU climate policy?

The previous analysis leads us to conclude that while CPI has been strengthened in the EU over the years, it is not yet at the level required for the EU to achieve a holistic transformation toward climate neutrality. In particular, CPI in the EU faces the following challenges going forward (i) uneven progress and neglected sectors; (ii) factoring in sector coupling, (iii) integration of innovation, investment and infrastructure, and (iv) ensuring alignment in the face of other seismic changes.

[16] The Innovation Fund was established under Article 10a(8) of Directive 2003/87/EC.

Uneven progress with CPI across sectors

After three decades of EU climate policy, several sectors and policy areas are increasingly aligned with the objectives of climate policy - in particular in the areas of energy efficiency, renewable energy, but also regional development funds prioritizing low-carbon technology and infrastructure. Yet other parts of EU policy making remain relatively unaffected by specific climate policies, in particular agriculture, regional and economic development, trade and parts of the transport sector (Rietig, 2021).

Among the different sectors, climate policy integration is arguably most advanced in the energy sector. There are different reasons for this: first, since the energy sector accounts for a quarter of EU GHG emissions in and of itself, lowering energy sector emissions is key for the achievement of climate neutrality. Second, the supply of climate-neutral energy is also central for the decarbonisation efforts of other sectors, in particular where these efforts involve electrification (direct or indirect).

While renewable energy and energy efficiency have been part of EU climate policy since the early 1990s, the 2009 climate and energy package made their link more explicit than before (Dupont et al., 2023), setting targets for 20% renewable energy and enhancing energy efficiency by 20% by 2020. It also introduced stronger implementation measures, most notably, binding national targets for renewable energy (Kulovesi et al., 2011). The 2030 Climate and Energy Framework[17] raised the targets for renewable energy (while replacing, however, binding national targets with an EU-level one) and energy efficiency. It was also closely related to the Energy Union – an initiative responding to Russia's 2014 aggression against Ukraine aiming at creating a more comprehensive and integrated approach to energy policy and governance in the EU. Relevant new EU policies included revised rules on the EU electricity market, including the recast Regulation and a recast Directive on the Electricity Market, a Regulation on Risk Preparedness, and a recast Regulation on the Agency for the Cooperation of Energy Regulators (Kulovesi & Oberthür, 2020). The Fit for 55 package further strengthened the energy efficiency and renewable energy targets (42.5% but aiming at 45% renewable energy sources in the EU's overall energy mix). Other reforms included modifications to the ETS: while the ETS cap does not distinguish between the sectors it covers, the rapid decrease of the ETS cap will effectively require a largely decarbonized electricity sector in the early 2030s, as the remaining (and shrinking) cap will be increasingly consumed by industrial emitters and aviation.

While EU energy policies are largely aligned with climate objectives, this is less evident for transport. Like energy, transport accounted for about a quarter of the EU's greenhouse gas emissions in 2021 – yet in contrast to energy, absolute emissions from transport in 2021 only began to decline modestly in 2007, and were about 20% above 1990 levels in 2021. In legal terms, transport falls under the so-called effort-sharing sectors, covered by the national emission targets for each Member State and included in their NECPs. At the same time, various EU-level

[17] For a comprehensive overview see Kulovesi & Oberthür (2020).

policies and measures have been put in place to strengthen the alignment of climate and transport policies.

The subsequent EU climate packages expanded and strengthened climate-relevant regulations in the transport sector. The 2009 climate and energy package included, for the first time, a 10% target for renewable energy in the transport sector as well as the Passenger Car Regulation, setting legally binding fleet standards for carbon dioxide emissions from new passenger cars (Kulovesi et al., 2011). From 2012 onwards, emissions from flights within the EU have been covered under the EU ETS; as of 2024 this will be extended also to maritime transport. As of 2027, emissions from road transport will be covered under the to-be-established ETS2, which will complement the existing EU ETS. The 2030 Framework strengthened EU-level policies and measures targeting emissions from transport, setting a 14 % target for renewable energy in the transport sector by 2030 (European Parliament & Council of the European Union, 2023a) and tightening energy efficiency and emissions performance requirements for cars and trucks (European Commission, 2023j; European Parliament & Council of the European Union, 2023c). The Fit for 55 package introduced further measures to control CO_2 emissions from vehicles and advance electric mobility, including by promoting electric vehicles and setting targets for the deployment of charging infrastructure in the Member States. At the same time, the progressive tightening of vehicle emissions standards amounts to a de-facto phase-out of internal combustion engine-powered cars by 2035. Measures were also introduced to promote sustainable fuels, including for aviation.

The sector where arguably climate policy integration has progressed least is agriculture. The European Scientific Advisory Board on Climate Change (ESABCC, 2024) notes that the agriculture sector remains a significant challenge, with non-CO_2 emissions persisting at levels similar to those in 2005. The sector's mitigation potential, although limited compared to others, necessitates substantial reductions to comply with the EU's climate goals. While there have been repeated efforts for greening the key EU policy in this field, the Common Agricultural Policy (CAP), there is still no quantified, stand-alone emission reduction target for the sector. As observed by the ESABCC, that this gap is further exacerbated by policy inconsistencies and discretionary national implementation in CAP Strategic Plans (ESABCC, 2024). Current agricultural policies inadvertently support high-emission practices, notably in livestock production. To change this, the CAP should be revised to enforce specific emission reduction targets and promote environmentally beneficial practices. Addressing policy inconsistencies, particularly in bioenergy, and reinforcing the Farm to Fork Strategy with concrete, enforceable policies are imperative for aligning the agricultural sector with EU climate objectives.

Sector coupling as a challenge for traditional CPI

The traditional concept of climate policy integration, i.e. the mainstreaming of climate goals into sectoral policies, is challenged by the trend that these very sectors are becoming increasingly interdependent. In particular, this concerns the processes of electrification and sector coupling.

This builds on the idea that, as sectors transform to climate neutrality, they will be increasingly interconnected and therefore require a systemic solution.

As the power sector transitions away from fossil fuels and towards variable renewable energies (in particular wind and solar), energy production becomes more volatile, with periods of excess production as well as shortfalls. This requires solutions to either store the surplus electricity, or to adjust or shift energy demand. At the same time, electrification is a key element to decarbonise the main energy-using sectors (such as transport, industry and buildings) – be it directly, e.g. through electric vehicles and heat pumps, or indirectly, e.g. through the production of green hydrogen from surplus renewable electricity. While there are different interpretations of the sector coupling concept, it generally refers to the integration of variable electricity generation, direct or indirect electrification of end uses, and the potential for storage (in particular thermal or chemical storage) (Ramsebner et al., 2021). Sector coupling seeks to manage and optimise these interactions between generation, conversion / storage and end uses with the goal of optimising the energy system as a whole. A crucial driver of sector coupling is the electrification of energy-using sectors and processes – preferably directly, or, where that is not possible or feasible, indirectly through synthetic energy carriers produced with green electricity (green hydrogen, green ammonia or synthetic fuels) (Olczak & Piebalgs, 2018). As a storage / conversion option, sector coupling therefore is also used in conjunction with different "power-to-X" concepts, which refer to different storage options or use cases for surplus electricity – such as power-to-heat, power-to-gas, power-to-liquid (fuels) or power-to-chemicals etc. In such applications, excess electricity from renewable sources is used to produce other forms of energy, fuels, or products, such as green hydrogen (electrolysis) and synthetic methane (methanation) (Olczak & Piebalgs, 2018).

From the perspective of the EU's climate neutrality transition, sector coupling holds significant potential to contribute to the transition in publicly acceptable as well as cost-competitive way. This requires, however, fundamental changes to the energy system and it has hence been argued that "sector coupling cannot be realised without integrated infrastructure planning" (Olczak & Piebalgs, 2018, p. 4). Furthermore, it requires "rules enabling the proper functioning of the highly integrated energy system" (Olczak & Piebalgs, 2018, p. 5).

At the outset, sector coupling may thus seem primarily as a technical coordination and management challenge. But it also implies a governance challenge, certainly for governance approaches that rely on sectoral responsibilities and mechanisms:

- First, the feasibility of any sectoral strategy in the energy-using sectors depends on whether sufficient amounts of clean electricity (or derivatives) are available at competitive cost, and whether the grid is in place to supply the electricity to where it is needed. As long as clean electricity (and its derivatives) remain scarce, this also constitutes a coordination problem: which sectors, applications or use-cases should have access to the scarce clean energy resources? Should these be distributed purely on the basis of willingness/ability to pay, or the availability of alternatives, or are there other considerations? This relates in particular to the availability of (green) hydrogen and derivative products, which offer a decarbonisation option for multiple sectors and applications – but are bound to remain in scarce supply for the foreseeable future.[18]

- Second, not only do the energy-using sectors depend on the supply of clean electricity, but also vice versa: adding flexibility options in the energy-using sectors, such as storage/conversion or flexible loads, enhances the economic viability of expanding renewable energy production, and influences the shape of the grid that will be needed. In this way, the strategies pursued in the energy-using sectors also affect developments within the energy sector.

- Third, by blurring sectoral boundaries, sector coupling also complicates the accounting of emissions and emission reductions, and hence a challenge for political accountability. To the extent that transport or heating are electrified, the resulting energy use no longer counts towards the emissions of this sector, but (as long as electricity generation is not fully renewable) will show up as part of the power sector emissions.

In terms of governance approaches, this means that a purely sectoral approach, whereby distinct sectors develop and pursue their own, distinct strategies, and are solely accountable for their sectoral emissions, becomes increasingly questionable as a governance approach – in this way, sector coupling also presents a challenge to governance mechanisms that rely on sectoral emission targets or sectoral carbon budgets. Instead, sector coupling introduces a need for integrated, cross-sectoral planning and coordination, all the more so since the change processes in the different sectors proceed in parallel. As a result, the challenge of policy integration across different sectors takes on a much more material dimension, as it requires providing direction and coordination also for the (socio-economic and technological) change processes that happen within each sector. As a challenge for EU climate and energy governance, the question arises whether the existing EU competences concerning energy are sufficient to support such an integrated, systemic approach to the energy sector, including infrastructure planning and further integration of EU energy policies.

Integrating Innovation, Investment and Infrastructure

Transformative climate policy needs to address several cross-cutting challenges, among them to stimulate low-carbon innovation in technologies and business models, mobilise private and public investment into low-carbon solutions, and to deploy the necessary infrastructure – while at the same time managing the phase-out of existing, fossil-based structures (value chains, business models, assets and infrastructure). To make things yet more complex, these challenges themselves are interdependent: scaling up innovation is also a matter of mobilising investments

[18] Other elements in this list of cross-sectoral linkages include the supply of carbon dioxide removals, which may be a last resort for the so-called "hard to abate" emissions, or the supply of biobased materials and energy carriers.

into such novel technologies, finding a good blend of public and private investments (and sharing of returns). Whether or not innovative technologies will succeed commercially depends, among other factors, on whether the supporting infrastructure is in place, from electricity grids to data networks and from Carbon Capture, Utilization, and Storage (CCUS) to (green) hydrogen infrastructure. Against this background, the challenge of climate policy integration also encompasses the alignment of the other three "I's", i.e. of innovation, investment and infrastructure.

Regarding investment and finance, the EU's main effort to date align financial flows with climate neutrality is the Sustainable Finance Framework. This includes several elements, such as corporate disclosure of climate-related information, creation of low-carbon benchmarks and European Green Bond Standard, but most prominently the Taxonomy Regulation (European Parliament & Council of the European Union, 2020). The EU taxonomy seeks to promote sustainable investment by creating a classification system that helps companies and investors to identify sustainable economic activities. Investors remain, however, free to choose where they invest. As an integration tool, the EU Taxonomy seeks to mainstream climate considerations in private investment decisions. While its voluntary nature makes it difficult to assess its concrete impacts, concerns have been raised whether the taxonomy will direct investments appropriately (Rayner et al., 2023b). Also, in addition to the controversy created by the inclusion of nuclear energy and natural gas in the list of sustainable economic activities, the taxonomy leaves a noteworthy gap by excluding the agricultural sector.

With respect to public spending, the EU has also sought to integrate climate objectives. According to the climate mainstreaming approach applicable to the Commission's 2021-2027 multiannual financial framework, financial resources have been earmarked for both climate change mitigation and adaptation with the aim of allocating 30% of the EU budget to climate goals (European Commission, 2020b). Also, the "do no harm"–principle is applicable, restricting EU expenditure with potentially negative climate and environmental impacts. In addition to earmarking a share of the EU budget to advancing climate policy objectives, the EGD includes the Sustainable Europe Investment Plan, seeking to mobilise €1 trillion by 2030 (Rayner et al., 2023b). The EU launched several initiatives that seek to integrate climate objectives into EU funding in a way that also promotes innovation, investment and infrastructure. These include the Strategic Technologies for Europe Platform, which seeks to reinforce, leverage and steer EU funds – both existing and new – to investments in, *inter alia*, clean technologies (European Commission, n.d.-e); the Recovery and Resilience Facility and the RePowerEU plan, which seek to reduce the EU's dependency on Russian fossil fuels and accelerate the clean energy transition, and which the Commission estimates will require additional investment of €210 billion by 2027 on top of what is needed to implement the Fit for 55 proposals (European Commission, 2022b); and the Sustainable Europe Investment Plan implemented via the European Investment Bank (Rayner et al., 2023b). The EIB pledged to increase its support to climate action and environmental sustainability to more than 50 percent of its overall lending activity by 2025. This lending is expected to leverage about €1 trillion of public and private investment during the 2020s (Mertens & Thiemann, 2023).

In the area of infrastructure, there are dedicated EU policies in place, such as the planning for trans-European energy and transport networks (TEN-E and TEN-T). However, as elaborated above (2.3.4) the current planning instruments does not deliver cross-border integration based on a pan-European view on the energy system in the EU in 2050. A fragmented, incremental approach that merely responds to bottlenecks where they occur is not conducive to achieve the necessary transformation of energy grids (Vendrik et al., 2023). Likewise, current policies do not support an EU-wide integrated approach for different energy carriers, which would make sure that electricity and hydrogen needs are served and that the replacement / repurposing of natural gas grid with hydrogen or synthetic fuels is well-coordinated and matches the demand.

Thus, various EU policies and programmes are in place, seeking to integrate climate considerations into innovation, investment and infrastructure decisions in various sectors and policy areas. Nonetheless, researchers have raised several concerns, including the likelihood of sufficient finance being mobilised, the implications of using particular policy instruments to raise it; and the implications for existing rules on government debt levels (Rayner et al., 2023b).

Ensuring alignment in the face of other seismic changes

In a world where "all policy is climate policy", climate policy will also need to be continuously balanced with and re-calibrated against other political priorities. In particular, this requires continued alignment of climate policies with geopolitical objectives, social and distributional objectives, competitiveness, as well as the need to protect biodiversity and adapt to the unfolding climate change.

The sectors and policy areas that are key for the EU's climate neutrality transformation are also strongly affected by international developments, including those related to geopolitics and security, as well as trade and industrial policy. Such trends increasingly impact EU climate policy, requiring its closer integration with other policy areas, such as energy security, industrial policy, trade policy and digital transformation policy.

An important example is Russia's illegal war of aggression against Ukraine, resulting in EU policies to step up the EU's clean energy transition, boost energy security and end the EU's dependence on Russian fossil fuel exports (European Commission, 2022b). Also highly relevant are the EU's recent policy responses to extensive subsidies to the development and production of green technologies by China and the United States of America (USA) (European Commission, 2023i, 2023h). The latter reflects the accelerating race between economic superpowers to dominate the emerging global markets for green technologies[19] and to secure access to critical raw materials.[20] At the same time, there have also been signs of stronger cooperation: in October 2021, the EU and USA signed a joint statement on a Global Arrangement on Sustainable Steel and Aluminium,

[19] The race between China and the EU started over a decade ago, centering first on solar and wind energy technologies. See, for example, Kulovesi (2014).
[20] Also this race has a longer history, building on China's policies to dominate and control global trade in rare earths (Kulovesi, 2016).

agreeing to work together towards decarbonising the steel sector and end their trade dispute related to steel and aluminium tariffs.

One example of how these international developments influence EU climate policies is the 2022 RePowerEU Plan (European Commission, 2022b) and related Regulation (European Parliament & Council of the European Union, 2023b), containing several initiatives designed to integrate the EU's climate objectives with, *inter alia*, energy security ones. Another example is the EU's new "de-risking" policy regarding China, which includes the goal of producing at least 40% of the clean technology needed for the EU's climate internally and reducing "critical dependencies and vulnerabilities, including in its supply chains" (Council of the European Union, 2023, p. 9). A key existing initiative to implement the de-risking policy is the Commission 2023 proposal for a regulation designed to ensure a secure and sustainable supply of critical raw materials (European Commission, 2023h). The objectives of the proposed critical raw materials regulation include integrating policies related to the EU's "twin" green and digital transition by increasing investment in support of innovation (European Commission, 2023d). The impact of international developments on climate policy integration in the EU could become even more evident in the coming years.

3. The four policy avenues in EU climate policy

In this chapter we analyse the EU climate policy acquis and describe its evolution over time from the lens of four different paradigms of climate policymaking. In previous work we identified four policy paradigms – distinct approaches that guide the design and instrumentation of climate policy – through a comprehensive scoping of the academic and policy literature (Görlach, Hilke, et al., 2022).[21] These paradigms served as the basis for the development of four policy avenues representing different combinations of policy instruments, reflecting the different paradigms and all geared at achieving climate neutrality in the EU.

This chapter investigates the EU's current climate policy mix, its evolution over the last two decades and the foreseeable future through the lens of these paradigms, to reflect upon the policy pathway the EU has been taking. To achieve this, based on a literature review, interviews with experts and an internal workshop, we identified key instruments of the EU's climate policy mix, and clustered them according to the different policy paradigms they most clearly embody.[22] This analysis illustrates the different policy paradigms, their relevance for the evolution of EU climate policy, and the extent to which they are recognisable in the current EU climate policy landscape. It serves as the point of departure for an integrated assessment of the policy avenues (Chapter 4).

The selection of policy instruments focused on substantive, mitigation-focused policy instruments that have a clear causal mechanism to reduce emissions. It does not include instruments of a more procedural nature, which indirectly support the transition to climate neutrality by creating the necessary framework conditions (such as planning, expert advice, and public participation) (Moore et al., 2023).[23] Clustering the instruments around the four policy paradigms involved an internal draft allocation process, followed by discussions and validation through interviews with policy experts from academia and practice. In the clustering exercise, the four paradigms identified in Görlach, Martini, et al. (2022) served as the basis for assigning the instruments to

[21] The Report "Policy Avenues Towards a Climate-Neutral Europe" investigates four distinct policy paradigms and, based on these, defines different policy avenues for transformative EU climate policies.
[22] For this purpose, we conducted a literature review to pinpoint central EU climate policy instruments. This review drew from comprehensive analyses of the EU climate policy landscape from academic articles (Delbeke et al., 2015; Delbeke & Vis, 2020; Drummond, 2013; Dupont & Oberthür, 2015; Duwe et al., 2023; Jordan et al., 2010; Oberthür & von Homeyer, 2023; Weitzel et al., 2023) and official information from EU institutions. Instead of focusing on legislative acts, which often bundle numerous policy instruments, our unit of analysis centred on individual instruments, enabling a more detailed exploration of each instrument's specific intervention logic. From this extensive review, we identified and focused on 20 key instruments pivotal to EU climate policy in an internal expert workshop.
[23] There is also no focus on *general* targets for emissions reduction, renewable energy, or energy efficiency, because they are implemented differently at member state level, limiting the ability to clearly assess their alignment to the different paradigms. These targets include member state targets under the Effort Sharing Regulation, the Energy Efficiency Directive, and the Renewable Energy Directive. Similarly, legislations where the concrete operational mechanism is not (yet) certain, like for the proposed Regulation on an EU certification for carbon removals, are excluded from the analysis.

the paradigms (see summary in Table 3). For each instrument, it was then assessed to which degree it aligns with the characteristics of the different paradigms.

3.1 EU climate policy - now and then

Ideas matter for policymaking. According to the political scientist Peter Hall (1993, p. 280), "policymakers customarily work within a framework of ideas and standards that specifies not only the goals of policy and the kind of instruments that can be used to attain them, but also the very nature of the problems they are meant to be addressing." Hall calls these frameworks "policy paradigms" – a shared, theory-based understanding of the problem and the (best) way of solving it. These policy paradigms change and evolve over time, driven by new knowledge (as new ideas and experiences enter the political discourse), by (exogenous) shocks (economic crises, wars, pandemics), by changing political majorities and political fashions, or by influences from abroad – be it international institutions and the advice they give, or developments in countries outside the EU that affect the European policy discourse.

Since the 1990s, when EU climate policy gradually emerged as a separate policy area distinct from environmental policy, EU climate policy has evolved in terms of its instruments, institutions, and governance. EU environmental policy had traditionally relied on classical regulation, such as targets and timetables, standards and limits (Rayner & Jordan, 2016). The limited EU climate policy that began to emerge in the 1990s relied predominantly on voluntary and informational instruments, and to a smaller degree on regulations (Oberthür & von Homeyer, 2023). As the EU climate policy mix evolved and diversified in the 2000s, market-based elements began to play an increasing role, specifically carbon pricing that was established in the form of the EU Emissions Trading System. More recently, i.e., since the mid-2010s, there has been increasing attention to elements and tools of green industrial policy, which seek to promote innovation, strengthen, and retool the industrial base, and thereby accelerate the transformation to a climate-neutral economy.

The evolution of EU climate policy was driven by different factors. Since the 1990s, and particularly in the 2000s, climate issues gained prominence on the political agenda. With the adoption of the Kyoto Protocol in 1997 and its first compliance period between 2008 and 2012, the EU entered into a binding commitment to reduce emissions, and thus needed to advance beyond the (largely voluntary / informational) initial climate policy instruments of the 1990s to develop a more sophisticated set of substantive policies (Convery, 2009; Oberthür & von Homeyer, 2023). When it came to choosing the policy instruments for doing so, several factors worked in favour of market-based elements. The "flexible mechanisms" of the Kyoto Protocol introduced market-based elements such as emissions trading into international climate policy. While, strictly speaking, this would not have required signatories of the Kyoto Protocol to also enact such policies as a domestic instrument, it did have this effect in the EU. Intellectually, the ground for the introduction of market-based policies had been prepared both by academic research and by the work of international organisations such as the Organisation for Economic Cooperation and

Development (OECD), and both benefited from the experiences with non-climate precedents outside Europe, such as the USA Acid Rain Programme (Convery, 2009). By contrast, direct regulation in other environmental issues was perceived or observed as heavy-handed and incapable of unleashing a sufficient transition dynamic, leading to renewed interest in new types of environmental regulation (Jordan et al., 2003). Politically, the turn towards market-based instruments in climate policy coincided with influences from pro-business and market-liberal forces in key Member States and the Barroso and Juncker Commissions, supporting a general political preference for more market-based forms of governance at the Commission and in many Member States.

In the 2010s, however, it became increasingly apparent that carbon pricing alone would not be sufficient to deliver on all the aspects where a transformation would be needed, particularly concerning innovation and social equity, and would therefore need to be combined with companion policies. In particular, the EU climate policy mix increasingly turned its attention to elements of a green industrial policy – with the publication of a Commission Communication for a new industrial policy in 2012, setting out a roadmap for reindustrialising Europe (Tagliapietra & Veugelers, 2023). The transformation to climate neutrality, and the resulting need to re-orient basic industries, played an increasing role in these strategic considerations, culminating in the 2020 "New Industrial Strategy for Europe". In terms of instrumentation, the NER 300 (as of 2012) marked a first (timid) step towards funding for climate-neutral investments, later succeeded by the EU Innovation Fund.

More recently, the Fit for 55 package combines different strands with the ambition to make EU climate policy fit for the drastic emission reductions needed in the 2020s and beyond. Its primary focus is to extend the use of emissions trading and increase its ambition, both by expanding the EU ETS and introducing a second ETS to cover emissions from transport and buildings. Additionally, the package includes efforts to strengthen standards and regulations, exemplified by phase-out regulation for combustion engine vehicles (Duwe et al., 2023; Rayner et al., 2023a). Finally, in response to the pandemic, Russia's invasion of Ukraine, and a trend towards industrial policy in other countries, exemplified by the USA's Inflation Reduction Act, the package was followed up by industrial policy initiatives such as Green Deal Industrial Plan and Net Zero Industry Act.

3.2 The four policy paradigms and their alignment with key EU climate policy instruments

The four paradigms embody distinct ideas and principles of policy design and have different ideas of what constitutes "good" public (climate) policy. Over time, each has contributed differently to the formulation of EU climate policy. Real-life climate policy is inevitably a blend that has evolved gradually, incorporating influences of the different paradigms. This becomes apparent when we categorise elements of the current EU climate policy acquis according to the paradigms. The categorisation of policies is not always clear cut (as becomes apparent in Table 4): they comprise different functions and intervention logics, sometimes even multiple instruments under the roof of one policy, and they change and evolve over time, reflecting influences of different paradigms.

Table 3. Overview of policy paradigms

	Green Economic Liberalism (GEL)	Green Industrial Policy (GIP)	Directed Transition (DT)	Sufficiency & Degrowth (S&D)
Primary intervention mechanism	Correct market failures	Direct and accelerate technological change	Provide certainty of emission reductions	Facilitate lifestyle change
Main criteria for instrument selection	(Static) efficiency Cost-effectiveness	Dynamic efficiency; environmental effectiveness	Environmental effectiveness	Environmental, intra-, and inter-generational justice Conviviality
Main instruments	Market-based instruments, carbon pricing	Investments, standards, innovation support	Direct regulation through bans, standards, quotas, targets, carbon budgets, and planning tools	Participatory and inclusive governance Bans, taxes, behavioural change
Political theory of change	Climate action at lowest cost generates political acceptance	Coalition building, create and mobilise constituencies	Political legitimacy of interventions derived from climate targets	Policies to change societal norms and values
Faith in markets	High	Medium	Low	Low
Faith in state	Low	High	High	Medium
Technological openness	High	Medium	Low	Low
Faith in technology	Medium to high	High	High	Low
Political disruption necessary	Low	Medium	Low	High

Source: Based on Görlach, Martini, et al., 2022, pp. 20. *Notes*: "Technological openness" refers to the extent to which the instruments make explicit technological choices and convey advantages to some technologies or energy carriers. For example, a tax credit for electric vehicles would be a technology-specific instrument. "Faith in technology" refers to the extent to which technology (including novel and untested ones) is seen as a solution to climate change, and that policies (or the market) will be able to deliver such technologies.

Our analysis reveals that all paradigms have influenced the EU climate policy instrument mix, but with different emphases at different points in time. While examples of the first three paradigms – green economic liberalism, green industrial policy and directed transition – can be identified easily in the EU's climate policy mix, there are fewer examples of instruments that emphasise sufficiency aspects and behavioural and lifestyle changes.

In the following, a summary of each policy paradigm is provided based on the more detailed elaborations in Görlach, Martini, et al. (2022). For an overview of all paradigms also see Table 3. Furthermore, we outline in more detail which role the respective paradigm played for the evolution of EU climate policy and which instruments from the current acquis are aligned with the different paradigms and why.

Table 4. Alignment of key EU climate policy instruments with the four policy avenues

Instrument	Legislation	GEL	GIP	DT	S&D
GHG emissions cap & trade systems: ETS 1 & ETS 2	ETS Directive	high	medium		
Carbon Border Adjustment Mechanism	Carbon Border Adjustment Mechanism Regulation	high	medium		
Obligatory energy performance certificates for new buildings	Energy Performance of Buildings Directive	high			
Mandatory energy consumption audits for large companies	Energy Efficiency Directive	high	low		
Social Climate Fund	Social Climate Fund Regulation	high	medium	medium	medium
Horizon Europe research & innovation programme	Horizon Europe Regulation	medium	high		low
LIFE Programme	LIFE Regulation	medium	high		
Net Zero Industry Act *(assessed as one bundle)*	Net Zero Industry Act *(proposal)*	low	high		
InvestEU Programme	InvestEU Regulation	low	high		
Innovation Fund	ETS Directive	low	high		
Sustainable finance taxonomy	Taxonomy Regulation	low	high	low	
Just Transition Fund	Just Transition Fund Regulation	low	high	low	medium
Modernisation Fund	ETS Directive	low	high	high	
Renovation requirements for the public sector	Energy Efficiency Directive		medium	high	
CO_2 emission standards for cars and vans	Regulation Setting Emission Standards for Passenger Cars and Vans		medium	high	

Instrument	Legislation	GEL	GIP	DT	S&D
Limits and bans on F-gas usage	F-Gas Regulations		medium	high	
Bans on methane venting and flaring, mandatory leak detection and repair	Regulation on Methane Emissions in Energy Sector			high	
Obligations for net-zero buildings & mandatory solar energy installations, Electric Vehicle (EV) charging and bike parking infrastructure, minimum energy performance standards	Energy Performance of Buildings Directive		low	high	low
Minimum energy efficiency standards for energy-related appliances, performance & information requirements for most physical goods categories	Ecodesign Directive		medium	high	medium

Source: Own illustration

3.3 Green Economic Liberalism

Green economic liberalism sees climate change above all as a consequence of market failure, mostly since the external costs of greenhouse gas-emitting activities are not reflected in consumption or investment decisions. The main response is therefore to rectify these market failures by internalising the external costs. This suggests carbon pricing as the instrument of choice, complemented with other market-based instruments. Generally, proponents of this paradigm seek to harness market dynamics and private enterprise while being cautious about excessive government intervention. For policy instrument selection, the paradigm stresses (static) efficiency and cost-effectiveness, aiming to achieve given climate targets at least cost. Accordingly, the theory of change focuses on achieving political acceptance through low-cost climate action and generally low levels of political disruption. Lastly, the paradigm encourages technological openness, i.e., it aims to let the market decide which technological option ultimately prevails, instead of the regulator picking winners.

Green Economic Liberalism traditionally has had a strong influence on EU climate policy, which can be seen in a heavy reliance on market-based instruments. This development reflected the prevailing EU view of economic policy since the 1980s, which emphasised the need for integrated and horizontal policies that sought to promote open competition and the internal market, and limited government interventions, including through state aid rules and regulations. Intellectually, the development driven partly by economic ideas brought into the debate by international organisations such as the International Monetary Fund, World Bank, OECD, etc. (Jordan et al., 2013; Meckling & Allan, 2020), but also by internal developments: economists took key positions in the climate change unit of DG Environment in the Commission, such as Jos Delbeke, who were strong supporters of market-based instruments and pushed the commissioner to make emissions trading its key EU climate policy instrument (Convery, 2009; Skjærseth & Wettestad, 2010). Moreover, the "Better Regulation" agenda was introduced in 2002 and defined criteria according to which EU climate policy should be designed and evaluated, emphasising cost-effective policies and thereby supporting use of market-based instruments. While a proposal for an EU carbon tax was unsuccessful a decade earlier, the political consensus for market-based solutions was there in the early 2000s, when the core elements of the EU's approach to climate policy were developed.

Hence, **key instruments** in the current acquis that are assessed to align strongly or mostly with the GEL paradigm are:

- **Emissions Trading Systems** (the existing EU ETS and the forthcoming ETS for road transport and buildings, referred to as "ETS 2") set a cap on emissions and introduce a price on them. The price signals from emissions trading provide the incentive for reducing emissions while certificate trading allows for flexibility, ensuring that emission reductions occur in the most cost-effective manner (European Commission, 2023g). For these reasons, emissions trading clearly embodies the logic of the Green Economic Liberalism paradigm and, in this paradigm, is seen as the cornerstone of EU climate policy.

- The forthcoming **Carbon Border Adjustment Mechanism** (CBAM) is closely linked to the EU ETS. It seeks to contain the risk of carbon leakage resulting from the difference in carbon prices inside and outside the EU, which puts European-based producers at a competitive disadvantage. It needs to be noted that several (external) actors view CBAM as a means of protectionist industrial policy which increases the costs for importers and leads to trade distortions (Hancock, 2022; Lim et al., 2021). The EU, in contrast, emphasises that CBAM strives to ensure a level playing field by applying carbon costs to imported goods according to their carbon content (European Commission, 2023b). By incorporating carbon pricing into international trade, CBAM aims to rectify a shortcoming of the EU ETS by adding another market-based instrument, albeit one extending beyond the EU, and is thus in line with the GEL paradigm. Additionally, the CBAM also has the effect of increasing the cost of energy-intensive inputs and products, thus enhancing incentives to use such inputs more efficiently, and thus opening up further efficiency potentials along the value chain. Moreover, it underpins the shift away from free allocation in the ETS by providing carbon leakage protections, making it possible to shift to (more efficient) auctioning of allowances.

- Obligatory **energy performance certificates for new buildings** – as mandated by the Energy Performance of Buildings Directive – aim to address the market failure of incomplete information by providing consumers with information on the energy performance of buildings, thus reducing transaction cost. The information provided through the certificates allows businesses and individuals to make more informed choices leading to monetary and energy savings (European Commission, 2023f) and allowing the energy performance to be incorporated in the market price of buildings. Moreover, labelling instruments like energy performance certificates come with a low level of political disruption, they enable the market mechanism to function better by lowering transaction costs for consumers, and they do not prescribe the use of specific technologies, in line with the ideal that instruments under the GEL paradigm should have a high degree of technological openness.

- Mandatory **energy consumption audits for large companies** as foreseen in the current revision of the Energy Efficiency Directive (European Commission, 2023e) are assessed to align with the GEL paradigm. While at first glance mandatory measures seem more in line with the Directed Transition paradigm, regular surveillance audits can raise awareness on how energy savings can be accomplished and encourage energy efficiency measures. They do not prescribe specific measures or targets and leave it to companies to decide which technologies they would like to apply (if any). Hence, they can be seen to be in line with the GEL paradigm.

- Instruments designed to reduce inequalities, such as those offering temporary direct income support for the vulnerable, largely resonate with the S&D paradigm. The **Social Climate Fund**, however, plays an important role as a political enabler for a strategy that heavily relies on carbon pricing: distributional implications are the Achilles heel of carbon pricing and may erode public acceptance. Therefore, companion policies are needed to address these distributional effects and compensate for hardships and accordingly advocates of carbon pricing typically endorse compensating measures. The Social Climate Fund is intended to fulfil this role by distributing parts of the revenues from the ETS 2.

Several other instruments align with the GEL paradigm to a lesser degree. These include funds and instruments that aim to direct financial flows (the Horizon Europe, the LIFE and the InvestEU programme; the Modernisation as well as the Just Transition and the Innovation Fund; the sustainable finance taxonomy). These instruments can be justified as correcting market failures in research and development (R&D), where knowledge spillovers would otherwise lead to underinvestment in R&D, promoting green innovations and ensuring that market dynamics support sustainable economic growth. The sustainable finance taxonomy is not fully aligned with the GEL paradigm – in the logic of this paradigm, the incentive set by the carbon price should have the role of directing financial investment towards climate-neutral and sustainable solutions. However, since the taxonomy is more of a labelling instrument, it can also be justified as a means to avoid transaction costs and overcome information asymmetries.

3.4 Green Industrial Policy

A different paradigm emerges from heterodox schools of economic thought such as post-Keynesian, Schumpeterian, and Evolutionary economics. It views climate change as a complex political and social issue rather than (primarily) a market failure. Underpriced greenhouse gas emissions, in this logic, are but one of many interacting market failures. Likewise, non-price barriers such as path dependencies, institutions, infrastructure, and political lock-ins are crucial and need to be addressed. Finally, establishing and defending ambitious climate policy also needs to consider the political economy, for instance by aligning climate measures with other (economic, social, or political) objectives, compensating the anticipated losers of the transformation, or building a support base for transformative climate policies among domestic constituencies. The green industrial policy paradigm maintains some faith in markets and private initiative, but also foresees a need for a strong and active government to shape and direct markets towards a climate-neutral economy, with public and private actors ideally progressing in partnership. Specifically, green industrial policy seeks to drive innovation and investment and overcome first-mover disadvantages. Directing and accelerating technological change, as well as fostering clean investments, are therefore primary intervention mechanisms and dynamic efficiency a main criterion for the selection of instruments, i.e., enabling economies of scale and reducing costs over time. Key instruments employed include public investments and innovation support, but also information disclosure requirements and standards to provide clarity to market participants. Some technological openness is maintained, in that the paradigm starts from the premise that not all technological solutions are available and competitive but require further improvement. At the same time, the paradigm reflects a high faith in markets, assuming that technologies will become available and (with public support and guidance) can be scaled to reach market maturity. Politically, green industrial policy is seen as a strategy to garner support for climate action by decreasing the costs of clean technologies, improving consumer choices, and establishing business models that stand to benefit from the transition to climate neutrality. In this way, unlike other paradigms, the theory of change includes coalition building and creating and mobilising constituencies.

Vertical industrial policy, the targeted promotion of sectors and technologies deemed "strategic", had been common in many parts of Europe up until the 1970s, with the history of Airbus serving as a prominent example of European industrial policy dating back to the 1960s (Ahrens, 2020). However, as market-oriented principles gained ground in the 1980s and 90s, the vertical industrial policy approach fell out of favour and gave way to horizontal policies which sought to create the right framework conditions for industrial development through R&D programmes, competition policy and internal market regulations (Tagliapietra & Veugelers, 2023). The rules and institutions geared toward safeguarding competition in the internal market constrained industrial policy both at member state level but also foreclosed the development of an EU-level industrial strategy for a long time. This is well exemplified by the restrictive state aid rules that existed until recently and the failure to establish compensating EU-level funds.

Of late, this trend has been partially reversed. EU climate policy has increasingly prioritised innovation and the active transformation of the industrial base, culminating in the formulation of elements of an industrial policy for the EU (De Ville, 2023). This shift suggests a stronger role for governments, not only by setting the guardrails and otherwise letting the market work its course but getting actively involved by taking on risks and driving investments to support a green industrial transformation. The Innovation Fund (2015) and its predecessor the NER 300 marked the first noteworthy steps towards embracing a more strategic industrial policy at EU level – albeit at limited scale – recognising that the pull effect from the carbon price is insufficient to drive the necessary changes, and in particular to mobilise investment and foster innovation at the needed scale and pace (De Ville, 2023; Fahl et al., 2021). Under the impression of the pandemic a marked acceleration of a coordinated EU (industrial) policy could be noted, both in response to the threat from the pandemic itself (efforts to rapidly develop and deploy a vaccine, procurement of personal protective equipment, respirators etc.), but also the supply chain disruptions it caused (in particular supply of microprocessors). Another notable example of concerted state intervention has been the support and adjustments made to help industry and households cope with the energy crisis in the aftermath of Russia’s attack on Ukraine in 2022. Above all, however, external factors like the introduction of the USA’s Inflation Reduction Act as well as China’s industrial strategies bolster the EU’s strategic industrial endeavours to stay competitive and secure its position in the global market (De Ville, 2023; Tagliapietra et al., 2023). These competing industrial strategies illustrate the emerging clean technology race among nations and blocs that governments feel compelled to actively structure.

Of the current EU climate policy mix, the following **key instruments** are most strongly aligned with the Green Industrial Policy paradigm:

- the **Horizon Europe research & innovation programme**, the **LIFE Programme**, **InvestEU**, the **Innovation Fund,** the **Just Transition Fund** and the **Modernisation Fund** are all seen to be highly aligned with the GIP paradigm. Despite different focus areas and concrete goals, their general aims are to increase the supply of clean technologies through research and/or innovation (e.g. Horizon Europe, the Innovation Fund), accelerate structural change through investments (e.g. InvestEU, the Just Transition Fund, and the Modernisation Fund), inducing dynamic scale economies and learning processes (e.g. LIFE), and overcoming barriers to private investment (e.g. InvestEU) (European Commission, n.d.-d, n.d.-c, n.d.-b, 2021d, 2023n, 2024b). Thus, instead of relying mostly on “sticks”, i.e., direct regulation, the funds and programmes support developments in the desired direction and aim to accelerate the transformation, using “carrots” as is characteristic for GIP.

- By defining criteria for economic activities that align with achieving a net-zero trajectory by 2050, the **Sustainable Finance Taxonomy** can also be seen as aligned with the GIP paradigm. The taxonomy aims to “direct investments to the economic activities most needed for the transition” (European Commission, n.d.-a, section "What the EU is doing and why"), and in doing so does not shy away from defining the technologies and sectors that ought to receive greater investment. Both the goal and the approach align with the Green Industrial Policy paradigm.

The proposed **Net Zero Industry Act**[24] is a recent effort by the EU to flesh out an industrial policy geared at climate neutrality. By allowing regulatory sandboxes, cutting red tape by streamlining administrative requirements, speeding up permitting as well as enhancing market access in public procurement processes and auctions, the Net Zero Industry Act would address non-price barriers such as institutions and political lock-ins. In this way, it can be interpreted as the EU's attempt to strengthen its industrial policy (European Commission, 2023m) and orient it towards climate neutrality. What it lacks, however, is sufficient funding to drive the necessary investments at the necessary scale.

Additionally, several standards, requirements and bans (including e.g., CO_2 emission standards for cars, limits and bans on F-gas usage and minimum energy efficiency standards for energy related appliances) are aligned to a medium degree with GIP ideas: while GIP would generally rely on "carrots" more than on "sticks" to steer the market into the wanted direction, standards can be a useful complement to give greater clarity and orientation to the market, even if they would not be seen as the main drivers of change. Likewise, emissions trading aligns to some extent (medium) with the ideas of GIP, as the carbon price would provide the "demand pull" to encourage investments in innovative low-carbon technologies (European Commission, 2023g) that complements the "technology push" from other, more technology-specific instruments.

3.5 Directed Transition

The Directed Transition paradigm relies heavily on direct regulation, also referred to as "command-and-control" policy instruments. It favours standards, bans, quotas, targets, carbon budgets, and other forms of regulation to mandate or prohibit certain actions, technologies, or fuels. Climate targets and the urgency to act provide the political legitimacy of such interventions, together with the conviction that, in many sectors and applications, the technological solutions for climate neutrality have become sufficiently clear – or time is running out to search for better alternatives. Proponents argue that strong regulatory guidance is necessary to achieve a climate-neutral economy within the limited time available, and that the main contesters – i.e., market-based instruments – are insufficient to bring this about: a price signal that would be strong enough to bring about the necessary change would be politically infeasible; nor can they create the necessary framework conditions for their success (e.g. regarding innovation or infrastructure). Hence, this paradigm generally is more sceptical of the role of markets and sees a clear role for governments to direct market forces in the desired direction. The two main arguments in favour of direct regulation are that it addresses head-on the technological and economic path dependencies that perpetuate fossil fuel use, and that it facilitates the roll-out of infrastructure for climate neutrality. Its proponents therefore see it as more effective than alternatives, and more certain to achieve the desired outcomes (which can be at the level of policy targets to be

[24] Note that, in contrast to other key policies, we assess the proposed Net Zero Industry Act as one package of instruments. While containing a host of different instruments, these instruments show a clear representation of the IP paradigm when considered separately but even more so when considered jointly.

achieved, but also how this target is achieved, i.e., deployment of specific technologies). The paradigm embodies a low faith in markets and technological openness is limited: it necessarily involves regulators picking winners – even if this choice should turn out to be misguided in hindsight.

Directed transition involves prescribing specific goals that private actors need to achieve, specific solutions that they need to implement, as well as sectoral planning, e.g., in the form of sectoral carbon budgets. Transformative policies therefore require strong government coordination, including within the EU and among stakeholders and sectors. Governments thus play a crucial role in managing the transition, including compensation for social hardships arising from the transition.

Historically, direct regulation has been widely used in EU environmental policymaking and remains prevalent today, despite the increased attention to market-based and/or voluntary approaches during the last two decades (Jordan et al., 2003, 2013). As EU climate policy evolved into a distinct policy area separate from environmental policy more generally, it inherited many of the rules and regulations initially targeted at air pollution or energy conservation. Many of these were rooted in classical environmental regulation, prominently featuring direct regulatory approaches, such as standards and bans. Notable legislations such as the Integrated Pollution Prevention and Control Directive (now known as the Industrial Emissions Directive) and the Ecodesign Directive (which was preceded by the Directive on energy-using products and efficiency standards for appliances dating back to the 1990s), as examples of the EU's reliance on environmental standards. Other instances where the EU has set strong guidance through standards are the air pollutant emission limit values for cars (introduced in 1992) that later evolved into CO_2 emission limits. Finally, the EU policy portfolio also includes mandated phase-out processes for specific products and substances, like light bulbs and fluorinated hydrocarbons.

In line with the above, **key instruments** that are assessed to align strongly or mostly with the Directed Transition paradigm are direct regulation instruments in the form of bans, limits, minimum standards, and requirements that address (technological) path dependencies and create certainty in achieving desired outcomes through strong government coordination are:

- **CO_2 emission standards for cars and vans**, a regulation limiting EU fleet-wide CO_2 emissions and becoming more restrictive over time, prescribing 100% reductions from 2035 onwards, implying the (effective) phase out of combustion engine passenger cars and light commercial vehicles in the EU from 2035 (European Commission, 2023c);

- The Ecodesign Directive has long established minimum energy efficiency standards for energy-related appliances. In the currently ongoing revision, the directive is proposing new performance and information requirements for most physical goods categories. These proposed requirements are comprehensive and may encompass aspects such as product reusability, durability, reparability, and upgradability; recycled content; the presence of substances inhibiting circularity; resource and energy efficiency; recycling and remanufacturing; environmental and carbon footprints, as well as information requirements, including a Digital Product Passport (European Parliament, 2023a);

- **Renovation requirements for the public sector** – as prescribed in the Energy Efficiency Directive – which aim to achieve more efficient energy use in the public sector and bolster its exemplary role (European Commission, 2023e);

- **Limits and bans on F-gas usage** – as set in the proposal for a regulation on fluorinated greenhouse gases – to prevent emissions of these highly potent GHGs (European Parliament, 2023c);

- **Bans on methane venting and flaring** as well as **mandatory leak detection and repair** as prescribed in the agreed EU Methane Emissions Regulation that aims to sharply reduce methane emissions in the energy sector (European Parliament, 2023b);

- Obligations for nearly zero-energy buildings and mandatory solar energy installations, electric vehicle charging and bike parking infrastructure as well as minimum energy performance standards for new buildings – all introduced over a set timeline for the public and the private sector – as proposed in the revised Energy Performance of Buildings Directive (European Commission, 2021a).

- Moreover, the **Modernisation Fund** highly aligns with the paradigm of a Directed Transition, since it facilitates the infrastructure rollout for climate neutrality in a very targeted manner by supporting selected investments and members states (European Commission, 2020c).

Other funding tools are found to be less clearly aligned with a Directed Transitions approach. The Social Climate Fund, for instance, fulfils an important function – but a different and perhaps less important one than it would in the Green Economic Liberalism paradigm.[25] While a just transition and equal sharing of burdens is important to foster acceptance under any paradigm, the Social Climate Fund is less crucial in the Directed Transition logic than in the Green Economic Liberalism case: in the former, the carbon price has to do less of the heavy lifting, and the personal cost of the transition may also be less salient, implying less of a need for direct compensation. However, bans and mandates also create costs and can elicit opposition, implying a similar need to support households in adapting to new regulation. The sustainable finance taxonomy is technologically explicit, which makes it commensurate with a Directed Transitions approach – yet it provides only

[25] The idea or intervention logic of the Social Climate Fund is to address the social impacts that may result from the cost increases for households induced by carbon pricing. It does so by using the revenues generated by the ETS 2. While high costs for consumers might also arise from bans of e.g., fossil technologies like gas-boilers and combustion engine vehicles and the subsequent (mandatory) roll-out of new technologies, the typical logic under the DT paradigm would be one of subsidising these specific investments instead of compensating the higher costs of carbon emissions.

a whitelist of desirable investments, where the Directed Transition logic would also support a blacklist of non-investable technologies.

3.6 Sufficiency & Degrowth

Ecological economics and post-growth thought forms the basis for the Sufficiency and Degrowth paradigm that challenges the compatibility of economic growth, as measured by Gross Domestic Product, with planetary boundaries. Proponents argue that GDP growth cannot be decoupled from resource consumption and GHG emissions quickly enough to stay within the boundaries set by global ecosystems. Since the scope for and pace of efficiency improvements is limited, and since any gain in efficiency is likely to lead to a rebound effect, an effective strategy must also include elements of sufficiency, i.e., finding ways that individuals and society can thrive and flourish while consuming fewer (material) goods. The primary intervention mechanisms of a sufficiency-oriented policy are therefore to facilitate changes of consumption behaviour and lifestyles, abandoning economic growth as a priority and orienting policies at a different understanding of human well-being. Some propose deliberate contraction of economic activity, while others are more agnostic about reducing GDP as such and argue for a focus on reducing harmful economic activities and sectors. Unlike a recession, which is a chaotic and socially destabilising process, degrowth describes a planned and managed process that seeks to mitigate distributional effects primarily through redistributive measures and by promoting convivial,[26] participatory forms of economic activity (Hickel et al., 2022). Under this approach, instrument selection is guided by considerations of environmental, intra-, and inter-generational justice, as well as conviviality. Post-growth approaches call for lifestyle changes towards sufficiency, reducing resource-intensive consumption, and addressing social structures and collective norms. The theory of change underlying this paradigm is centred around policies aimed at shifting societal norms and values.

One limitation of the Sufficiency & Degrowth paradigm is that, unlike the other three, it has little grounding in past or current EU (climate) policy. While concepts of sufficiency, lifestyle and behavioural change have received some rhetorical attention, there has been much less political impact. The notion of moving "beyond GDP," which serves as a more moderate version of moving "beyond growth" and exploring alternatives to traditional growth-oriented models, found its place on the agenda during the Barroso Commission, but failed to gain substantial political traction in subsequent years. More recently, the "Beyond Growth 2023" conference convened numerous high-profile speakers from the European institutions, civil society; yet also here, practical impact remains to be seen.

Accordingly, while the paradigm is generally well-developed in terms of goals and concepts, it is weaker on specific instruments and their practical implementation, let alone embedding such proposals in existing EU (climate) policy frameworks. Proposed instruments vary but are often

[26] The term "convivial" emphasizes community-oriented, participatory, and socially enriching forms of economic activity that prioritize human well-being and social cohesion over mere profit or productivity.

described in general terms only. They include shifting taxation from labour to wealth and material consumption and promoting local production, but also more general strategies to reshape the overall economic and social governance, institutions, culture and education or the set of indicators used to measure (economic) development (Fitzpatrick et al., 2022). Specifically related to climate policy, they include prohibitive taxes or outright bans on activities that are considered particularly harmful and/or add little to overall welfare – such as private aviation (Fouquet & O'Garra, 2022), mass-produced meat and dairy, luxury consumption (Büchs et al., 2023; Oswald et al., 2023), and advertising for fossil-intensive or ecologically destructive products. Furthermore, personal carbon budgets, work-time reductions, bans and limits on energy and material use are proposed as policy instruments that facilitate lifestyle changes and promote behavioural change (Lorek et al., 2021).

The paradigm generally expresses low faith in markets and technological solutions, as over-reliance on (unfettered) markets are seen as the root cause of the problem. Instead, the paradigm emphasises reducing consumption and reliance on resource-intensive technologies, and does not shy away from identifying specific products or technologies that are seen as particularly problematic.[27] Political disruption is considered necessary for bringing about the desired changes, yet proponents argue that the acceptability of such disruption will increase since the sufficiency policies will also deliver high-quality public goods, greater equity, a more inclusive and just society and a higher quality of life.

The Sufficiency and Degrowth paradigm is not very recognisable in the current EU climate policy and there are no explicitly "degrowth" instruments in the EU's policy mix.[28] Only five instruments that are assessed here were seen to have a low or medium alignment with the Sufficiency and Degrowth paradigm:

- The **performance and information requirements for most physical goods categories** prescribed in the proposed recast of the Ecodesign Directive – especially **requirements on durability, repair and reuse** – carry notions of reducing consumption through longer product usage as well as a pro-jobs attitude. Especially repair requirements bear the potential to grow the reverse logistics sector and create jobs in this

[27] To the contrary, targeting interventions at specific uses or products is seen as desirable. Pricing instruments, for instance, can be found in the toolbox of both the Green Economic Liberalism and the Sufficiency and Degrowth Paradigm. Yet in the GEL logic, a uniform carbon price should apply as broadly as possible across uses, products and sectors to achieve maximum (static) efficiency, i.e. mobilising the least-cost abatement potentials. Proponents of sufficiency and degrowth, by contrast, maintain that this results in carbon prices that are both ineffective (too low to curb emissions at the pace needed) and unjust (by affecting low-income consumers disproportionately), and rather advocate tiered approaches such as very high carbon taxes on luxury consumption or highly emission-intensive behaviour (Fouquet & O'Garra, 2022; Oswald et al., 2023).
[28] This analysis is limited to policy instruments that are (scheduled to be) implemented and have a foundation in EU legislative texts. At the level of broader strategy documents, for instance, the European Commission Communication (2022a) "Save Energy"—published in light of the Russian invasion into Ukraine and its effects on the EU energy market—could clearly be placed under the S&D paradigm.

field (European Parliament, 2023a). These aspects align (medium) with some characteristics of the S&D paradigm.

- Putting justice aspects in focus, the **Just Transition Fund** and the **Social Climate Fund** also partially (medium) align with the S&D paradigm because just transition considerations are one main criterion for the instrument selection under the S&D paradigm. (European Commission, n.d.-c, 2023k)

- The **Horizon Europe research & innovation programme** is partially (low) aligned with the S&D paradigm as research projects are commissioned that investigate post-growth and sufficiency ideas and policies, thus laying the base for a development into that direction (see e.g. European Commission, 2022b)

- Lastly, the strengthening of **bike parking infrastructure** in the proposed revision of the Energy Performance of Buildings Directive (European Commission, 2021a) also carry notions of the S&D paradigm as they aim to make cycling more attractive through better infrastructure, thus facilitating behavioural and lifestyle changes, characteristic for sufficiency and degrowth ideas.

4. Ability of the policy avenues to address the 4i challenges

In this chapter we present an assessment of the four policy avenues and in particular address how and to what extent the PAs are able to close the transformation gap identified in chapter two. We assess the policy avenues with a customised assessment framework that focuses centrally on the "4i challenges": innovation, investment, infrastructure, and integration. We identify the inherent strengths and weaknesses of the respective policy avenues in addressing key aspects of each challenge. Importantly, the assessment of strength and weaknesses focuses on the *inherent* ability to address a given challenge, i.e., assuming it is fully implemented. It thus abstracts from political barriers that prevent a policy avenue from being (fully) implemented.

It is worth noting, that real-life policy is rarely implemented purely according to abstract norms and principles. Instead, as the policy mix evolves over time and reflects different political priorities, priors, and ideas, it typically takes the form of a blend of different approaches that evolves dynamically over time. We therefore look at the political feasibility and plausibility of each policy avenue in the second part of the assessment. The goal of this assessment is to identify the strengths and weaknesses of different approaches to climate policymaking for addressing the transformation gap.

The chapter is structured as follows. First, we briefly describe the methodology. Second, we present a summary of our assessment of the inherent strengths and weaknesses as well as the politics for each policy avenue. Finally, we discuss the results for each of the 4i challenges: innovation, investment, infrastructure, and integration.

4.1 Methodology

In this chapter, we assess all four policy avenues through a customised assessment framework, in order to determine to what extent they are fit to solve the transformation gap identified in Chapter 2. Our assessment framework is based on the SWOT methodology, which originally distinguishes internal aspects (expressed as strengths and weaknesses) and external aspects (opportunities and threats). We translate this reasoning into our own approach, distinguishing between the inherent strengths and weaknesses of a policy avenue, assuming it can be implemented as described, and the (external) opportunities and threats, what we refer to as the politics of the policy avenue.

Internal aspects: inherent strengths and weaknesses

We understand the internal aspects of a policy avenue to reflect the theoretical ability of the policy instruments deployed under the policy avenue to address the different aspects of the transformation gap. In doing so, we treat each policy avenue as if it were fully implemented, as described in Görlach, Martini, et al. (2022). That is, we abstract from political realities that may prevent a policy avenue from being implemented in full. The PAs differ in the way they understand the nature of the challenge at hand, and consequently in the approach they pursue to address the different aspects of the challenge. Our analysis identifies the strengths and weaknesses of each policy avenue to solve the different aspects of the transformation gap.

In Chapter 2, we described the transformation gap along the 4i challenges, discussing the issues that are particularly relevant for each challenge to transform to a climate neutral economy within the time available. To structure the assessment of the PAs, we identified three to five key aspects of each of the four transformation gaps. These aspects serve as indicators, expressing how well each policy avenue is able to solve the associated element of the transformation gap. To do so, we assign a score between 1 and 4 to each of the indicators, expressing whether addressing the aspect at hand is a major weakness (score 1), a weakness (2), a strength (3) or a major strength (4) of the policy avenue. This score reflects a qualitative assessment, analysing how the instruments available under the PA would theoretically handle the specific aspect of the transformation gap and, therefore, to what extent the PA would be able to solve the challenge at hand.

We score each indicator to improve the structure and comparability of our assessments of the four policy avenues. Only describing the ways in which all PAs address all aspects of the transformation gaps of all 4i's would lead to a high number of qualitative assessments, but it would be challenging to obtain an overview of the underlying key strengths and weaknesses of the PAs. The indicator approach is aimed at improving this overview, enabling us to compare scores both across the PAs and across the 4i's. The indicator scores provide a first-level insight into the features of the PAs, and the assessments underlying the scores provide more detailed information on the different approaches of the PAs and the extent to which these approaches are able to solve the various aspects of the transformation gap. A more detailed explanation of how this methodology was operationalised, as well as the assessments themselves, is presented in Annex 2. The indicators used for the 4i's respectively – each representing a main aspect of the transformation gap for this i – are presented in Box 1 below.

Box 1. Assessment Indicators

Innovation

- Ability to provide clarity and direction for innovation
- Ability to support research and development (R&D) (TRL 1-6)
- Ability to demonstrate promising technology fully
- Ability to deploy innovations and technologies
- Ability to disincentivise fossil-based technologies

Investment & finance

- Ability to undertake public and mobilise private investments
- Ability to prevent investments in fossil-based assets
- Ability to address information-related market failures

Infrastructure

- Ability to deliver sufficient and timely infrastructure investment
- Ability to support a timely choice for certain infrastructure
- Ability to accelerate planning, permitting and implementation
- Ability to improve transnational planning of infrastructure

Integration

- Adequate administrative and institutional capacity
- Requirement to mainstream climate policy in all policy areas
- Capabilities to align innovation, investment (support) and infrastructure
- Capacities and mechanism for sector coupling

External aspects: politics of the policy avenue

The second stage of our analysis looks at the external political context of the policy avenues. It basically assesses the plausibility that the policy avenue under consideration would actually be implemented. In contrast to the first step, which focuses on the ability of the instruments under the policy avenue to solve the transformation gap, this political assessment does not consider instruments separately, nor is it subdivided in separate assessments for each of the 4i challenges. It is rather focused on the policy avenue and its underlying paradigm as a whole and how this relates to existing EU policy, in order to establish what challenges and opportunities exist for moving towards the theoretical ideal of the policy avenue.

To structure our assessment, we defined three assessment categories – or indicators – each reflecting a key aspect of the politics of adopting the PA. The first indicator, and the broadest in scope, is *political attainability*. Here, we look in the first place at the general political and ideological support among stakeholders and political factions. Next, we consider public support for the policy avenue and its main implications. Lastly, we assess the institutional compatibility with the EU's existing climate policy, and the extent to which the existing policy would need to change – assuming that a large gap here decreases the plausibility of the policy avenue to be adopted.

The second indicator considers the *international attainability* of the policy avenue, looking at how well it aligns with policy frameworks in third countries and the international community, as well as with the EU's foreign policy and climate diplomacy.

The third and last indicator focuses on *socio-economic goals and co-benefits* outside the realm of climate and energy: it assesses to what extent the policy avenue would achieve positive side-effects in achieving other goals than those related to the transition itself, assuming this would contribute to the plausibility of the acceptance of the policy avenue as the new paradigm.

Again, the details on how this approach was carried out, as well as the assessments for each policy avenue, can be found in Annex 2.

Limitations of the assessment framework

Our methodological approach has some limitations that should be acknowledged. The assessment framework is customised to correspond with the understanding of transformation used in this project. In Görlach, Martini, et al. (2022) we defined transformative policies as policies that differs from conventional policy in terms of its depth, breadth, and speed. Transformative policies move away from the incremental approach focused on optimisation. We moreover defined the four cross-cutting challenges that transformative climate policy must address: innovation, investment, infrastructure, and integration. We used this conception of transformative change to guide our assessment framework. This biases our assessment in a certain way:

First, we depart from conventional categories for instrument selection by focusing on the 4i challenges. Notably, we do not use economic efficiency as a central category for instrument selection. While economic efficiency remains a very important concept, we argue that it favours more incremental approaches focused on gradual optimisation rather than transformative change. Since this is centrally at odds with the underlying premise of this research project, we do not use efficiency as an important assessment category. This, in turn, biases the assessment against policy approaches where economic efficiency is the guiding principle, notably Green Economic Liberalism.

Second, the way the transformation challenges are formulated leads to biases against certain PA. The transformation challenges put the focus on some issues, while deemphasising others. For example, one policy avenue – green industrial policy – has an explicit focus on technological innovation and investment, which corresponds best with how the transformation gap is defined in Chapter 2. In a similar vein, all the 4i challenges and respective gaps presuppose that government intervention is needed, at least to some extent, to resolve them. For some challenges, notably infrastructure or integration, government coordination even seems inevitable. In general, this favours those policy avenues that see a greater role for the state over those policy avenues that want to limit the state's involvement in the economy.

Third, we approach the policy avenues from an EU perspective, and this is how they were first conceptualised. We assume that transformative policy must start with the EU policy framework and also requires greater coordination at EU level. This consequently also favours those policy avenues, where the EU is the central player over other policy avenues that foresee more decentralised action.

Finally, the qualitative approach of our assessment has some limitations. While we try to motivate our assessment in detail in the annex and provide arguments, the exact scoring of each indicator can be contested. We used internal peer review to improve the robustness of the scoring and validate the assessments. However, in the end, the scoring reflects our interpretation of the policy avenues, the indicators, and the ability of the former to address the latter.

4.2 Results

Figure 5 provides an overview of the results of our assessment. As can be seen, some clear patterns emerge. Overall, Green Industrial Policy performs best, followed by Directed Transition. Green Economic Liberalism has more mixed results, with its main strengths concentrated in the deployment of innovations and clean solutions. It is less strong in the areas where government coordination and funding are needed, most centrally in the early phases of the innovation chain, and regarding infrastructure. Sufficiency and degrowth, while scoring the lowest overall, shows strengths with regard to the phase-out of fossil fuel technologies. The politics of all policy avenues are challenging. Green Economic Liberalism seems to perform strongest with regards to political feasibility, because it is the clearest continuation of the EU's existing climate policy mix.

Figure 5. Assessment of policy avenues – overview of results

weakness 1 2 3 4 strength

		GEL	GIP	DT	S&D
Innovation	Ability to provide clarity and direction for innovation	2	4	3	3
	Ability to support R&D (TRL 1-6)	2	4	3	3
	Ability to demonstrate promising technologies fully	3	4	3	2
	Ability to deploy proven innovations & technologies	4	4	3	2
	Ability to disincentivise fossil-based technologies	3	3	4	4
Investment	Ability to undertake and mobilise investments	2	4	2	2
	Ability to prevent investments in fossil-based assets	3	3	4	3
	Ability to address information-related market failures	3	4	3	3
Infrastructure	Ability to deliver sufficient and timely infrastructure investment	2	4	3	2
	Ability to support a timely choice for certain infrastructure	1	3	4	2
	Ability to accelerate planning, permitting, and implementation	2	3	3	2
	Transnational planning of infrastructure	1	3	4	2
Integration	Adequate administrative and institutional capacity	2	3	2	2
	Requirement to mainstream climate policy in all policy areas	3	2	3	3
	Capabilities to align innovation, investment (support), and infrastructure	2	4	3	1
	Capacities and mechanism for sector coupling	2	3	3	1
	Political attainability	3	2	2	1
	International attainability	2	3	1	2
	Achievement of socio-economic goals	2	3	2	3

Source: Own illustration

4.2.1 Green Economic Liberalism

Internal strengths and weaknesses of the policy avenue

The Green Economic Liberalism policy avenue is centred on carbon prices delivered through emissions trading system – ideally economy-wide. One core premise is that any government intervention should be justified by correcting a specific market failure. As such, the approach relies heavily on mobilising private initiative (guided by the carbon price) and private knowledge and is sceptical about the capacity of the regulator to identify and implement the most suitable mitigation options, or the most promising strategy towards climate neutrality. Our assessment consequently shows that the policy avenue has its strengths in innovation and the deployment of proven technologies. However, the policy avenue is less strong in tackling non-price barriers that require government coordination and shows some major weaknesses in two aspects of the transformation: the ability to provide more certainty about technological change and the ability to ensure the roll-out of infrastructure.

Regarding the *innovation* challenge, the policy avenue is stronger in later stages of the innovation chain (deployment), than it is in the first stages of innovation (RD&D).[29] Given the (expected) high carbon price, the policy avenue performs best in policy areas where price signals are important determinants of decision-making, and where the transition to a climate-neutral economy is impaired by the relative cost-competitiveness of fossil-based technologies and assets over cleaner alternatives. This is specifically the case with regard to the ability to *deploy proven technologies fully* – here price-signals are very efficient at the margin. High carbon prices can make many solutions cost-competitive and thus support their diffusion. Carbon-price compatible instruments like Carbon Contracts for Difference can complement the ETS and address challenges earlier in the innovation chain where carbon prices may not be sufficiently high to incentivise investments, i.e., in the *demonstration of promising technologies*.[30] In this respect, the policy avenue may be more efficient than others because subsidies are explicitly linked to the carbon price and the cost difference to incumbent technologies – as this difference shrinks, subsidies will automatically be adjusted downwards.

In contrast, the policy avenue performs less well on basic research and early innovations, as here the carbon price does little to remedy R&D related market failures. But this can be easily compensated by additional support schemes and funding basic and applied research. As with its insufficient ability to supporting early innovations, the policy avenue's *lack of certainty and direction regarding technology* and, by extension, the PA's conviction to technological neutrality is a major weakness. First, while not all technological choices should be pre-judged, lack of certainty and direction regarding technology choices and the policies to support innovation can

[29] For a review of ex-post analyses of the effect of carbon pricing on technological change, see Lilliestam et al. (2021).

[30] For the role of carbon contracts for difference to remedy this see Gerres & Linares (2020) and Agora Industry et al. (2021).

jeopardise or slow down the achievement of decarbonisation goals as research, innovation, investment, and infrastructure development is not streamlined. The policy avenue's aversion to narrowing technological choices through standards and the legislative framework beyond the ETS can perpetuate lock-ins into fossil-based value chains. Moreover, while carbon pricing has been shown to be effective for incentivising emission abatement at the margin, using available technologies, there is scepticism about whether it can also incentivise deep decarbonisation and drive structural change, bringing down the costs of abatement options that are currently not viable or competitive.[31]

The policy avenue's performance is equally ambiguous when it comes to *investment*. A stringent ETS with a hard cap effectively disincentivises fossil-based technologies, provided there is persistent political commitment to the instrument. This makes fossil-based assets less profitable over time. It also makes the operation of fossil-based technologies more costly over time, driving the adoption of low-emission alternatives.[32] However, while it disincentivises fossil-based technologies by changing relative prices and provides incentives to shift investment to low-emission alternatives, it does not *prevent investments in fossil-based assets:* for different reasons, market actors tend to operate with a limited time horizon, and therefore may not fully anticipate the future scarcity of allowances over the lifetime of the investment (Knopf et al., 2018; Quemin & Trotignon, 2021). Particularly to investors focused on short-term profits, investments in fossil technologies continue to appear profitable. Clear standards, bans, or sectoral strategies can create more certainty in this respect and provide clearer signals to innovation and investment in the short-term. While the carbon price will (to some extent) guide private investments into lower-carbon alternatives, a weakness of this policy avenue is that, through its focus on private investment, it is less equipped to deliver timely and large-scale public investments required for the transition, especially where due to learning costs and network externalities the marginal abatement cost is substantially higher than the (short-run) carbon price.[33] Public investments are crucial in those areas where the carbon price is insufficient to remedy the risk aversion and liquidity preference of private investors.[34] This is especially pronounced for (energy) infrastructure, where large sunk costs, long lead times and clustered risks limit the scope for private investments, or in areas where chicken-and-the-egg type problems (network externalities) are persistent and public investment is needed to crowd-in private investment. Likewise, public support may be necessary where households' ability to pay and commit capital investments prevents the adoption of low-emission technologies.

[31] For the limited effects of carbon pricing in incentivising technological change as well as more expensive abatement options and hence deep decarbonisation, see, for example, Grubb et al. (1995), Lilliestam et al. (2021), Tvinnereim & Mehling (2018), and Wilson & Staffell (2018).
[32] The correction of relative prices is the prima facie argument for carbon pricing, see Stavins (1997).
[33] As Vogt-Schilb et al. (2018) have shown, optimal abatement *investments* are not necessarily aligned with the lowest cost abatement options (i.e., those that a carbon price would incentivise first). In a dynamic context with a longer time horizon, it may make sense (and be economically efficient) to invest into more expensive abatement options where long-term reduction in GHG requires investment in long-lived abatement capital.
[34] On the relation between carbon pricing and investment in climate policy, see Krahé (2022) and Mason (2021)

Addressing the *infrastructure* challenge is a major weakness of this policy avenue. The main mechanism of the policy avenue is to change the relative prices of different technologies, and thereby the investment calculus, including for infrastructure investment – which is a mechanism not as clearly recognised in the other policy avenue. Yet the aversion of Green Economic Liberalism to government coordination and public investments and the commitment to technological neutrality compromise the policy avenue's ability to develop the right infrastructure for climate neutrality in a timely way: Given its commitment to technological neutrality, the policy avenue is not equipped to support explicit infrastructure choices that will (inevitably) favour certain technologies over others. An open-ended search for the best alternative – which market mechanisms excel at – is less suitable for infrastructure choices, especially under tight time constraints. A further weakness concerns the *transnational planning of infrastructure*, as this requires extensive government coordination and the joint commitment to large-scale infrastructure projects by different states. While market actors are relevant in the delivery and operation of infrastructure, the planning and design of climate-neutral infrastructure of the future is a genuine responsibility of the regulator. A policy avenue that seeks to limit the role of government will therefore struggle to deliver the necessary infrastructure on time.

The policy avenue takes a particular approach to tackling *integration*. It relies on the coordination and signalling function of an economy-wide cap-and-trade mechanism, which allocates the mitigation effort across all covered emitters. For this reason, this policy avenue performs strongly with regards to climate policy mainstreaming. This presupposes a uniform (and sufficiently high) carbon price extending across all major emitting activities and sectors. It should be stressed that this represents a different understanding of climate policy mainstreaming and integration than the other policy avenues, which rely more on legal mandates and mechanisms, such as (sectoral) targets, to ensure that all sectors and emitters contribute adequately to the overall mitigation effort. By implication, the policy avenue is weaker in those areas where the carbon price cannot play a role, or only a very limited one. This is the case with regard to the *integration of investment, innovation, and infrastructure*, which requires stronger coordination and guidance from the regulator. Similarly, the focus on lean government prevents this policy avenue from developing the administrative capacities to accelerate planning, permitting, and implementation of infrastructure and renewable energy projects. While cutting red tape can improve efficiency, a well-resourced and capable administration will be essential. All in all, this makes the policy avenue weak on integration.

Politics of the Green Economic Liberalism policy avenue

The politics of this policy avenue are complicated – both domestically and internationally. However, we consider the political feasibility of this policy avenue to be a moderate strength. On the one hand, the EU ETS covering electricity generation, industry and aviation has been the EU's flagship climate policy instrument and will continue to play a central role in the EU's policy mix. The revisions of the EU ETS as part of Fit for 55 have made it much more stringent, with a cap that will effectively approach zero by 2040. Moreover, a separate ETS 2 for buildings and transport was agreed in 2023, to take effect as of 2027, thereby extending the scope of emissions trading in the EU to cover almost 80% of EU GHG emissions. In this regard, the policy avenue could be seen as a continuation of the EU's existing policy mix. On the other hand, there are several political barriers that question the political feasibility of this policy avenue, in particular since it would require a much more stringent carbon pricing regime sustained over time.[35]

The focus on emissions trading means that this policy avenue aligns well with central elements of the EU's existing policy strategy. With the EU ETS having operated for almost 20 years, emissions trading has broad support within EU institutions and large parts of the business community. With the recent addition of the CBAM and the Social Climate Fund, the EU has expanded its emissions trading architecture to better account for unwanted side-effects on competitiveness and distributional equity, thereby pre-empting possible sources of opposition. Moreover, many economists have argued in favour of carbon pricing instead of other policy instruments (such as standards or subsidies). Given the EU's rich experience in setting-up and operating emissions trading, a ramped-up ETS would thus not present a significant administrative or technical challenge.

Another important political strength of this policy avenue – and one that sets it apart from the other approaches – is that carbon pricing generates revenues that can be used to compensate or assist social groups and industries affected by the transition. The revenues bring a high degree of political freedom for recycling them strategically. The approach for revenue recycling that is most commensurate with Green Economic Liberalism would be to redistribute them in a lump-sum way, yet they could likewise be directed strategically to certain industries or social groups in order to lower political resistance or used to support climate-related investments. In sum, while carbon pricing creates visible and direct costs, the revenue recycling can be used strategically to offset these costs in a way that is unmatched by the other policy avenues.

At the same time, the policy avenue would imply an intensification of existing EU policy as it would require a yet more comprehensive ETS – ideally covering also the remaining 20% of emissions – and the corresponding sidelining of other policy instruments. The carbon price would need to be allowed to rise to much higher levels than currently observed, as it becomes the primary instrument to induce emission reductions. This development may run into political challenges.

First, the political feasibility of sustaining the very high carbon prices that are needed to drive the necessary change may be questioned. This is particularly relevant for the new ETS 2 for transport and building. The negotiations around the ETS 2 bore evidence of the strong opposition to carbon pricing as the central instrument within the Parliament and the Council, resulting in safeguard

[35] With a more stringent carbon pricing regime, we mean an ETS (or several ETS), whose cap is compatible with the EU's climate targets as well as the corresponding market management instruments (such as a Market Stability Reserve) that ensure a well-functioning emissions market. Ideally, this policy avenue assumes a single ETS for all sectors, but presupposes parallel ETS systems for now (i.e., for transport and buildings, and power and industry, plus one for land-use). Given the steep reduction trajectory of the ETS caps already decided, this would clearly imply much higher prices of emission allowances. The political constraints of carbon pricing have been extensively described and discussed in the literature, see for instance Aklin & Mildenberger (2020), Jenkins (2014), and Jenkins et al. (2020).

mechanisms that could allow for discretionary interventions if the price should rise too high. The 2022 energy price crisis served as a reminder of the political sensitivity of rising energy bills, leading many EU member states to introduce temporary price caps on energy, or lower energy-related tax components. This illustrates the political challenges of a policy mix that builds on high carbon prices as the central climate policy instrument.

Second, even when high carbon prices can be politically sustained, there will be challenges and credibility problems. While carbon pricing may be the most cost-effective and thus efficient policy strategy for the economy as a whole, it will still create structural change with all its social consequences. The policy avenue shies away from presupposing outcomes and therefore refrains from proactively managing the transition, for example by actively supporting the reskilling of workers, using regional policy to create alternative industries, or supporting households in the substitution of fossil technologies with clean ones. In this way, the reliance on the carbon price as the central mechanism carries a considerable social and political risk.

Finally, the EU's climate policy has become more heterogeneous and differentiated. While the existing ETS was reformed and its stringency increased as part of the Green Deal, only few still advocate a strategy of "carbon pricing only", but instead argue for strengthening the role of the EU ETS in the EU's climate policy mix ("carbon pricing mainly").

With regard to the international politics of this policy avenue, some tensions will be likely. As the coverage and levels of carbon pricing remain limited among the EU's main trading partners, this policy avenue would need to rely on carbon-border adjustment mechanisms for EU industries to remain competitive, as has been put in place with the EU's CBAM. These would need to be extended in scope, including the need to find a solution for exports from the EU. Further reliance on border adjustment and increasing prices may be perceived as protectionist and thus create trade tensions. In consequence, we assess the international feasibility to be a moderate weakness.

Finally, the socio-economic co-benefits of this policy avenue are mixed, with both risks and opportunities. Carbon pricing can, in principle, lead to economically efficient outcomes, as it ensures that prices fully reflect external costs. So, in theory, it promises to attain the transition to net-zero at least cost, while bringing all its benefits. However, this assumes such prices can be reached and other barriers (political, economic, etc.) overcome. There are serious social risks that must be mediated. Carbon pricing can create social hardship for households that cannot switch to low-emission technologies or change their behaviour. Similarly, carbon pricing will undermine the economic viability of some businesses and sectors. While this is also true of other policy avenues, it creates a larger political risk for GEL: first, for GEL, undermining the economic viability by changing relative prices is an explicit goal and part of the causal mechanism, whereas for other avenues it is an implicit consequence. Second, as other policy avenues (such as GIP) put greater emphasis on fostering particular alternatives for the affected businesses and sectors, they are better equipped to respond to political backlash from these sectors.

4.2.2 Green Industrial Policy

Internal strengths and weaknesses of the policy avenue

The Green Industrial policy avenue performs strong over most assessed indicators because it is based on a coherent industrial strategy that tackles the innovation, investment, and infrastructure challenges in an integrated way. Given its focus on directing and accelerating technological change, it performs very well in terms of stimulating innovation and leveraging investment. Guided by the goal to accelerate the diffusion of clean technologies, it identifies and tackles in a structured way the barriers that may prevent this, including infrastructure. A key mechanism is an integrated industrial strategy, as well as a central institution mandated to develop and implement the strategy (the Mission Coordination Board). Overall, we identified very few inherent weaknesses in GIP, which can be partly explained by our assessment framework, as we explain above. The main challenges for the feasibility of GIP are of a political nature, including the need for a sustained commitment to provide the necessary funding.

Innovation is a major focus of the GIP policy avenue and its primary strategy for reaching climate neutrality. The policy avenue includes elements to tackle the entire innovation chain, from base research and invention to diffusion. The need to tackle innovation through both demand and supply side instruments is now widely acknowledged in the literature.[36] It does so by providing a clear *direction and certainty about the direction of technological change*, through standards and a "mission framework" that identifies and prioritises areas of technological change. It aims to create an effective innovation ecosystem that involves both public and private stakeholders and to provide sufficient funding e.g., through the establishment of a large EU "Transformation Fund" that bundles the different EU funds. The policy avenue includes broad support for research and development, combined with more targeted support for promising inventions in the demonstration and piloting stage to move them up to higher levels of technological readiness. Likewise, GIP is well positioned to overcome the challenges related to the *deployment of new technologies* by combining supply-push with demand-pull measures and using both sticks (standards) and carrots (subsidies). However, as any solution that relies on subsidies, it faces the risk of timely phase-out of support when it is no longer required, potentially creating inefficiencies, rent-seeking and subsidy dependence.[37] Lastly, in terms of *exnovation* of fossil-based technologies, while GIP acknowledges the challenge, its primary focus is to bring clean alternatives into the market. Compared to other policy avenues, GIP therefore provides a less defined response to the issue of phasing out incumbent technologies.

In the area of *investment and finance*, GIP is especially strong in *mobilising* both public and private *investments* for a sustainable transition as well as *addressing information-related market failures*.

[36] For a comprehensive review of induced technological change in energy systems, see Grubb et al. (2021). For a theoretical introduction to the role of industrial policy for the green transition, see Criscuolo et al. (2023).
[37] This risk naturally depends on the exact design of the support schemes and could be mitigated through the use of dynamic and variable subsidy designs, as is the case with Carbon Contracts for Difference, for example.

It employs a mix of subsidies, tax credits, and loan guarantees to incentivise private investments, while also making large, direct public investments. It moreover uses green public procurement to create demand for low emission products and mobilise associated investments. Moreover, government action is considered effective in mandating transparency and directing investments towards sustainable sectors. When it comes to *preventing investments in fossil-based assets*, GIP relies on standards, the existing ETS, and prudential regulation to discourage fossil-based investments. However, as it lacks tools to address the continued profitability of fossil assets, this is a weak spot that is addressed better in other policy avenues.

When it comes to *infrastructure*, the policy avenue's rather pro-active and affirmative role of the state is beneficial, resulting in an overall strong assessment. The industrial strategy and corresponding identification of infrastructural needs reduce uncertainties for private investors. There is moreover a clear acknowledgement of the need for administrative capacity to accelerate planning and implementation of infrastructure. *Delivering sufficient and timely investments* is a strength of the policy avenue because it significantly reduces uncertainties for private investors through deliberate technological choices and commits direct investment or crowds in private investments through the Transformation Fund. The Mission Coordination Board helps to create a strong and binding framework for *transnational infrastructure planning*. The "missions" that are focused on certain sectors and the rapid replacement of fossil assets by clean ones, pre-empts chicken-and-egg problems where technology and infrastructure are mutually dependent. GIP acknowledges the need for high administrative and planning capacity and proposes the establishment of an intra-institutional body such as the Mission Coordination Board. However, the effectiveness of such an institution depends on the balance of power between the EU institutions and Member States, leaving the potential for national interests to prevail over a pan-European approach.

With the EU industrial strategy as a guiding framework and the establishment of an executive body such as the Mission Coordination Board, the policy avenue performs fairly well on integration, fostering the cooperation of different branches of public policy in a whole-of-government approach. However, as the name suggests, the avenue is most suited for industrial emitters, or more generally those emissions sources that are amenable to be addressed by industrial policy and support of clean technologies. This creates a risk that some sectors – or mitigation options within sectors – are not covered adequately, i.e. instances where technological solutions are limited or where industrial policy tools cannot reach, but where behavioural changes or a reduction of activity levels may be necessary. In particular for the agri-food sector and mobility, this means that the policy avenue is not well-equipped to address non-technological mitigation options. Moreover, one may argue that the focus on fostering particular solutions creates a risk that industrial policy overlooks constrains or biases competition among them. For these reasons, GIP scores weaker in mainstreaming climate policy across all areas of policy. The industrial policy approach that tries to tackle all challenges involved in the transformation of a given sector means, however, that the policy avenue is strong when it comes to aligning innovation, investment, and infrastructure development and reaping the potentials of sector coupling.

A major risk of this policy avenue is the over-reliance on some form of central planning. It is questionable whether or not the EU institutions will be able to coordinate an effective industrial strategy that is flexible and dynamic. Likewise, the close public-private coordination, large public investment and subsidy programmes, and also the use of standards bring the risk of regulatory capture.[38]

Politics of the Green Industrial Policy avenue

The politics of the Green Industrial Policy avenue are challenging. All in all, we consider the political feasibility of this policy avenue to be a moderate weakness. However, its international attainability and socio-economic benefits can be considered relative strengths.

The EU currently relies on a policy mix that seeks to promote the adoption of greener technologies and, by extent, supports the development of green industries. The Green Deal is explicitly framed as a strategy to transform the EU into "a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050" (European Commission, 2019a, p. 2). However, as argued in the previous chapter, vertical industrial policy – the targeted promotion of selected sectors – has not featured prominently in EU policy. Instead, EU rules and institutions were primarily geared at safeguarding competition in the single market, constraining industrial policy at member state level (e.g., via state aid rules), which for a long time also foreclosed the development of an EU-level industrial strategy. The historically developed EU climate policy mix can therefore not be considered as a coherent industrial strategy, as described in the Green Industrial Policy avenue. While the political momentum is currently relatively supportive of a shift to this policy avenue, there are several political challenges.

The Achilles heel of the Green Industrial Policy Avenue is the requirement for sustained and significant public funding, in the form of public investments or support to private investments. The policy avenue would see (public) investments in a low-emission economy rising substantially. This would necessitate more financial resources, as well as commitment to provide them in the future. If the EU was to administer these funds directly, this would likely also require additional fiscal capacities for the EU.[39] Yet the EU has struggled to agree on additional funding, let alone a fiscal capacity, for many years. This could recently be observed, for instance, with regard to the Recovery and Resilience Facility proposals for common borrowing, which did meet fierce resistance, especially among powerful member states such as Germany (Chazan & Fleming, 2022). Similarly challenging is the reform of the fiscal rules that apply to member states, which would allow them to borrow more to finance the transition. Reforms of the Stability and Growth Pact that would allow more investments have proven very difficult (Fleming et al., 2023). EU

[38] Government failure and regulatory capture are central critiques of industrial policy. However, they are widely acknowledged in the literature on industrial policy and the risks can be effectively mitigated. See, for example, Rodrik (2014) and Tagliapietra & Veugelers (2020).
[39] The need for a reform of the EU's fiscal rules and an EU-wide fiscal capacity has been widely discussed in recent years. See, for example, Baccianti & Steitz (2022) or Darvas & Wolff (2021).

investments in the transition are expected to decrease in the medium-term (Pisani-Ferry et al., 2023).

Recently, the EU proposal for the Green Deal Industrial Plan (GDIP) highlighted these difficulties. The investment arm of the GDIP – the Sovereignty Fund, now labelled Strategic Technologies for Europe Platform – would have merely repackaged existing funds (Bourgery-Gonse, 2023) and it increasingly becomes clear that there will be little new funding. Instead, the Commission loosened the State Aid Framework, allowing member states to increase support to their industries. This in turn created tensions among member states, as some have more budgetary space to support their industries than others. Relying on state aid rather than EU-level funding therefore risks fragmentation in the single market and, consequently, a fragmented transition (Jansen et al., 2023).

The Green Industrial Policy would require ramping up the industrial policy competencies and powers of the EU. This would likely also imply a greater centralisation of competencies in the field of industrial policy: In principle, it would be more coherent and efficient if the EU coordinated an industrial strategy rather than if such policies were developed and implemented in the national capitals. Yet it is debatable if the EU possesses the administrative capacities to do so. It is even more questionable whether member states would be willing to concur to the EU the powers and competencies that a more vertical industrial policy would require, since this would also involve decisions to support a certain industry in a given location – and therefore not in other locations. In light of these considerations, member states could resist a greater Europeanisation in this realm and instead prefer to see the EU limited to horizontal industrial policy.

Connected to this, it will be doubtful if there will be sustained political support for the interventionist turn that this policy avenue implies. Faced with the threat of the 2020 pandemic and the 2022 energy crisis, governments across Europe have intervened much more strongly in the economy than in the years or decades before, and stakeholders and the electorate have been much more willing to accept such state interventions as an element of public policy. Yet there also remains a strong undercurrent of opposition to such government intervention (outside acute emergency situations).

When it comes to public support, this policy avenue may be more promising. A core mechanism of the policy avenue is to accelerate technological change and in the process drive down costs of low-emission alternatives, including through deployment subsidies. While this approach also incurs a cost, these costs and their distribution may be less visible than is the case under a policy avenue that centrally builds on high carbon prices (i.e. GEL). Also, the policy avenue's main emphasis is to support new technologies and make them widely accessible, with less of an emphasis on phasing out existing technologies, but rather the expectation that incumbent technologies will be pushed out of the market by new, cheaper, and better alternatives. Developing new and green industries also creates corresponding potentials for employment, which may further elicit public support. Similarly, when it comes to the mobilisation of interest groups, the policy avenue may have a more favourable political economy. Since it creates concrete rents to green industries, it builds political coalitions that support the policy avenue.[40] However, this also brings major risk related to rent seeking and regulatory capture, which this policy avenue must mitigate carefully with the design of its support schemes.

The international politics of this policy avenue are also not easy. Support schemes and standards can – yet do not need to – be structured in ways that favour European producers. This can be perceived as protectionist and result in trade tensions with third states – also with allies – as the discussions about Chinese state support to EVs and offshore wind[41] and the USA's Inflation Reduction Act show. Yet, depending on the design, there may also be opportunities: Given that the USA has been moving towards an industrial climate strategy, there may be more opportunities for international cooperation than there is on matters of carbon pricing. Given the political momentum is moving towards industrial policy internationally, and the possibilities for designing support measures in ways that allow for international cooperation we consider its international attainability a relative strength overall.

The socio-economic co-benefits of this policy avenue are not completely clear-cut but considered a moderate strength overall. The strong support for green technologies and industries, as well as the strong focus on innovation and technological change, will create opportunities for jobs in this field. Conceivably, the strategy will support the long-term competitiveness of the EU economy and allow it to assume or defend its technological leadership in key technologies needed for the transition to climate neutrality. However, the substantial support for businesses may also create new economic inequalities and may come at the cost of households. However, these risks can be limited if there are effective strategies for sharing the costs of the support schemes with the private sector, such as corporate taxation, governments taking stakes in companies, or through new approaches to sharing the intellectual property created.

4.2.3 Directed Transition

Internal strengths and weaknesses of the policy avenue

In general, the Directed Transition approach performs well across all challenges: only two weaknesses (score 2) and no major weakness (score 1) were identified for the assessed indicators. This reflects the main policy mechanism of this policy avenue (see Chapter 3), which ensures emission reductions by direct state intervention. It makes use of strong regulatory instruments such as binding targets, bans, and standards, and deploys strong coordination to select transformative technologies and put in place the necessary infrastructure in time. However, while this approach may be effective in bringing down emissions across sectors, it comes with

[40] The importance of building political coalitions for long-term climate action is centrally acknowledged in the literature, see Meckling et al. (2015).
[41] The EU filed a World Trade Organisation complaint and investigation into Chinese state support for EVs and is considering a similar probe into Chinese wind technologies. See Hancock et al. (2023) and Hancock & Bounds (2023).

different risks and challenges, which are summarised below on the basis of our detailed assessment.

Stimulating *innovation* can be considered an overall strength of the Directed Transition PA. The PA provides clear signals to the market regarding the direction of innovation, including by making an explicit selection of the most promising technologies to deliver the transformation. The selection is based on both scientific insights and periodical evaluation of policy instruments used and strategic choices made. This may lead to some friction between the need for a clear long-term goal, the accompanying pathway, and the need for short-term adaptation and flexibility. But for the selected technologies, the Directed Transition provides sufficient and early support, making use mainly of large-scale public R&D funds. In doing so, it incurs a risk of misallocating public funds, if technologies do not live up to expectations: yet this risk and the related costs are considered acceptable given the need for a fast transition. However, the policy avenue does not fully recognize the associated risk that selecting technologies at an early stage could hamper the development of other ones, create path dependencies, and lead to inefficient outcomes (Kärnä et al., 2020).

In the demonstration phase of new technologies, moreover, the provision of sufficient public funding remains the main strategy for the Directed Transition. In the last phases of the innovation cycle, involving commercialisation and market penetration, strong instruments such as standards are deployed to mandate the use of the new technologies and discourage incumbent ones, including through the use of explicit phase out dates for fossil-based technologies and value chains. One potential risk here is that mechanisms for deployment support, such as subsidies, are underdeveloped in the PA. A particular strong point of this policy avenue is that it considers enabling conditions such as necessary infrastructure across the innovation phases, including the timely replacement or re-use of fossil-based infrastructure.

On *investment*, the Directed Transition policy avenue delivers mixed results. It is particularly strong with regard to phasing out investments in fossil-based assets. However, it is less well equipped to mobilise private investments or to direct public investments. Its focus is geared towards targets and standards, with less consideration for how to deliver the investments needed to reach these targets. Compared to GIP, investments play a much smaller role in the policy avenue's strategy. While the policy avenue acknowledges the need to support novel technologies and bring them to maturity, this strategy bears the risk that investments do not always work out as anticipated, because the supported technologies may turn out to be inefficient or ineffective in hindsight, leading to financial risks for the state.[42] This is clearly a weakness of the policy avenue. As the Directed Transition mandates a phase out of fossil technologies through bans and

[42] There are three distinct but related risks here. First, the risk of overcompensating certain technologies and firms, and thus the inefficient allocation of (public) resources. Second, the risk of rent-seeking behaviour and regulatory capture, which may cause the first risk. Third, the risk of supporting the wrong technology, which can be the result of regulatory capture, but could also result from insufficient information a false perception of risks and benefits or the like. All in all, these can be summarised as forms of "government failure" (Helm, 2010).

standards, it is well positioned to disincentivise any further investments in those fossil technologies.

Compared to the preceding two policy avenues, Directed Transition relies much less on markets and private initiative to achieve its objectives. Therefore, private investments are also not very central in the Directed Transition policy avenue, possibly underestimating their role for advancing the transition. The policy avenue acknowledges the need for transparent financial flows, for instance through prudential regulation of banks, but as it does not focus on private investments the regulatory solutions to achieve this remain underdefined.

With its focus on standards and cross-sectoral roadmaps, the Directed Transition PA is overall well-positioned to deliver the necessary *infrastructure* in time. The roadmaps provide clarity and certainty for investments into infrastructure, as they deliver clear orientation for which infrastructure will be needed. Indeed, this policy avenue is particularly suited to solve the chicken-and-egg type coordination problem (related to demand and supply waiting for each other to develop), by creating deliberate path dependencies. Additionally, specific targets for Transmission System Operators (TSOs) and Distribution System Operators (DSOs) will help them to plan their investments in energy infrastructure in time. Infrastructure is funded by both private and public channels, possibly also at EU level, but it remains unclear how sufficient funding should be guaranteed. As the Directed Transition presupposes a capable administration with sufficient coordination and planning capacity, it is relatively strong in accelerating planning and permitting procedures for infrastructure. However, it is not a given that this strength also trickles down to the implementation phase, as procedures within a large administration may also be slow and bureaucratic. Finally, although Member States have a strong role in the implementation of this policy avenue, the EU still provides guidance about the overall direction. The Directed Transition therefore delivers well on a binding framework for transnational planning for infrastructure at EU level.

The ability of the Directed Transition policy avenue to provide the necessary *integration* balances different aspects. On the one hand, the policy avenue builds heavily on binding legislative instruments based on scientific input, such as targets and standards, and on strategies, including planning of sectoral roadmaps and infrastructure. This implies an administration that can bring together information from different sectors, coordinate amongst them, and devise and adjust appropriate legislation. It means that the Directed Transition PA is relatively strong in mainstreaming climate policies in relevant policy areas and in facilitating sector coupling, including the coordination of investment, innovation, and infrastructure. On the other hand, the policy avenue is less well-equipped when it comes to translating these strategies and roadmaps into concrete policy measures. Furthermore, the implementation of all these instruments and strategies is largely delegated to regulators and other agencies, mostly at the Member State level. Given the high ambitions of the policy avenue, there is a risk that the implementation will get stuck as the high number of detailed prescriptions overwhelms the capacity of regulators, particular as they are required to coordinate efforts across sectors and across governance levels. Consequently, there is a clear risk of government failure in this policy avenue, scored as a weakness of the Directed Transition policy avenue regarding the administrative and institutional capacity.

Politics of the Directed Transition policy avenue

Although elements of the Directed Transition policy avenue have been present in the EU's climate policy mix and continue to play a role (see Chapter 3), the feasibility to drastically ramp up the role of such instruments appears questionable, given fears of regulatory overreach.

Standards and de-facto bans are part of the EU's climate policy-mix – such as the agreed ban on selling new combustion engine cars. Yet the policy avenue would imply a much stronger role for state institutions in directing and orchestrating the transformation to climate neutrality. This would mark a departure from the current state of EU climate policy, which is centred around market mechanisms, yet more so with the adoption of the Fit for 55 package. Mobilising the political majorities for a move towards a much more state-centred, directed transition therefore seems questionable. Adherence to science as a basis for deriving emission targets may be less contested. But the Directed Transition approach requires to translate such emission targets into concrete technological or economic prescriptions, which are much less unequivocal and therefore bound to be contested much more severely.

Giving a more central role to governments and public agencies will also challenge the institutional set-up of the EU. A more affirmative role of the EU – and in particular the European Commission – will plausibly be challenged by Member States. In addition, the European Commission, with its relatively limited administrative apparatus, would soon run into troubles if it was endowed with more competences and tasked with much more detailed regulation. The policy avenue therefore assumes that most of the implementation burden would be carried by the Member States. But given the different levels of administrative capacity and ambition across Member States, delivering the Directed Transition in a decentralised fashion might easily result in a heterogeneous and divergent implementation across Member States, both given the pace of the transition and the priorities for implementation.

Another risk of this policy avenue is the risk of government failure. Public authorities would be instrumental for developing, planning, coordinating, and implementing all the regulatory instruments that form the core of this policy avenue, to keep the instruments aligned and adjust them in a responsive and timely manner. As argued above, it will be questionable if the EU and the Member States will have the administrative capacity to conduct such a detailed management of the transformation. The risks for government failures are acute – not only of government agencies taking the wrong choices, but also of getting bogged down in this herculean task.

As for public opinion, the scientific basis of this policy avenue could be a positive aspect of the Directed Transition, as it offers a clear, independent yardstick and legitimacy for ambitious climate action. At the same time, forcing the phase-in of new technologies and the phase-out of incumbent ones through standards and targets may trigger opposition for being overly prescriptive, all the more so if it results in increased costs or reduced convenience. While the resulting opposition could be accommodated, e.g., through targeted assistance, this further complicates the (already considerable) challenge of governing the transformation. All-in-all we therefore consider the *political attainability* of the Directed Transition PA a serious weakness.

Likewise, the policy avenue brings some international risks. Cooperation and regulatory alignment with third countries will be very difficult. Also, adoption of the Directed Transition may be resisted by the EU's main trading partners, who would find themselves confronted with many new product standards and other export limitations. The EU may be accused of being protectionist with corresponding retaliatory measures. Therefore, also the *international context* is not very supportive of this policy avenue.

Lastly, because the Directed Transition is focused strongly on delivering climate neutrality in time, it runs the risk of side-lining *other socio-economic goals*. As mentioned above, standards and bans may incur high adjustment costs for citizens. Likewise, the massive public funding needs to be financed, either increasing the fiscal burden or leading to cuts in other public services. At the same time, positive side-effects may arise in the form of job opportunities in technology sectors and the public administration.

4.2.4 Sufficiency and Degrowth

Internal strengths and weaknesses of the policy avenue

The fourth policy avenue, Sufficiency and Degrowth, differs from the other three in many respects. It challenges some main assumptions of the current economic system, including its focus on economic growth and the positive connotation of (technological) innovation. Therefore, the indicators used may be interpreted in some cases as biased against this policy avenue. Also, while the policy avenue is well-defined at the level of its political philosophy, the concrete policy solutions that this approach entails are less evident. In some areas it therefore remains unclear how S&D would address a certain challenge, as neither the literature nor its principal paradigm allows deriving a concrete strategy for an S&D approach. This complicated the scoring in some instances, especially for the indicators related to infrastructure, where this uncertainty on the proposed solutions was translated in low scores. Overall, the policy avenue shows substantial weak spots, mainly in sector coupling and integrating innovation, investment, and infrastructure, but also some particular strong points, for instance in phasing out fossil technologies.

On *innovation*, the Sufficiency and Degrowth policy avenue shows a mixed picture, originating from its particular stance towards innovation, which is different from that of the other three policy avenues. In contrast to those, S&D does not assume a strong need for technological innovation to achieve the transition, and instead focuses more on decreasing consumption and changing behaviour. It therefore prioritises social innovations, encouraging and creating social momentum for low-carbon lifestyles and behavioural change. However, while it can be doubted if this conception of innovation is adequate and sufficient, within the confines of the concept S&D is largely able to provide clear signals on what types of innovations are needed. Also, its ability to select and further develop early innovations can be considered a (moderate) strength, although it is less clear how the necessary funding should become available.

During the later stages of the innovation cycle, dealing with demonstration and commercialisation, the shortcomings of the S&D policy avenue are more apparent. The lack of a clear policy framework for supporting innovation as well as its overall scepticism towards technological solutions for the transformation render this policy avenue less fit to deliver such solutions at scale, and to enable their market diffusion. The selection of technologies is driven by the overall philosophy of the policy avenue, for instance its focus on a low-consumption lifestyle: rather than seeking the most efficient way of delivering a certain good or service (heating a square metre or traveling a kilometre), it also includes an assessment of the underlying need (the square metres that need to be heated or the kilometres that need to be travelled). However, while this different approach broadens the spectrum of available solutions, many of these solutions are not easily mobilised through the market (at least at the scale and pace needed), since they lack alternative business models that would support them.

There is, however, one aspect of innovation where S&D performs strongly: disincentivising fossil-based technologies and supporting exnovation. Phasing out fossil technologies is a core element of this policy avenue, and is implemented through a variety of instruments, such as the elimination of fossil subsidies, technology bans, as well as the general orientation of the policy avenue to decrease fossil-based consumption.

As with innovation, the S&D policy avenue also treats *investment & finance* fundamentally different than the other three policy avenues. A core tenet of S&D is that GDP growth is driving environmental impacts and climate change and must be decoupled from resource consumption and emissions. S&D therefore pursues a (focused) reduction in economic output, i.e., consumption and production, by shrinking those parts of the economy that drive environmental degradation. Yet investments – especially private ones – depend on profit expectations. The deliberate and explicit goal to limit economic growth can therefore be expected to depress private investments, and over time may also affect the tax base that is available to pay for public investments. This approach, however, lacks a clear strategy on how those investments that are necessary for the transformation to a low-carbon society, such as infrastructure, public services, energy efficiency, or renewable electricity generation, can be exempted from the overall more restrictive stance on investment activity. The policy avenue does not provide a clear plan to mobilise such investments, which we consider a weakness. It is, however, much clearer in its approach toward disincentivising investments in the fossil sector, as it adopts strong regulatory measures to phase out fossil technologies. As S&D is sceptical towards the role of (financial) markets in the transition, it could mandate financial institutions to publish and carry out transition plans as well as to increase the transparency of their financial flows, which we assess as a strength of this policy avenue.

Providing the *infrastructure* needed for the transition towards a climate neutral society is an overall weak spot for the S&D policy avenue. As it focuses on reducing consumption, behavioural change, social equity, and local governance, it does not provide clear guidance on which of the existing infrastructure will still be needed, how it could be transformed, and how the roll-out of new infrastructure could be coordinated and funded. Some types of infrastructure would clearly be compatible with (and needed for) the transition that the policy avenue seeks to bring about, in particular infrastructure for public or non-motorised transport, but less so for electricity grids in general or electric charging infrastructure in particular. For these, it does not provide clear guidance on the types and quantities of infrastructure that would be needed. Neither does the policy avenue provide clear guidelines for how to handle (or accelerate) planning and permitting of infrastructure projects, which we consider a further weakness. Since S&D favours local governance and community-based solutions, it is unlikely to develop a European-wide planning or coordination of energy and transport infrastructure. Overall, we regard infrastructure as a weakness of S&D.

Also on *integration*, the policy approach emphasises the locally rooted and participatory forms of governance and bottom-up initiatives at community scale. While this may serve to increase social acceptance or even support, the lack of top-down coordination (and the lacking acknowledgement of the need for it) constitutes a weakness. For mainstreaming climate policy across relevant policy areas, one could argue that the general focus on developing societal wellbeing within planetary boundaries serves as a de facto mainstreaming principle, which is why we consider this aspect a (moderate) strength of the policy avenue. However, in the integration of innovation, investment and infrastructure, the policy avenue clearly does not perform well. Since it largely lacks a strategy for industrial decarbonisation, technological innovations or the infrastructural requirements of an increasingly electricity-based energy system, it lacks clear mechanisms to coordinate these three aspects. In the same way, it does not provide any instruments to explicitly enable the coupling of different sectors or to set up cross-sectoral governance, as it focuses primarily on sectors and activities that are more amenable to behavioural change and bottom-up governance. We consider this a strong weakness of the S&D policy avenue.

Politics of the Sufficiency and Degrowth policy avenue

More than any of the other policy avenues assessed, Sufficiency and Degrowth would entail a significant departure from the current EU policy and institutions, not only in terms of climate policies, but also regarding the general orientation of (economic) policy. Adopting S&D would imply moving away from economic growth as a core objective of public policy and a way of delivering social progress, from GDP as a central indicator of wellbeing, but would also more generally limit the role of markets as a central coordinating mechanism. Such a fundamental structural changes is likely to be opposed by many social groups, and especially by business, and most political fractions except "deep-green", ecology-minded parties.

Mobilising widespread public support for this paradigm change would therefore be a challenge, as it would entail finding different ways of satisfying human needs – which, in a more traditional understanding, means a reduction of consumption levels. Likewise, the strong government interference in personal choices is likely to attract resistance.

More so than in other policy avenues, both the EU's policy acquis and institutional set-up would need to undergo a fundamental overhaul to realise S&D. Also, this reform need would go far beyond the domain of traditional climate and energy policy but would need to address much broader questions of economic governance. However, it is not always clear exactly what would need to be reformed, as the policy avenue does not deliver very concrete ideas on the role of national and European administrations or the preferred development of certain economic sectors. In general, therefore, we consider the *political attainability* of this policy avenue a major weakness.

Although political leaders in the EU and elsewhere have repeatedly questioned GDP as an indicator of progress and its growth as an overriding policy objective, such considerations have much less traction in day-to-day policy making, and the EU – as the rest of the world – tends to give high priority to economic (i.e. GDP) growth. As a minor positive aspect, some international actors might appreciate a policy shift in which the EU assumes greater responsibility for the environmental footprint of the goods it consumes (and imports). Even so, we regard the *international attainability* of S&D a weakness.

According to the premises of the S&D policy avenue itself, its main advantage is that it *delivers on other socio-economic goals*, other than the transformation to climate neutrality. If successful, the S&D approach would lead to a society of sufficiency, living well within the planet's boundaries and minimising pressure on the environment. Because of lower consumption, there may be less need to work and earn money, improving the work-life balance and reducing associated challenges, such as (mental) health and overall well-being. However, these developments are highly uncertain. Critics of degrowth point out that an (explicit or implicit) contraction of economic activity, will also put social welfare systems, redistribution mechanisms and most public services under pressure, which have been designed to depend on economic growth. Notwithstanding this intrinsic uncertainty, we consider the (albeit uncertain) implications of S&D in other socio-economic areas a strength of the policy avenue.

4.3 Ability of the policy avenues to close the transformation gap

After summarising the results of our assessment for each policy avenue, in this section we discuss their relative strengths and weaknesses regarding the 4i challenges: innovation, investment, infrastructure, and integration.

4.3.1 Innovation

The innovation challenge requires, on the one hand, the development and deployment of technologies that accelerate the decarbonisation of the economy and, on the other hand, the phase- out of emission-intensive technologies and value chains. Each policy avenue approaches these issues in a different way. Our assessment finds some strengths and weaknesses in each of the approaches.

The policy avenues that use explicit support schemes and standards to direct technological change are best at providing clarity and direction in terms of innovation needs. In this context, the GEL approach, characterized by its hands-off and technology-neutral nature, is perceived as the least robust. Although it can be doubted if regulators are well equipped to take the right (technological) choices, the alternative – leaving it to the market to filter out the best solutions and thus provide direction for innovations – is unlikely to deliver in the short time available. Furthermore, market failures related to R&D as well as the valley of death may persist. GIP, DT, and S&D, in different ways, provide greater clarity by setting up processes to determine which technologies should have a prominent role, and through which mechanisms they should be supported. These more state-centred approaches, however, carry the risk of making the choices that turn out to be excessively costly – or even fail to meet the expected targets. Control and monitoring mechanisms, as well as competitive screening and selection, and competitive processes can mitigate this risk at least partly. Among these three policy avenues, GIP offers the most sophisticated, integrated strategy, which includes mechanisms to involve and coordinate various public and private stakeholders, and which combines the use of both state support and competitive market mechanisms.

The path to introduce new technologies to the market comprises several stages, each presenting its own set of risks and challenges. In this context, the GEL approach, which complements the carbon price incentive with market-compatible instruments like carbon contracts for difference, proves to be better suited for efficiently supporting the later stages of innovation, particularly the commercialisation and deployment of new technologies. The approach is less suited, however, for the initial stages, where the prevailing market failures (such as R&D spillover effects) are not remedied by the carbon price. However, this could be remedied by the use of ETS revenues for RD&D funding.[43] Conversely, the S&D approach to innovation is primarily focused on social aspects and reducing consumption and may consequently be ill-equipped to support technological innovations at early stages. Moreover, it lacks specific guidance on navigating technologies through the more difficult stages of their commercialisation.

Both the GIP and DT policy avenues propose adapted strategies and instruments to address each innovation stage effectively. The GIP places a stronger emphasis on innovation and aims to systematically tackle all challenges that may arise along the innovation chain, including future infrastructure requirements, placing it ahead of the other PAs. Meanwhile, the DT policy avenue adopts a more technology-specific and interventionist approach, relying on standards to

[43] This is already part of the EU's current climate mix with, for example, the Innovation Fund.

accelerate the deployment of existing technologies. Because both approaches are more open to supporting specific types of technologies (through standards or financial support) they are more likely to bring technologies to higher levels of technological readiness (TRL).

Finally, exnovation, particularly the phase-out of fossil fuels, is addressed in all policy avenues, yet the different strategies they embody differ in the clarity and strength of the signal they send. The strength of the GEL approach lies in its ability to encourage early substitution towards less carbon-intensive alternatives (e.g., transitioning from oil to gas) and later, as carbon prices increase, towards carbon-neutral alternatives. However, while sufficiently high carbon pricing will ultimately render fossil-based technologies uncompetitive, this does not prevent the installation of new fossil-based technologies in the meantime, particularly if myopia or short-term profit orientation limit the planning horizon of the investor. For these reasons, carbon pricing alone may not be able to prevent a lock-in into fossil-intensive technologies. GIP places substantial confidence in new technologies to replace existing ones, relying on standards and carbon pricing. Nevertheless, the approach generally puts much more emphasis on phasing-in clean technologies and making them cheap, than on actively phasing out fossil technologies. The risk associated with this strategy is that the incumbent technologies – favoured by the existing infrastructure and business models and supported by vested interests – remain attractive for consumers and investors.

The more interventionist policy avenues, DT and S&D, may be better equipped to effectively address short-term phase-outs. DT takes a coordinated and directed approach, establishing clear phase-out dates in addition to removing subsidies. Meanwhile, S&D prioritises the direct ban of fossil fuels (and fossil fuel technologies) and, moreover, assumes an absolute reduction in energy consumption.

4.3.2 Investment

To address the investment challenge, the policy avenues must deliver on three crucial issues: (i) undertake public investments and incentivise private investments in the transition; (ii) prevent investments in fossil-based assets; and (iii) address information-related market failures that undermine efficient financial markets and the tracking of financial flows. Overall, Green Industrial Policy performs best on the investment challenge, reflecting the strong focus of this strategy on (public and private) investment. The other policy avenues show more mixed results, all having difficulty in mobilising sufficient investments, but being similarly strong at discouraging investments in fossil technologies.

The scores on the different investment-related indicators are an expression of the profoundly different views towards the role of investments in the transition. For GIP, directing investment towards clean economy assets and technologies is a central focus, and the primary strategy for achieving climate neutrality. The other approaches see investments in a more subordinate role. GEL focuses on correcting price signals as a way to redirect investment flows. DT sets clear targets and standards, expecting investment to follow the path mapped out by regulation, while S&D

wants to restructure the economic system, with a substantially different role for investment. These different views on the centrality of investment give rise to different instruments and strategies.

Relatedly, there are very different views on the respective roles of private and public investment. GEL mostly relies on private investments and foresees public investments only where market failures and barriers would prevent private investment. Indeed, private investments are a major driving force behind the transition in this policy avenue, incentivised by the carbon price. While revenues from carbon pricing could be used to support investments, the preferred strategy is to compensate households through lump-sum payments so as to not distort the carbon price signal. Here, the question is whether the carbon price is sufficient to mobilise the necessary investments given the existing non-price barriers and other market failures (such as myopia, incomplete information, etc.).

Green Industrial Policy – in contrast – is much more open in its approach and formulates a strategy where private and public investments act together, rather than in opposition. It puts public investment into a central position to direct investment flows and "crowd-in" private investments, as we describe above. Directed Transition by contrast puts less emphasis on public and private investments overall. Sufficiency and degrowth sees no substantial role for private investments, and its strategy on public investments builds centrally on the reallocation of resources from dirty to clean sectors.

Likewise, the four avenues show major differences when it comes to preventing fossil-based investments. For GEL, the carbon price set by the EU ETS should disincentivise further investments in fossil assets and technologies, by changing the expected revenue streams and profits from such investments. Yet as long as fossil investments are still profitable in the short term, or if investors have reason to doubt the commitment of the regulator to tolerate future carbon price increases, there is nothing to stop private parties from investing into fossil assets. Similarly, households may lack the information, tools and foresight to adequately incorporate the carbon price signal into their decisions, and as a result may choose to invest into fossil appliances, such as gas boilers. GIP lacks a clear approach to preventing investments into fossil assets: its primary approach is to ramp up investments into clean technologies, in the expectation that this will obliterate the need for fossil investments and lower the costs of fossil-free alternatives. By contrast, DT and S&D explicitly ban investments into fossil-based assets and technologies.

The policy avenues converge with regard to information-related market failures. While all policy avenues offer tools to address these, they attach different degrees of relevance to the issue. For GEL, remedying market failures so that financial markets can function efficiently is very important. GIP foresees an active and supportive monetary policy, including on prudential regulation. For DT and S&D, however, the instrument is clearly secondary.

4.3.3 Infrastructure

As indicated in Figure 5 (page 77), the assessment of the strengths and weaknesses of the four avenues is most pronounced for infrastructure, where Green Industrial Policy and Directed Transition perform better than the other two. For these two, all four indicators assessed are considered a moderate or a major strength, while for GEL and S&D, they all reflect a moderate or major weakness. This particular result reflects the premise that the roll-out of the necessary energy and transport infrastructure for the transition to climate neutrality within the time available requires a substantial amount of planning and coordination, which can only be delivered by public agencies with sufficient administrative capacity and funding.

At a more detailed level there are more nuances to how the four PAs address the transformation gap for infrastructure. To realise infrastructure projects, large up-front investments are needed, which will only deliver a return in the long term. Private investors are mostly reluctant to take up large infrastructure projects unless they are derisked or otherwise supported by the state. The carbon price generally shortens the payback period for investments into clean infrastructure (and makes fossil-based infrastructure less attractive), but it does not provide investors with sufficient guidance on which type of clean infrastructure will be needed in the long run. Changes in market design, such as nodal pricing on electricity markets, may provide additional incentives for infrastructure investments (e.g. investing into transmission capacity to exploit price differentials), but by themselves will not be sufficient to drive and coordinate infrastructure expansion. This still requires explicit guidance and planning by administrations at EU or Member State level (depending on the scale of the project). For this reason, GEL lacks the tools to provide timely and sufficient investment into green infrastructure. GIP and DT are less shy to entrust public agencies with a mandate to identify and plan the necessary infrastructure and the resources to coordinate its roll-out. They differ in the mechanisms to deliver this, with GIP using public funding as a way to leverage private investments, for instance through a Transformation Fund, while DT relies mainly on direct public funding of infrastructure projects.

Another aspect of the infrastructure challenge is that decisions are not technology-neutral, and have long lead times. This means that in the short-term decisions need to be taken on which types of green infrastructure will be needed for the long term. New energy or mobility technologies will not scale up unless there is sufficient certainty (or at least a strong expectation) that the necessary infrastructure will be in place, and investors will not build this infrastructure unless there is (reasonable) certainty about the future demand. This chicken-and-egg problem constitutes a considerable challenge for GEL: there is no credible way in which an ETS, conceived as technology-neutral, could deliver this type of firm commitment to specific types of infrastructure. Policy avenues that are less shy to entrust coordination to a public entity and to take technology-specific choices are therefore better equipped to address this challenge. GIP explicitly includes infrastructure as an important element to be assessed in its "missions", although it is not entirely clear on what basis it selects certain types of infrastructure and dismisses others;

DT picks winners even more explicitly and addresses infrastructure as part of its sectoral roadmaps.

Related to this issue is the ability to ensure a strong and binding framework for transnational infrastructure planning at EU level, where the policy avenues perform in the same pattern. Again, GIP and DT dispose of instruments and institutions to provide long-term transboundary planning, although strong Member States may challenge EU institutions' primacy here, while the market-based approach lacks a convincing way of addressing this challenge.[44]

Infrastructure planning is also relevant for the shorter term, especially the implementation of concrete infrastructure projects. Permitting processes, environmental impact assessments, and consultations of local communities slow down the realisation of these kind of projects. Also here, the policy avenues differ in their approach. GEL emphasises the need to reduce the regulatory and bureaucratic burden for project developers, in line with the more limited role for government in general. In this way, instead of expanding administrative capacity for planning and permitting procedures, it seeks to reduce the amount of capacity required through leaner planning and permitting procedures. It is questionable, however, whether this provides sufficient tools to address the planning challenges and resolve the conflicts and tensions around infrastructural projects. Importantly, infrastructure planning remains fundamentally a government activity, which is why this aspect was considered a weakness of the GEL policy avenue. GIP and DT score better, but for both it is not a given that their more directing approach in terms of policy instruments guarantees an efficient and capable administration at the implementation level.

Regarding all the aspects discussed above, S&D lacks a clear approach towards infrastructure. As it focuses on lowering consumption and developing local, bottom-up solutions, it does not offer clear guidance on the infrastructure needed for such a low-carbon, low consumption economy, nor for effective planning and permitting processes to deliver them.

4.3.4 Integration

The policy avenues express fundamentally different views of the state and the public's role in the transformation to climate neutrality. Resulting from this, their approach to integration differs significantly. Green Economic Liberalism relies primarily on the carbon price to integrate climate considerations in the decision-making of all actors, and on the ETS to distribute mitigation efforts across the emitters and sectors it covers. Government coordination is therefore limited to those instances where the ETS is not suited to deliver effective coordination. The other policy avenues, in contrast, rely much more on government coordination as well as (sectoral) strategies and targets.

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[44] On the role of transnational infrastructure planning in the EU, see Vendrik et al. (2023).

Sufficiency and Degrowth does not perform very well in general. This is because of its rather selective approach to integration. As discussed above, it runs the risk of neglecting certain sectors (such as industry) and transformation challenges (such as innovation). Moreover, it envisages much more bottom-up change and decentralised coordination, which seems less suited to deliver the large-scale coordination across different sectors and across different transformation challenges. All in all, the S&D approach towards the integration challenge remains underspecified.

All policy avenues, except for GIP, contain strong mechanisms for mainstreaming climate policy in all sectors. However, their approaches to mainstreaming differ substantially. GEL centrally relies on the carbon market and as a coordination mechanism; sectoral targets by contrast are seen as contradicting the logic of the carbon market, driving up the costs of target achievement with no gain for the climate. GIP, although pursuing a whole-of-government approach, is less equipped to address those sectors where industrial policy has its limits, such as land use and agriculture. The DT approach with its sector targets and sectoral strategies offers the most comprehensive approach to climate mainstreaming.

Ensuring adequate administrative capacities and capabilities is a challenge for all policy avenues, but for different reasons. Generally, the administrative capacity needed (at EU and other levels of governance) depends on the policy instruments chosen. More interventionist policy approaches that seek to govern the transformation in greater detail will require much more administrative capacity. Moreover, more detailed regulations tend to incur a greater risk of regulatory capture and government failure, including by overburdening policy makers and implementing agencies. This is the main risk for the more interventionist policy avenues, to be mitigated by putting adequate administrative capacities in place, as well as checks and balances to limit the risk of regulatory capture. For example, subsidy schemes can be designed in ways that maintain performance incentives and competition and thus reduce risks of providing too much support (and allowing rent-seeking). The GIP was assessed to have a comprehensive approach for strengthening administrative capabilities to deliver on its industrial strategy. While the risks are not eliminated, the challenges are acknowledged and tackled. GEL, which requires much less administrative capacity and thus incurs a lower risk of government failure, runs the opposite risk: relying too much on private initiative and coordination and thereby not devising adequate capacities to direct those activities where the market does not provide guidance (such as infrastructure, permitting, etc.).

In those areas where some form of non-market coordination is needed, the policy avenues that foresee a stronger role for government planning, strategies and coordination perform better. This is why GIP and DT have strong capabilities for integrating innovation, investment, and infrastructure and are better positioned to enable sector coupling, while GEL is weaker in addressing these issues. Green Economic Liberalism, with its strong reliance on emissions trading as an integration and coordination mechanism, has its limitations when it comes to removing non-market barriers and ensuring coordination. Here, the approaches that foresee a stronger role of the state in providing guidance, coordinating different actors, and removing barriers have an advantage. S&D is considered very weak in both these dimensions. This is in part because it fails to deliver a comprehensive economy-wide strategy, neglecting crucial sectors such as industry or transformation challenges like technological innovation. But also, because it does not adequately reflect the role of investment and infrastructure and is therefore likely to address these challenges insufficiently.

5. How can the policy avenues inform the future development of EU climate policy?

The policy avenues assessed in the previous chapter represent different approaches to climate policy, which – to different degrees – are grounded in the existing EU climate and energy policy. While these archetypes are an abstraction from reality, they offer a useful tool to think about climate policymaking, and to distil some of the drivers that influence its future evolution. This chapter therefore presents the conclusions we draw from the assessment, with a view to the further development of EU climate policy. We start with going back to the question what speaks for, and what against a purer policy mix, i.e., one that is more clearly aligned with one of the four policy avenues, as opposed to an approach that combines elements of different policy avenues.

5.1 Benefits and drawbacks of a "pure" policy mix

The policy avenues analysed in the previous chapter – by assumption – do not differ in the level of climate ambition they express, as they were all designed to put the EU economy on track to climate neutrality. Yet the policy avenues embody very different ways of thinking about climate policy – how it should be designed, which instruments it should use, around which principles it should be organised, and which criteria should guide the understanding of "good" or successful climate policy (Görlach, Martini, et al., 2022). This also includes different understandings what the relative roles of government and private businesses should be, or which trade-offs to consider in policy formulation.

The four policy avenues are based on different policy paradigms, i.e. frameworks of ideas that shape how policy makers understand the problem, the options they see to address it, and the corresponding decisions they make (Hall, 1993). The policy avenues each offer an internally consistent strategy: As ideal types, they represent the best conceivable way of organising climate policy, addressing what, under the prevailing policy paradigm, is identified as the root cause of the problem: e.g., for Green Economic Liberalism, this is the fundamental failure to internalise external costs into market prices, or for Green Industrial Policy the multiple, overlapping market imperfections, technological path dependencies and vested interests that inhibit a techno-economic transformation towards climate-neutrality.

5.1.1 EU climate policy as a blend of the four policy avenues

As elaborated in Chapter 3, different ideas about the "right" kind of climate policy have prevailed among policy makers in the EU and the Member States at different points in time. The underlying policy paradigms have left their mark on the EU policy debate and, as laid out in Chapter 3, can be recognised to some extent in the EU's current climate and energy policy. Having evolved over decades, current EU climate and energy policy reflects different influences, priorities, and academic influences prevalent at the time different regulations were introduced. Changing political majorities in the European Parliament and in key Member States have left their mark, as have different Commission presidents and their agendas and priorities, but also external political and economic influences (Dupont et al., 2023; Oberthür & Von Homeyer, 2023). Yet despite efforts to give EU climate policy a common framing and narrative, not least through subsequent packages of policy changes, it is not organised around a clear and coherent set of design principles.

In consequence, as described in Chapter 3, different regulatory approaches have left their imprint on EU climate policy – which can be related to the four policy avenues:

- Traditionally, EU *environmental* policy has strongly relied on (technical) standards and norms, i.e. the instruments at the core of the Directed Transition policy avenue. As a consequence, this is still evident in much of the environmental regulation that is also relevant for climate and energy policy such as regulations on vehicle emission standards or the Industrial Emissions Directive. Even the EU ETS as the prototypical market-based instrument builds on administrative infrastructure that has been established for such traditional environmental regulation, e.g. when it comes to definitions of installations or reporting structures.

- Since the turn of the century, there has been increasing role for the instruments that also feature prominently in the Green Economic Liberalism policy avenue, i.e. carbon pricing and economic / market-based approaches more generally. The core manifestation of this trend is of course the EU ETS, over time complemented by the CBAM and the forthcoming ETS 2 for buildings and road transport. The reliance on market-based approaches is aligned with the 2001 Lisbon Strategy and Better Regulation Agenda – which sought to improve regulation by prioritising cost-effectiveness, achieving targets at least cost and with minimal impact on competitiveness. Commensurate with this thinking, the role of the regulator is to set regulatory frameworks and to provide incentives (or to correct incentives where they are inconsistent with public goals), but otherwise abstain from direct intervention.

- While the Lisbon Strategy is very much aligned with horizontal industrial policy, the EU, since the financial and Eurozone crisis, has also seen a re-emergence of vertical, technology-specific industrial policy, which is at the core of the Green Industrial Policy avenue. Outside of climate policy, elements of vertical industrial policy had been part of MS economic policy up until the 1980s, most visibly for instance in the European aviation industry and the Airbus consortium. Yet in the 1990s-and 2000s, industrial policy came to be viewed with scepticism particularly from a liberal economic perspective. Since the financial crisis, a re-emergence of industrial policy in Europe can be observed, which for the first time also includes elements of a green industrial policy. For example, more interventionist policy includes the Innovation Fund and its predecessor or policies to support renewable energy or storage technologies. The European Green Deal represents a more active, interventionist understanding of the role of the state.

- A stream of thinking that has, by and large, failed to leave an imprint on EU (climate) policy is the debate around degrowth, sufficiency and lifestyle change, which defines the Sufficiency & Degrowth policy avenue. While there has been some rhetorical support for such ideas in the EU Commission – particularly regarding the call for better measures of economic and societal welfare – these calls have, by and large, failed to gain political traction and the Green Deal, for example, has been explicitly framed as the EU's "growth strategy" (European Commission, 2019a, p. 2).

5.1.2 Would it be beneficial to have a (more) pure mix?

Is it problematic to combine elements of different policy avenues, and would it be preferable to have a (more) pure policy mix? There may be substantial benefits in a policy mix that more clearly follows a coherent approach and logic. The main benefit of a purer mix is that its constituent parts follow an internal logic: it has a clear objective function that it seeks to maximise (such as achieving a given emission reduction target at least cost). This makes it easier to assess whether a (proposed or existing) policy instrument fits into the policy mix, to specify what function it should serve, and to evaluate how it performs in achieving this specific role. It also provides a clear basis for trading off different competing objectives. All this also makes it easier to communicate why a certain policy intervention is needed, and on this basis negotiate with stakeholders, but also easier to resist demands for change that would violate the internal logic. In this way, a consistent strategy is also more credible to the actors it seeks to cover.

Furthermore, the different policy avenues reflect different policy paradigms, which originated from different schools of thought. These schools of thought have developed in reference to each other, by picking up perceived shortcomings or alleged fallacies of alternative approaches and seeking to overcome them. In other words, they depart from different understandings of what the problem is and how it can be fixed – but these different understandings do not only relate to different facets of the same thing, viewed from different angles, but to the nature of the problem itself. Thus, from the perspective of either of the four avenues, the other ones can be (and have been) criticised as overlooking crucial elements, departing from flawed assumptions, or suffering from fallacies:

- Proponents of GEL would maintain that alternative, more interventionist approaches run the risk of making climate policy unnecessarily expensive and economically inefficient, prone to regulatory capture, and/or out of synch with the preferences of consumers. Interventionist approaches were also more prone to regulatory capture and rent-seeking, as beneficiaries of such policies influence the policy process to their advantage. They would require governments to pick winners – which governments are not well-equipped to do, and therefore carry a high risk of leading to inefficient and wasteful results. If there is a finite amount of (monetary or political) capital that can be spent on climate policies, less efficient climate policy also means that less ambition is (economically or politically) feasible.

- Proponents of GIP would stress that other schools of thought do not give adequate consideration to the political economy and the socio-economic dynamics of the policies they advocate, i.e. whether their proposed policies would likely lead to emergence of new markets, business models and jobs, generating political support among core constituencies and beneficiaries, and therefore ideally giving rise to a self-reinforcing (political and socio-economic) dynamic. They also depart from a different conception of economics, including an evolutionary understanding of technological change and different view on role of public investments to crowd in private investments. Developing clean tech manufacturing capacity and supporting the deployment of climate-friendly technologies at scale lowers their cost and creates new investment opportunities. These can, over time, undermine the veto position of interests vested in the status quo – dynamic elements that are not sufficiently reflected in the more static worldview of alternative PA's. Proponents of GIP tend to be more open about the instruments chosen, as long as they get the job done – they are optimistic about the role of markets, but also see a strong role for governments in shaping and directing markets.

- Advocates of the directed transition approach emphasises the need for clear guidance and orientation in the transition – which other tools cannot provide, particularly given the interdependence of transformation strategies pursued by different actors in different sectors. To provide orientation, a clear set of targets is needed along with monitoring and oversight to understand if different sectors evolve in the right direction. Given the limited time available for the transformation, the potential for trial and error (which is central for market-based approaches) is limited. Beyond, the coordination needs across different, interdependent strategies exceeds the coordination capacity of markets, e.g. where it involves investments in long-lived and lumpy infrastructure assets.

- Supporters of sufficiency and degrowth would maintain that GEL's preoccupation with economic efficiency and GIP's emphasis on innovation and growth are not only insufficient to deliver the necessary change – but actually counterproductive. Via the rebound effect, efficiency gains are bound to be offset by consumption increases, as other policy approaches fail to address behaviour and lifestyle changes. The emphasis on innovation and investment locks in (and creates a need for) future economic growth, thereby also increasing consumption of natural resources. Moreover, the other policy avenues lack a convincing answer to mobilise the necessary social momentum and groundswell for change.

From this perspective, combining elements of different policy avenues or merging them would risk combining elements that do not fit to each other, and therefore a risk of leading to an inconsistent outcome. Applying them in combination muddies their internal logic, and thereby creates a risk of frictions and internal contradictions. Such inconsistencies risk slowing down the process of agreeing which policies are needed and implementing them. Pursuing multiple approaches in parallel risks increasing the administrative load as well as the costs of reaching a desired outcome, they make it harder to communicate the policies, their justification, and their need to stakeholders, and may therefore undermine the political acceptance.

5.1.3 Why an impure policy mix may be needed and justifiable

In theory, proponents of either of the schools of thought would argue that an EU climate policy could be substantially improved if it were re-organised to pursue one of the four policy avenues, as this would reduce internal inconsistencies. Yet there are several (conceptual and procedural) reasons why such a fundamental reset is unlikely to deliver better results, and why a (coordinated) blend of elements from the different policy avenues offers a more robust strategy:

- The assessment of the different PA's and their suitability for transformative climate policy established that neither of the four avenues would offer a superior approach to address the combined transformation challenges of innovation, investment, infrastructure, and integration. The assessment revealed strengths and weaknesses of the different policy avenues and suggested aspects where some avenues are better suited than others.

- The policy avenue that is closest to addressing all aspects more convincingly than the alternatives is Green Industiral Policy, which performs well for all four challenges. The achiles heel of this strategy, however, is its political attainability. This points to a broader observation: those policy avenues that perform relatively better on addressing the four challenges (Green Industrial Policy, to a lesser degree Directed Transition) suffer from lower political attainability. The policy avenue that is deemed more attainable – Green Economic Liberalism – performs worse on addressing the four transformation challenges.

- Conceptually, there is not one single "right" policy avenue. The policy avenues depart from different assumptions about the nature and the root cause of the problem they seek to address. Which avenue is deemed superior therefore depends on these underlying assumptions. While the public perception and the political relevance of these assumptions change over time, there is no absolute standard that would allow dismissing either of the avenues as irrelevant or misguided.

- Transformative climate policy is also running up against procedural and institutional limitations: the political capital to agree on policies is limited, as is the administrative capacity for implementing them. And, most importantly, given the drastic emission reductions needed until 2050, the time for policies to deliver the needed outcomes is short – which limits the time available for tinkering with different approaches. A substantial re-organisation of EU climate policy around a new dominant paradigm would require a clear and strong mandate from the European electorate and the heads of government, which is not evident. And it would take several years to implement and to take effect – including the necessary changes to the EU legal framework, and to build up the necessary institutional and administrative infrastructure.

For these reasons, the more convincing case is for an evolution rather than a revolution of the EU climate policy mix, building on the strengths of the different policy avenues.

One way to conceptualise this is that the transformation to a climate-neutral economy requires interventions of different types, and the policy avenues differ in their strengths to deliver these. Specifically, the following intervention types for transformative climate policy can be distinguished:

Table 5. Intervention types for transformative climate policy and their representation in policy avenues

Intervention type	Approach	Relevant policy avenues
Transform the existing stock of productive assets in an economy	**Optimisation**: Improve the efficiency of existing assets through technical or organisational changes	**Green Economic Liberalism** Green Industrial Policy Directed Transition
	Replacement: invest into new assets compatible with climate neutrality, to either directly substitute existing, fossil-based assets or crowd them out over time	**Green Industrial Policy** Green Economic Liberalism Directed Transition
	Phase-out: phase out inefficient / fossil-intensive assets (or convert them to fossil-free uses where possible)	**Directed Transition** Green Economic Liberalism Green Industrial Policy
Reduce activity levels	**Reduction**: deliver equivalent level of welfare involving less consumption of material goods	**Sufficiency and Degrowth** (Green Economic Liberalism) (Directed Transition)

Source: Own illustration

When considering the different approaches, it is evident that no single one of them would suffice to ensure a transformative outcome. Rather, elements of all approaches are needed – with policies to reduce activity levels likely to be most contested. At the level of policy avenues, while they all encompass different types of approaches, they also emphasise certain approaches more strongly, and have less to offer for other approaches. Thus, for instance, the policy instruments in the Green Economic Liberalism avenue have proven their worth for incremental optimisation, whereas phase-out policies are most clearly addressed in the Directed Transition policy avenue. Reduction of activity levels is an almost exclusive domain of the Sufficiency and Degrowth policy avenue –

at best, green economic liberalism may be of limited relevance, since high enough carbon prices would also have this effect, without formulating it as an explicit policy goal.

Robustness of policy strategies and the importance of a credible commitment

A key requirement for transformative climate policy is that it ensures a credible commitment by the regulator towards the regulated entities (investors, owners / operators of emitting assets, consumers) and the electorate about the long-term orientation and durability of policies. This marks a difference from incremental, open-ended forms of climate policy: designing policies geared at achieving climate neutrality requires thinking back from the end (Dolphin et al., 2022; Görlach, Hilke, et al., 2022).

The yardstick of policy credibility is whether it succeeds in shaping expectations of the regulated entities, and in aligning them with the political goals (Dolphin et al., 2022). Only when regulated entities form expectations in line with the goals, and act on these expectations, will the transformation succeed. Otherwise, climate policy may find itself trapped in a self-defeating prophecy: if regulated entities do not trust the commitment of the regulator, they will not make the necessary investments. This, in turn, means that the politically set targets slip out of reach, which further erodes trust in the political commitment.

The credibility of a political commitment hinges on trust in the regulator to adopt the necessary policies and withstand the temptation to roll them back in case of setbacks and adverse reactions from stakeholders or attempts to renegotiate them. There are different commitment devices through which the regulator can strengthen their commitment, for instance by enshrining the commitment into law, by delegating its implementation to an independent, non-political institution, or by entrenching the commitment into private contracts (securitization) (Brunner et al., 2012).

An open question is whether a combination of different policy avenues is more or less likely to deliver a credible commitment, and to be perceived as robust over time. One argument against a blend of different avenues is that the consistency of policies suffers if different approaches, based on different perceptions of the problem, are combined. Yet policy consistency – regarding the underlying assumptions as well as consistency with the proclaimed goals – is an important determinant of policy credibility: strategies that are (perceived to be) inconsistent undermine the credibility of the political commitment (Dolphin et al., 2022). As consistency is easier to achieve in a pure mix, which follows one policy avenue only, this suggests that a purer mix would be more likely to generate a credible commitment.

At the same time, arguments can be made why a combination of different approaches may also lead to a more credible commitment. A more sophisticated version of the argument recognises that not only does the transformation to climate neutrality involve a multitude of different challenges, but also that the different policy avenues have recognised these challenges to different degrees, and therefore differ in their sophistication for addressing them. This is evident, for instance, from the overview of the different intervention types in Table 5 above (transforming the stock of assets via optimisation, replacement, phase-out; reduction of activity levels), and to what extent they are represented in the different policy avenues. Yet if some of the policy avenues do not even recognise certain parts of the challenge to be part of the problem, it is logical that the tools for addressing them will need to come from different toolboxes. The art of crafting such a well-orchestrated blend of different elements, however, is to arrive at a convincing explanation of what the specific contribution of each approach should be, thereby reconciling the different underlying paradigms.

A more pragmatic view would maintain that a "thicker" mix combining a multitude of (overlapping) instruments, might be less efficient, but also more resilient in the face of changing circumstances, and therefore more robust over time. Even though, in a case of overlapping instruments, some elements in the mix may turn out to be redundant in some respects, they still serve a function. This can be as a signalling device through which the regulator signals their commitment, or as an insurance – not only against policy failure (where a policy instrument fails to function as planned), but also against analytical failure (where key assumptions about the nature of the problem or the chosen solution turn out to be wrong). This argument can be illustrated with the example of phase-out policies (for coal-fired power generation, gas boilers or internal combustion engines). With a sufficiently high carbon price (as the Green Economic Liberalism policy would advocate), there would be no need for phase-out mandates (as could be found in the Directed Transition approach). The rising carbon price would eventually render these technologies uncompetitive, discourage new investments or purchases of such technologies, and eventually force existing assets out of the market. Yet it is questionable whether the regulator would politically sustain such high carbon, and whether consumers and investors would expect them to. Therefore, while explicit phase-out mandates and carbon pricing are to some extent redundant, the combination of the two may also be (perceived as) more credible than one without the other.

Beyond the self-commitment by the regulator, however, policies will also become more credible and more robust if they succeed in building up a constituency and support base, which expects to gain from the continuation of the policies. Policies that require sustained support – be it in the form of political backing of funding – face a greater risk of being rolled back if opposition intensifies or if climate ambition is superseded by other political priorities. In this regard, the four policy avenues offer substantially different approaches to mobilising and sustaining political support. Green Industrial Policy is most attuned to political economy considerations: in this avenue, one function of the set of policies is to build up a constituency and support base of business, who have a vested interest in the success of the transformation and would thus stand to lose from winding back policies or lowering ambition. Sufficiency and degrowth is the policy avenue that is most geared towards eliciting support and buy-in from stakeholders, incorporating participatory elements and the formulation of a shared narrative. Green Economic Liberalism, by contrast, is less geared to actively involve citizens or businesses and give them a stake in the transformation, but rather to minimise adverse consequences on them. There are two main channels how the policy avenue aims to foster acceptance or support of ambitions climate policy: first, by recycling the revenue from carbon pricing (either across the board or strategically by supporting particular groups or sectors in the transition), and secondly, by ensuring that the transformation is achieved in the least costly way while maintaining the freedom of choice for investors and consumers. This reasoning, however, does not appear to catch on with the public: surveys show that among the suite of policy instruments available to climate policy, several that are most clearly associated with Green Economic Liberalism (such as higher carbon prices) are regularly among the least popular options (Umit & Schaffer, 2020), whereas subsidies for green technologies and infrastructure are evaluated more positively (Abou-Chadi et al., 2024).[45]

5.2 Towards a clearer division of labour in EU climate policy

As argued above, an evolution of the EU climate policy mix that combines elements from different policy avenues is more likely to deliver the necessary impetus for change in the limited time available – more so than a revolution, i.e., a fundamental reorganisation of EU climate policy along either one of the four policy avenues. That said, also short of a fundamental overhaul, there is scope for a more consistent policy mix at EU level, that is organised in a more stringent way around a central set of principles.

At present, economic instruments play a central role in the EU policy mix. But while these instruments have proven their worth as a tool to coordinate incremental improvements and drive system optimization where market-ready alternatives are known and available (such as switching from coal to gas), their suitability to drive and coordinate transformative change is arguably more limited. Their limitations are particularly apparent for driving strategic choices and for coordinating change across mutually dependent sub-systems, for example, when coordinating the deployment of infrastructure. In particular, the future EU climate policy mix will need to deliver:

- **Greater directionality**: the interdependence of sectoral decarbonisation strategies (electrification, hydrogen), path dependencies, chicken-and-egg problems related to infrastructure all point towards a greater need for directionality and coordination – beyond the coordination that market mechanisms can deliver.

- **Greater social and political buy-in**: the transformation to climate neutrality is not only a management challenge or an engineering problem; resilient strategies also require more explicit consideration of political, economic and societal dynamics, of vested interests and

[45] One drawback of such surveys is that the costs of different options may be perceived very differently: while the costs of carbon pricing are felt immediately, those of other options are covered by the public budget, including by future generations. For this reason, the choice between different instruments may feel like comparing an expense (carbon pricing) with a free lunch (subsidies).

associated political power. This also includes strategies how climate policies can build up and maintain their constituency.

- **Explicit consideration of fossil phase-out**: the phase out fossil-based technologies and value chains will increasingly become a focal area of climate policy. The four policy avenues represent distinct approaches to bring this about: increase the cost of fossil-based technologies to render them uncompetitive and eventually force them out of the market (GEL), ban old technologies to make room for new solutions (DT & S&D), and make new solutions so cheap or convenient that they push out old ones (GIP). Yet as long as existing, fossil-based technologies are in the market and have a viable prospect to remain profitable, they will also form an obstacle for new solutions.

- **Greater consideration of external drivers**: the choice of political strategies is also influenced by external developments: international competition for the emerging green industries and support by other major economies is a strong driver for industrial policy, as is the desire for greater strategic autonomy and the re-shoring / friend-shoring of key technologies. Other forces, such as a social groundswell that would demand and support more drastic and interventionist policies, are currently less likely to play an important role.

Taking up these considerations and the results of the assessment of the different policy avenues, a new division of labour emerges from the current status quo. The role of the different avenues in this future climate policy mix can be envisaged as follows:

- **Elements of Green Industrial Policy to drive the development of new technological solutions and lead them to market maturity**, to mobilise investment, to facilitate the emergence of business models, and to coordinate the joint deployment of the infrastructure that is needed to support the emerging innovations. In addition, Green Industrial Policy tools also serve to expand the constituency that has a vested interest in the success of the transformation to climate neutrality and can mobilise political support to counter the defendants of the status quo.

- **Elements of Green Economic Liberalism to scale up the deployment of climate-neutral alternatives** after technologies have become market-ready and after other barriers have been removed. In parallel, the carbon price also has an important role in driving the market exit of fossil-based technologies and value chains by undermining their economic viability. The cap set by a comprehensive ETS may also serve as the failsafe in case other policies fail to deliver, making sure that emissions remain aligned with the reduction pathway and allocating reduction efforts across sectors (albeit only if the high carbon prices that would result in this case can be sustained politically).

- **Elements of Directed Transition to provide directionality throughout the process and give clarity where it can be given**. DT policies serve to provide strategic planning and overarching coordination, e.g. regarding the roll-out of infrastructure to support climate-neutral technologies. This also concerns the determination which types of infrastructure will become available where, and thereby enables or precludes certain mitigation options (e.g. infrastructure for green hydrogen and derivatives, CCUS). DT policies can provide certainty especially about phase-out of fossil-based technologies and value chains, thereby allowing consumers, investors, and other affected stakeholders (such as employees) to anticipate and adjust to the changing realities. DT policies also have a strong role to play in establishing / strengthening institutions and procedural mechanisms to firmly anchor climate and energy goals, establish mechanisms to monitor the achievement of such goals and to initiate corrective action if needed.

- Elements of Sufficiency & Degrowth to address those decarbonisation challenges where no suitable (technological) alternatives can be foreseen. Sufficiency policies have the thinnest prospect of implementation, as they are barely represented in the existing acquis, and lack of political support – to the contrary, in an increasingly heated and polarised political environment, could trigger massive resistance. Yet for some emission sources, for which technological solutions are unlikely to materialise (e.g., meat consumption, long-distance travel), it seems inevitable that a part of the solution would involve changing lifestyles and consumption behaviour: not only about delivering goods and services in the most efficient way, but also about which goods and services are needed, and how much of them. Sufficiency also more closely aligned than others with circularity and re-use, which in turn is a central but underutilised lever for industrial decarbonisation (Agora Industry, 2022).

5.2.1 Sequencing of policy instruments over time

The concept of policy sequencing offers a framework to understand how the combination of different policy instruments over time may enable greater policy ambition (Edmonson et al., 2022; Meckling et al., 2017; Pahle et al., 2018), and lead to more consistent and credible policies (Dolphin et al., 2022). Policy sequencing describes a strategy whereby the successful implementation of some policies removes barriers to the subsequent implementation of other, more stringent policies. For instance, technology support policies may serve to expand the range of mitigation options, provide infrastructure or lower the costs of or facilitate access to clean alternatives; redistribution policies and targeted support for vulnerable groups may address a (perceived) social imbalance and thereby pre-empt opposition. If implemented successfully, such policies increase the political and economic feasibility of stricter instruments, such as a stringent carbon pricing regime or a ban on fossil-based technologies, which would otherwise run into fierce opposition.

Transferred to the four policy avenues, the logic of policy sequencing suggests an approach that draws on the relative strength of the different avenues by emphasising different elements in different stages: elements of the different avenues will co-exist at the same point in time, but their relative weight in shaping the EU policy mix changes over time. A sequence of the policy avenues could be envisaged in the following way:

- In the near term, elements of **Green Industrial Policy** receive greater emphasis. Given the time lags involved in developing technological alternatives, leading them to market maturity, and allowing new markets and business models to emerge, greater efforts are needed in the present to develop future solutions. At the same time, rolling out a European version of Green Industrial Policy is even more urgent in the face of the growing international competition for the key technologies for climate neutrality (such as renewables, storage, electric mobility, heat pumps or electrolysis), and the active industrial policies of several other major economies. Going forward, tools and approaches of Green Industrial Policy will remain relevant to respond to other emerging technological challenges that are currently still in the invention stage (e.g. technologies and tools related to carbon management and carbon dioxide, or circular economy / bioeconomy applications to reduce the use of virgin materials). Yet to the extent that more and more of the key technologies achieve market maturity, and basic industries become increasingly aligned with climate neutrality, there may be less of a role for industrial policy for reaching climate neutrality in the medium term.

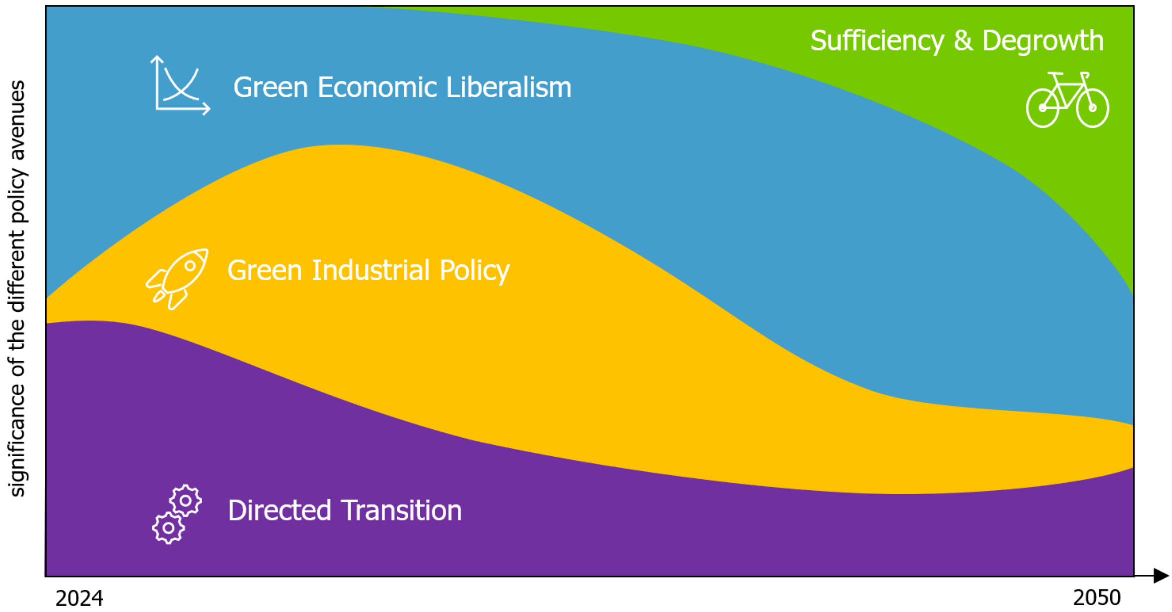
- Likewise, several elements of the **Directed Transition** policy avenue should be front-loaded, in particular where they relate to the coordinated deployment of the infrastructure that is necessary to support a climate-neutral economy. Given the considerable lead times involved in planning, permitting, and building infrastructure, it is imperative to ramp up the integrated planning and deployment of infrastructure – certainly for those parts of infrastructure where the need is widely agreed and consistent across scenarios (e.g. interconnection capacity and expansion of electricity grids). Also, beyond infrastructure, an important function of the Directed Transition approach is to provide orientation and directionality where possible, i.e. where different scenarios are consistent about the way forward. This directionality may also include phaseout timelines for fossil-based technologies and value chains. Over time, tools and instruments of the Directed Transition PA remain relevant to monitor progress, and to adjust policies if developments are not aligned with the goal of climate neutrality.

- The tools and instruments that are emphasised in the **Green Economic Liberalism** policy avenue are already firmly established in the EU's toolbox and have been further strengthened with the Fit for 55 package, inter alia through the extended use of emissions trading. The introduction of ETS 2 means that 80% of EU GHG emissions are covered by an ETS cap and a carbon price, both ETS caps will follow steep reduction pathways aligned with climate neutrality. Yet GEL policies will see their role changing over time: while now their focus is to optimise existing systems through incremental improvements (e.g. changing the dispatch order of power plants), one of their main functions in the 2030s and 2040s will be to drive the phase-out of fossil-based technologies and the value chains they support. At this point in time, a central role of the carbon price will be to undermine what is left of the profitability of fossil-based technologies, and thereby to drive the retirement of fossil assets (coal- and gas-fired power plants, gas boilers and combustion engine cars, along with the supporting infrastructure). In the 2040s, an increasingly important function will be to manage the balance between carbon removals and any remaining emitting activities – and thereby also determine which activities will be able to afford continued emissions (Pahle et al., 2023).

- **Sufficiency and Degrowth** is still an emerging (and contested) strand of climate policy. As it lacks a footing in the existing EU climate policy architecture, it currently is of limited relevance, but will eventually need to play some role for some sectors, activities, and emissions. Particularly when the shift away from fossil fuels and towards renewable-based solutions is (nearly) concluded in energy or road transport, political attention will need to also take those reduction potentials where technological alternatives are not available, and may not be forthcoming at the needed pace, scale, cost, and convenience. In this situation, some of the abatement effort will need to come in the form of reduced demand and changed lifestyles (e.g. through changed diets, mobility, or long-distance travel behaviour). This will also need to involve changing the underlying social norms and values that guide individual behaviour. Experiences with other social norms (such as smoking) shows that such cultural and behavioural shifts are possible, and while they cannot be implemented top-down, policies can support them by "seeding" new norms if the change in social norms is met by a bottom-up groundswell (Constantino et al., 2022). While there are tipping points where social norms may change abruptly (Nyborg et al., 2016), changing behaviour and routines will take longer and is likely to involve setbacks. Effects may therefore only materialise in the medium to longer term.

The following schematic representation sketches how, following the reasoning above, the relative significance of the four avenues in shaping the EU climate policy mix, i.e. their contribution to effecting the necessary changes to the EU economy, could evolve over time. "Significance" here relates to the effect that the policy instruments can achieve when they have been implemented – recognising that there is a time lag before policies can be expected to have an effect.

Figure 6. Schematic representation of the significance of different policy avenues over time



Source: Own illustration

However, this schematic representation abstracts from different factors. To begin with, the boundaries between policy avenues and the instruments they entail are not as clear-cut as they appear in the graph – in reality there is quite some overlap e.g. between the Green Industrial Policy and the Directed Transition avenues, where specific instruments can be subsumed under one or the other approach. Further, the representation ignores that the sequencing logic plays out differently for different parts of the economy and for different groups of emitters. For instance, for power generation the shift from fossil fuels to renewable energy sources is at an advanced stage, the solutions are available and generally cost-competitive, while challenges remain for grid integration and storage. This means that there is less of a role for industrial policy, and more for the instruments found in the Green Economic Liberalism policy avenues. By contrast, the decarbonisation of basic industries is at an earlier stage, with greater uncertainties about technological solutions – their technical feasibility and economic viability, as well as their infrastructural and regulatory requirements. This applies even more to emerging challenges such as carbon management or carbon dioxide removal. This suggests a stronger need for approaches from the Green Industrial Policy (and possibly Directed Transition) avenues for these sectors. For these reasons, the relative significance of the different policy avenues over time will differ for different sectors and technologies, depending on where they stand in the transition.

6. Conclusion

EU climate policy has made a great stride forward with the European Green Deal, the European Climate Law and the adoption of the Fit for 55 package. Yet the mere continuation of this existing policy trajectory, with its strong emphasis on carbon pricing, is unlikely to close the transformation gap that the EU faces with respect to fostering innovation, shifting investment, rolling out infrastructure for a climate-neutral economy and integrating policies across sectors and governance levels. This report has assessed different alternative conceptual approaches for EU climate policy instrumentation, formulated in the form of four policy avenues – Green Economic Liberalism, Green Industrial Policy, Directed Transition and Sufficiency & Degrowth. Yet while these all have their strengths and weaknesses, there is no dominant solution among them that would outperform the alternatives on all accounts. Overall, the Green Industrial Policy Avenue represents the most convincing strategy to address the transformation challenges of innovation, investment, infrastructure, and integration. Yet this approach also has deficiencies, above all the political feasibility of such an approach, if applied with the ambition and at the scale needed, but also in terms of leveraging mitigation potentials across a broad range of sectors.

To arrive at a more resilient and robust policy mix at EU level, we therefore conclude that a combination of elements from the different policy avenues offers the most promising way forward provided that they are organised around a set of principles and follow an internal logic. This report sheds some light on the strengths and weaknesses, and sketches how they can be combined.

- In the near term (before 2030), there is a convincing case that EU climate and energy policy should further emphasise elements of Green Industrial Policy. With the Innovation Fund and Carbon Contracts for Difference, the Net Zero Industry Act, the Critical Raw Materials Act and the Strategic Technologies for Europe Platform the EU has taken first timid steps in this direction, albeit lacking clear focus and at a too limited scale to have a transformative impact. Furthermore, the Directed Transition Policy Avenue exemplifies the need for integrated planning, which has relevance for EU policy especially when it comes to providing greater clarity and directionality in the coming years – e.g. about what types of infrastructure investors can expect to be deployed where and by when. The main tool to deliver this is integrated infrastructure planning, to be aligned with a long-term strategy for a climate-neutral Europe. A future EU long-term strategy would also be the place to seek the alignment of innovation, investment, and infrastructure policies as the quintessential integration challenge.

- In the medium term, i.e. in the years after 2030, the importance of Green Industrial Policy is expected to decline as supported innovations achieve market maturity, with a stronger role for tools to support market diffusion. Increasingly, climate policy will need to facilitate and coordinate the process of exiting from fossil-based technologies and value chains, and the decommissioning or repurposing of fossil infrastructure. This can include elements of Green Economic Liberalism (rendering fossil-based technologies uneconomical to operate) or Directed Transition (setting phase-out targets and timelines), but ideally a combination of the two.

- In the medium to longer term, the EU climate policy mix should also induce lifestyle changes and sufficiency, as shown by the Sufficiency and Degrowth policy avenue. These are currently absent from the EU toolbox, but also underrepresented in the policy discourse, not least since they are highly contentious politically. Yet there is a certain likelihood that behaviour and lifestyle changes will be needed for some parts of the transformation to climate neutrality, for instance where technological solutions are not forthcoming at the scale, pace and cost needed – such as meat consumption or long-distance travel.

On the positive side, this agenda sketches how a more resilient, more integrated EU climate policy mix could evolve over time, including elements to establish a political support base and create ownership, but also including some redundancy as a defence against policy failure. Yet there also remain several challenges going forward, among them the following:

- **Defining the appropriate role of "technological openness":** in the early phase of the transformation – where solutions are fundamentally uncertain – it is essential to allow for open competition between alternative solutions on the merit of their cost and their expected success. Yet at some point striving for technological openness is no longer sensible but can become a dangerous distraction: as the dominant solutions emerge more clearly, the call for "technologically neutral" approaches to regulation is little more than a thinly disguised lifeline for status quo technologies. Markets alone, however, may not be the best judge for the competition of different technologies, given the risk that vested interests and path dependencies distort the market outcome. At some point, regulators therefore need to be ready to take choices between different competing technological options and need to be equipped to do so in a structured, smart, transparent and market-compatible way – which may well involve competitive processes to select the best supplier of the best technological solution, but within parameters defined by the regulator.

- **Limiting the risks of regulatory capture / government failure:** the two policy avenues that are expected to feature more prominently in the EU climate policy mix, Green Industrial Policy and Directed Transition, both involve a stronger, more active role for government agencies. Given the limited administrative capacities of the EU institutions, and the limited appetite for expanding them, some scepticism about state-centred strategies at EU level is warranted. While there have been some positive examples of EU-led or -coordinated policy responses (e.g. the response to the 2022 energy crisis), there are also (very) negative examples of EU institutions managing markets with strong vested interests, above all the inability to agree on and implement a meaningful reform of the Common Agricultural Policy.

- **Ensuring sustained public funding.** Connected to the previous point, Green Industrial Policy and Directed Transition are not only more demanding in terms of administrative capacity – they also require considerable up-front investment, both public and private. More so, to be successful in forming expectations, they need to create a firm, credible commitment that the financial resources will be in place to fund the innovation and investment support programmes or the public infrastructure projects – as long as it takes, with as much funding as it takes.

7. References

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Annex 1 – Innovation gaps for key climate-neutrality technologies

Sector	Technology	TRL (IEA)	Importance to net zero (IEA)	Innovation gap/ challenge	Qualitative challenges	Current policy responses (EGD / Fit for 55) (*)
Energy	Solar thermal (large scale)	9	Moderate	Deployment	Deployment limited to areas with high solar energy potential and necessary development space. Limited to Southern Europe.	- Renewable Energy Directive (RED II/III) - Innovation Fund
Energy	Solar thermal (small scale)	10	High	Deployment	Mature technology; is widely deployed globally. Potential for further growth.	- Energy Performance of Buildings Directive (EPBD) - RED II/III - Social Climate Fund
Energy	Solar PV	10	Very High	Deployment	Mature technology with high deployment and global production capacity. Bottlenecks relate to power grid capacity to absorb growing solar PV and power/grid management.	- RED II/III - Electricity Market Design (EMD) - Net-Zero Industry Act - Social Climate Fund
Energy	Onshore wind	9-10	Very High	Deployment	Mature technology with potential for further development in Europe. Main deployment bottlenecks include spatial planning, permitting and grid integration.	- RED II/III - EMD - Net-Zero Industry Act - Innovation Fund
Energy	Offshore wind	8-9	Very High	Demonstration Deployment	Technology has matured with high(er) deployment expected over next decade. New emerging technologies will broaden the impact of offshore wind (e.g., floating offshore, offshore energy hubs and co-production of hydrogen offshore). Bottlenecks include (maturing/volatile) supply chains, possible conflicts with the fishing industry and shipping routes, permitting and adequate (onshore) grid infrastructure.	- RED II/III - Electricity Market Design - Net-Zero Industry Act - Innovation Fund
Energy	Green/blue hydrogen production	7-9	Very High	Demonstration Deployment	Climate-friendly hydrogen production is at different innovation	- RED II/III - EU Hydrogen Bank

					stages, with alkaline electrolysers in the deployment stage. High potential in countries with high PV electricity potential. The main bottleneck is the availability (and additionality) of (cheap) green electricity for widescale deployment.	- Net-Zero Industry Act - Innovation Fund - EU Gas Package
Energy	*Advanced geothermal (e.g., closed loop)*	6-8	Moderate	R&D Demonstration	Advanced geothermal (e.g., closed loop) can bring base-load geo-thermal power to more areas. This power source can be highly complementary to variable renewable energy sources. Currently large-scale trials are being considered. Bottlenecks include building support for large-scale demonstration and permitting.	- RED II/III - Innovation Fund
Energy	Power storage: Heat	5-9	High	R&D Demonstration Deployment	Different technologies under development. Important when linked to industrial applications (e.g., use of waste heat) and in context of higher shares of variable renewable energy. Important because it has capacity for longer-term storage (e.g., weeks). Must still be proven at scale (durability). Barriers include further R&D, demonstration, and deployment. Power market environment must allow flexibility/reward for this type of technology	- Innovation Fund - Net-Zero Industry Act - EMD
Energy	Power storage: Battery	5-9	High/Very High	R&D (for advanced battery technologies) Demonstration Deployment	Larger battery storage options (+100MW) are entering the market and are used for short-term grid balancing/back-up (replacing gas/diesel generators). Newer higher capacity/fast charge-discharge/lower critical metals content batteries are under development. Further deployment depends on policies/context that help with better recovery of Capital Expenditures and higher return on investment. Good power market design is important.	- Innovation Fund - Net-Zero Industry Act - EMD - Alternative Fuels Infrastructure Regulation - EU Battery Regulation

					Also, this technology will gain further traction in environment with higher amount of variable renewable energy.	
Energy	Power storage: Other (excluding hydro)	6-8	High	R&D Demonstration Deployment (early stage)	Different technologies are considered here including chemical storage (e.g., flow batteries, flywheel storage). Most are still under development with few demonstration projects in place. If successful, these technologies can broaden the means to store power over short or longer time periods. Demonstration support and support for "First of a kind" could advance these technologies	- EMD - Innovation Fund
Energy	Demand Response techniques/technologies	5-10	High/Very High	R&D Demonstration Deployment	This is a group of technologies, techniques, and new business models that help address growing number of variable energy sources and (related) power price fluctuations for companies. Demand response (e.g., lowering production temporary in industry) is being applied already but has potential grow by using innovative technologies or redesigning production processes. An important barrier is higher investment costs which need to be recovered through financial benefits from demand response. The latter will require public support and/or improved power market design that better rewards demand response.	- EMD - Energy Efficiency Directive
Energy	Advanced nuclear (4th generation fission; small Modular Fission Reactors; fusion)	3-8	Moderate/High	R&D Demonstration	A group of technologies at different stages of maturity. Small modular fusion reactors are moving into demonstration phase. Small modular reactors will only prove cost effective when produced at scale (large quantities of standardised models). Nuclear fusion is at significantly lower TRL. Financial support will be required for further R&D to demonstrate and "First of a kind" deployment.	- Euratom Research and Training Program - International Thermonuclear Experimental Reactor

Transport	Battery electric vehicles (cars, motorcycles, vans, Light Duty Vehicles)	TRL 8-10 (mostly 9)	Very High	Demonstration Deployment	Battery electric vehicles are gaining growing market shares and are likely to become the dominant car technology by 2030, aided by cost reductions and phase-out/exnovation laws for internal combustion engines in a growing number of countries. Bottlenecks include charging infrastructure and (possible local) power grid bottlenecks.	- Alternative Fuels Infrastructure Regulation - CO2 emission performance standards for cars and vans - Effort Sharing Regulation - ETS2
Transport	Synthetic fuels for transport (heavy duty)	TRL 3-8	Moderate	R&D Demonstration	Synthetic fuels can have applications in heavy duty transport as an alternative to electrification. Potential seems limited due to growing application range of battery electric vehicles. Synthetic fuels will likely remain more expensive compared to direct electrification.	- RED II/III - Effort Sharing Regulation - ETS2
Transport	Electrification of road transport (e.g., trucks, buses)	TRL 8-9	Very high	Demonstration Deployment	Electrification of buses is advancing rapidly; likely to become mainstream technology over next several years. Heavy duty transport electrification is in early stages of deployment. Improvement in battery energy density and fast charging will improve deployment. Fiscal incentives and stricter environmental standards will drive further electrification together with EU-wide coverage of charging infrastructure.	- Net-Zero Industry Act - Effort Sharing Regulation - ETS2
Transport	Alternative fuels and/or electrification of aviation	TRL 3-8	Very high	R&D Demonstration Deployment (early stage)	Biofuels and synthetic fuels can over time replace fossil kerosene as aviation fuel. Bottlenecks include technology development and scaling up of production to meet (global) demand. Electrification and use of hydrogen in aviation is still in development phase for commercial aviation. Higher alternative fuel costs are an important bottleneck and will require stronger regulatory push	- ETS1 - ReFuelEU Aviation

					(e.g., standards) for faster deployment.	
Transport	Alternative fuels and/or electrification of shipping	TRL 4-8	Very high	R&D Demonstration Deployment (early stage)	Several types of alternative fuels are being developed for international shipping (e.g., green ammonia, methanol, bio-based diesel). Smaller ships with shorter range are seeing early deployment of electrification. Deployment of alternative fuels will be driven by regulatory push (e.g., standards).	- ETS1 - ReFuelEU Maritime
Buildings	Electrification: Heat pumps	TRL 9	Very high	Deployment	Following the 2022 energy crisis in Europe, efficient electrification of buildings (via heat pumps) has accelerated. Further accelerated deployment will depend on favourable energy pricing/taxation (power<gas), (regional) production capacity of heat pumps and grid capacity to deal with increased power demand.	- EPBD - Energy Efficiency Directive - Effort Sharing Regulation - REDII/III - Social Climate Fund - ETS2
Buildings	Energy efficiency	TRL 10-11	Very high	Deployment	Technologies and techniques to increase the energy efficiency of existing housing is well known and widely applied. Newbuild passive or energy+ housing is common. Barriers to full deployment include high upfront costs and stock of old houses where energy efficiency improvements are too costly vs. newbuild.	- EPBD - Energy Efficiency Directive - Effort Sharing Regulation - Social Climate Fund - ETS2
Industry	Electrification: Low- to medium-temperature heating	TRL 9	High/Very High	Deployment	Electrified heating technology is mature except for high MW heat capacity and for processes that require fast heating and cooling. Main barrier is economical with natural gas prices (incl. CO2 costs) often being more competitive vs. electric heating, even when considering high efficiency gains of electrification.	- ETS1 - Innovation Fund
Industry	Electrification: High-temperature heating	TRL 3-7	High/Very High	R&D Demonstration	Electrification of high-temperature heating processes (> 1000°C) is possible but industrial applications are still in R&D or demo stage.	- ETS1 - Innovation Fund

					Next to research challenges, the same economic barrier (gas vs. power costs) facing low/medium-temperature systems.	
Industry	Industrial carbon capture and storage (CCS)	TRL 5-8	High	Demonstration Deployment (early stage)	For industrial process emissions and (limited) combustion emissions that cannot be electrified (at the moment) CCS will be an important technology. Capturing industrial process emissions (with high CO2 concentration) is relatively straightforward, affordable, and has been applied at large scale in the Haber Bosch process and ethylene oxide production. Bottlenecks include the requirement for extensive CO_2 transport infrastructure (pipelines, liquefaction, ships, storage sites) for complete and large-scale CCS to function. As with most industrial climate friendly technologies, the production cost (Capital Expenditures + Operating Expenditures) will be initially higher vs incumbent technologies, creating a risk of loss of competitiveness vs. these producers if the latter are not exposed to e.g., carbon pricing.	- ETS1 (storage) - Innovation Fund - CCS Directive - Carbon Removals Certification
Industry	Industrial carbon capture and utilisation (CCU)	TRL 2-8	High/Very High	R&D Demonstration	Using CO_2 as a raw material input is an area of major R&D efforts. Smaller scale demonstration plants are in operation. Most promising CCU approaches focus on mineralisation/carbonation of cement/concrete type materials and in development of polymers. Alternative fuels (renewable fuels) using CO_2 as input material are being developed at larger scales. These will eventually need to use CO_2 directly captured from the air to be consistent with net-zero emissions. Bottlenecks relate to costs with CCU based polymers being more costly esp. because of higher	- ETS1 - Innovation Fund - Carbon Removals Certification

					energy use and use of (green) hydrogen. Another barrier is the need for abundant green electricity to power these processes. For products using carbonation and mineralisation there are market barriers to entry given the conservative nature of the construction industry (risk averse to new/untested materials).	
Industry	Bio-based feedstock (non-food competition)	TRL 5-8	Moderat e/high	R&D Demonstration Deployment	Bio-based feedstock is a promising alternative to fossil fuels for the production of a wide range of chemicals. However, extraction processes are energy intensive and yields relatively low. Priority should go to bio-based feedstocks that do not compete with food production, such as wood residues and agricultural waste. Bottlenecks include scaling up of cost-effective production, and the development of sustainable supply chains.	- ETS1 - Innovation Fund
Industry	Hydrogen (green) feedstock for industrial processes	TRL 5-8	High	R&D Demonstration Deployment	Green/climate-friendly hydrogen will play a critical role in a limited number of industrial processes, including steel production, fertiliser production, production of green methanol/other high value chemicals, copper, and other metals. For hydrogen-based steel the first large scale production investments have been made with prospect of multimillion tonnes/year of global H2 steel production over the next 5-10 years. Green ammonia investments are happening too, mostly outside of Europe. The main bottlenecks relate to cost and access to high production volumes of green hydrogen. Large investments will likely happen in regions with low-cost and abundant renewables (e.g., solar PV, onshore wind).	- ETS1 - Innovation Fund - EU Gas Package
Industry	Circular plastics	TRL 3-9	Very High	R&D	Highly circular and efficient use of plastics will be very important to	- Innovation Fund

				Demonstration Deployment	meet 2050 net-zero targets. Circular use will lower the need for virgin production and fossil-fuel-based feedstock. While mechanical recycling of (some) plastics is an established and commonly used technology, there are technological and non-technological barriers to achieve full circularity and efficient plastics use. These include: - Not all plastics are or can be recycled mechanically. - Efficient plastics use (e.g., reuse, repair) is not a common practice. - Complex layered plastics can be impossible to recycle. - Chemical recycling of plastics has not reached large scale applications and is often stuck in demo or R&D phase. - Plastics that are not recycled are often incinerated for energy production. The energy production is a disincentive towards recycling. Most incinerators are not covered by the EU ETS. - Mechanical recycling leads to downgrading of plastics and hence is limited to a few cycles. - Much of EU's plastic waste is exported to third.	- Circular Economy Package
Industry	Circular metals	TRL 9-10	Very High	R&D Deployment	Metals recycling is common practice for iron and steel, non-ferrous metals, precious metals, and some rare earth metals. The EU sees the highest metal recycling rates in the world. R&D gaps exist for recovery of new metals products (e.g., lithium batteries) and avoiding (copper) contamination in steel recycling. Higher metals recycling rates are possible with stricter export controls out of the EU (e.g., electronic waste, second hand cars).	- Net-zero Industry Act - Critical Raw Materials Act - EU Battery Regulation

Annex 2 – SWOT analyses of the policy avenues

Methodology

As explained in Section 4.1, we analysed all four policy avenues with a customised assessment framework. We assessed the policy avenue's intrinsic ability to solve the transformation gap ("strengths and weaknesses") and the plausibility of their implementation ("politics") respectively. For both assessments, we made use of indicators that were scored on a 4-point scale. The strengths and weakness' part was carried out for each challenge separately, with 3-5 specific indicators per i. The assessment of the politics was done at the policy avenue level only, distinguishing three different indicators.

Below, all indicators are listed for both parts of the assessment respectively, together with a brief description of our understanding of when they are considered a major weakness of a policy avenue (score 1) or a major strength (score 4).[46]

In Section 2 of this Annex, the assessment of Strengths and Weaknesses is presented, structured along the 4i's. For each indicator, first a brief problem description is provided. Then, the indicator is assessed for each policy avenue separately. Each time, the assessment consists of a qualitative description of how the policy avenue in general would handle the aspect under consideration, based on the policy instruments it has at its disposal, followed by an assessment of the ability of the policy avenue to solve the associated challenge in particular. Finally, a brief conclusion is presented, including the score that was assigned.

In Section 3, the assessment of the politics of the policy avenues is provided. For each PA, it consists of a narrative assessing the three indicators consecutively, each time concluding with the score that was assigned.

The assessments were conducted by principal analysts and then reviewed by at least two – sometimes three or four – peers. This peer review is meant to improve the robustness of the results and increase its intersubjective validity.

The policy avenues that were assessed were described in in the report "Policy Avenues towards a Climate Neutral Europe", Deliverable 4.1 of the 4i-TRACTION project (Görlach, Martini, et al., 2022).[47]

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[46] For practical reasons, however, we will mostly use the labels "strength" and "weakness" throughout the assessment, as these are very intuitive, or just use other appropriate adjectives in case this does not create confusion. For instance, a score 4 on the indicator "political attainability" could be described as reflecting a major opportunity or major strength, or just as a "very high political attainability", and vice versa for a score 1, reflecting a major threat/weakness or a "very low political attainability".
[47] For reasons of brevity, in the assessments this particular source is referred to just by "D4.1, [page number]".

Overview of selected indicators for Strength/Weakness analysis for the 4i challenges

Gap element (challenge to be overcome)	Indicator (ability of PA to overcome challenge)	Understanding of major strength (score 4)	Understanding of major weakness (score 1)
Innovation			
Lack of certainty and direction for the market on what innovations are needed and will be supported	Ability to provide clarity and direction in terms of innovation needs	PA is able to provide clear and consistent signals to actors on the direction of technological change: what innovations will be needed with which priority/urgency for the transition and what support (financial, regulatory) is available	(Near) absence of signals as to what innovations are needed (or which direction of technological change) and what support is available
R&D gap: Lack of early support for innovations, low success rate for inventions to be taken any further	Ability to support R&D into new inventions and technologies and bring them to a higher TRL (1-6)	Risk-friendly support for innovations in their first stages and across the innovation ecosystem (R&D incl. base research, piloting, demonstration), both financial and otherwise (RD&D funding, general price and non-price innovation incentives);	No or limited support for clean solutions early in innovation chain, low chances of development into higher TRL

Demonstration gap: Insufficient development of prototypes into commercial products	Ability to demonstrate promising technology fully (under real-life conditions and at scale), ability to form markets and let business models evolve in order for new technologies to survive the "valley of death".	Creation of conditions conducive for fast development into higher TRL (including funding, but also regulatory conditions that provide room for experimentation, sandboxing, co-development of standards, new business models)	Limited support for demonstration activities, scaling of technologies and emergence of new business models and markets held back by regulatory hurdles and barriers
Deployment gap: Insufficient deployment support for commercially available solutions to reach wide-spread diffusion	Ability to deploy proven innovations and technologies and to enable their market penetration/diffusion	Strong support for deployment of proven innovations and their diffusion on the market (market-making, support deployment at scale through investment/price subsidies, performance/technology standards, supportive infrastructure etc.); support for realising self-sustaining diffusion and positive path dependencies (learning-by-doing, economies of scale, etc.)	No or little support for deployment, and diffusion
High levels of lock-in of fossil technologies that are incompatible with the transition	Ability to disincentivise fossil-based technologies and value chains to support exnovation	Active policies to discourage existing, fossil-based technologies and value chains (; moving innovation support from	Incumbent technologies are not disincentivised; no active policies to direct innovation efforts away from fossil-based

		incumbent to transformative technologies	technologies towards transition needs
Investment and finance			
Insufficient private and public investment in the transition	Ability to undertake and mobilise investments, availability of sufficient support mechanisms	Large-scale public investments in assets needed for the transition are committed with a medium to long-term perspective and dedicated policy instruments and support mechanisms are in place to mobilise private investments; clear rules to ensure an adequate balance for the blend of public and private funds.	Little or only short-term commitment of public investments in transition-related assets; few, weak and non-targeted policy instruments and support mechanisms to mobilise private investments are in place
Insufficient incentives to phase out investments in fossil-based assets	Ability to prevent any further investments in fossil-based assets and to mobilise investments in the transition of fossil-based businesses	Investments in fossil-based assets and other price-support to fossil technologies are phased-out and transition finance is actively encouraged	Investments in fossil-based assets are not discouraged; no or insufficient incentives for transition finance (through price and non-price measures)
Lack of financial transparency regarding the alignment of investment and financial flows with climate goals	Ability to improve data collection and information distribution, and to address information-related market failures	Harmonised data on private and public climate-friendly and climate-harmful investment flows across Europe is gathered on an ongoing basis and compared to investment needs.	Transparency requirements for financial institutions are too vague to collect meaningful data; no or limited monitoring and transparency on private and public investment flows

		Financial institutions are required to publish relevant data and disclose information on the alignment of their financial flows with climate goals and how they help finance the transition	
Infrastructure			
Lack of sufficient funding for infrastructure necessary for transformative change	Ability to deliver sufficient and timely financing and investment for infrastructure	Large funding needs are acknowledged and instruments are in place to make available public funding and leverage private investments	Very little recognition of investment needs; no dedicated instruments to deliver public and private funding
Chicken-and-egg-type coordination problem: infrastructure of a certain type and demand for this infrastructure are interdependent	Ability to support a timely choice for certain infrastructure / create a deliberate lock-in	Decision-making processes and structures for infrastructure developments are in place. Decisions on infrastructural needs are firm and timely, leading to certainty for potential users; strong coordination and willingness to make well-informed choices for specific solutions	No decision-making processes and structures for infrastructure in place; no clear decisions are made on what infrastructure is needed, leading to long delays in decarbonization efforts. Very little coordination or active exploring of the options.
Long lead times	Ability to accelerate planning, permitting and implementation of infrastructure projects	Lead times are kept short due to streamlined permitting and planning processes; there is	Lead times are very long as permitting, stakeholder engagement, spatial planning

		strong coordination; projects of particular importance to the transition are fast-tracked.	etc. are not coordinated and no fast-tracking exists
Lack of transnational/pan-European infrastructure planning	Ability to create strong & binding framework for transnational planning at EU scale	Pan-European infrastructural planning is strongly embedded in MS and EU processes, local investments are required to be in line with infrastructural needs for the transition at the EU level, a clear vision of which is obtained by thinking back from the end	Pan-European planning is non-existent or at most voluntary. A clear vision on what is needed is lacking. For local projects, no check on coherence with the pan-European network is required.
Integration			
Administration and institutions not able to coordinate, plan, implement, monitor and enforce comprehensive climate policy	Ability to ensure adequate administrative and institutional capacity to facilitate a whole-of government approach to climate policy	Adequate (administrative) capabilities or other mechanisms in place to coordinate, plan, implement, monitor, enforce and adjust climate policy (instruments)	Administration, institutions and mechanisms are weak, and unable to provide coordination and implementation of climate policy
Insufficient legal mandates and mechanisms to mainstream climate in all policy areas	Requirement to mainstream climate policy in all relevant policy areas and effective mandates, tools and mechanisms for mainstreaming both during the policymaking	Climate policy is well mainstreamed in all sectoral policies; climate considerations are included in all main policy outputs and existing policies are reviewed to ensure their	Climate policy is isolated and hardly mainstreamed in other areas, sectoral policies generally do not take into account climate considerations and may result in

	process and in the outcomes; Application of the "do no harm" principle	alignment with climate policy objectives; "do no harm" principle effectively implemented to prevent policies and outcomes that contradict climate policy objectives	outcomes that contradict climate policy objectives
Insufficient mechanisms to coordinate innovation, investment and infrastructure policies	Capabilities and mechanisms to align innovation support, investment (support) and infrastructure policies with the climate transition and to prevent support and policies that contradict the objective	The PA has dedicated mechanisms / institutions in place that ensure that innovation, investment and infrastructure policies are aligned with climate policies. These tools are responsive to changes, i.e., re-calibrate if necessary to ensure that policies remain aligned if circumstances evolve.	Innovation, investment and infrastructure policies are not / poorly aligned, creating frictions and stifling progress in all dimensions (innovation held back by lack of suitable infrastructure, infrastructure held back by lacking investment etc.); support for policies and activities that are harmful for the climate transition
Coordination of interactions across sectors	Capacities and mechanism to ensure cross-sectoral governance of coupled sectors	The PA has appropriate policy instruments and processes in place to facilitate sector coupling and manage coordination challenges resulting from it, such as integrated planning	No policy instruments and processes are in place to facilitate sector coupling, increasing the risk that sector coupling creates frictions and inconsistencies

Overview of selected indicators for Opportunities/Threats indicators for the PAs

Indicator	Definition of indicator/analytical question	Understanding of major strength (score 4)	Understanding of major weakeness (score 1)
Political attainability	How plausible is it that this policy avenue will be implemented politically? • Public opinion and support • Interest groups and stakeholders: Does the PA actively build new alliance and pro-climate coalitions, does it undermine the position of incumbents? How likely is it that it will overcome vested (fossil) interests? • Partisan and ideological alignment with key decision makers and parties in the EP / council / COM • Institutional attainability: how fundamental would the PA break with the current institutional set-up of the EU? How much new administrative capacity is	Implementation of policy avenue is politically plausible; high public support to regulatory approach; high partisan / ideological support by key parties/actors; high institutional and administrative alignment; little deviation from existing policy mix	Implementation of policy avenue is politically not plausible; low public support; alliance building is not plausible / there is a high risk of regulatory capture; there is low support by key parties / actors; institutional alignment is low and/or major new administrative capacity is needed; major breach with current policy mix

	needed to implement the PA? • Extend to which the existing policy mix needs to change direction		
International attainability	• Alignment with current EU/MS foreign policy; • Compatibility of PA with policies of key strategic partners – high prospects of cooperation	Implementation of policy avenue is aligned with EU/MS foreign policies and supported by key strategic partners; high probability that elements of EU approach will be copied by third countries	Implementation of policy avenue is not aligned with current EU/MS foreign policies and not supported by key strategic partners; third countries are critical towards EU policies
Achievement of socio-economic goals	• PA supports goals outside the area of climate and energy, specifically on socio-economic themes	Implementation of policy avenue has positive side effects in other areas across the EU and MS, such as gender, racial and economic equality, health, jobs, etc.; co-benefits are explicitly acknowledged; trade-offs are acknowledged and tried to be mitigated	Implementation of policy avenue has no or negative side effects in other areas across the EU and MS, such as gender, racial and economic equality, health, jobs, etc.; co-benefits are not explicitly acknowledged; trade-offs are ignored and no mitigation strategies are in place

Assessment Strengths and Weaknesses

Innovation

Indicator: Ability to create clarity and direction in terms of innovation needs

Problem Statement

The path to decarbonisation will require transitioning to clean technologies and phasing out polluting ones. However, there are multiple alternatives to face this transition and multiple technologies that can play a role in it. There are certain technologies already at advanced levels of maturity that just need to gain market share while there are other breakthrough innovations that show potential but are still at a low development level. This multiplicity of options can create a lack of certainty and direction regarding technology choices and the policies to support innovation that can jeopardise or slow down the achievement of the decarbonisation goals. Different PA approach this challenge from different perspectives with different intensities in terms of the amount of direction needed and how to provide it.

Green Economic Liberalism

Assessment of understanding the challenge and instruments to address it

The general direction is provided by high-level agreements related to both intermediate and final decarbonisation goals. With a general understanding that more carbon-intensive technologies need to be replaced by carbon-neutral technologies sooner rather than later, no further direction is considered necessary as carbon prices function as a primary signal. Through adequate carbon pricing as the main instrument, the market should be able to find the most efficient path to decarbonisation, and this includes finding the right technologies that enable it. Promoting or prioritising certain technologies above others via top-down approaches would be an unnecessary and potentially counterproductive measure, distorting price signals. However, Green Economic Liberalism foresees some supporting instruments to ensure carbon pricing performs as expected and to correct market failures and barriers. In the case of innovation, measures removing barriers to new entrants or financial support schemes such as the Innovation Fund and Horizon Europe are expected, and these may mitigate some of the risks and remove some uncertainty. Also, support schemes may provide some criteria of what is their expected focus but, at the same time, provisions to ensure competition on a level playing field based on cost and GHG reduction potential should be integrated.

Assessment of ability to solve the challenge

The whole premise of the policy avenue relies critically on the proper performance of the market and the capacity of carbon pricing to lead to the "right" choices. This, by definition, requires very limited intervention from governments, which might result in a lack of an identifiable clear direction regarding innovation needs. This open, bottom-up, approach is considered necessary to allow for an array of options to emerge from which the most efficient ones prevail. Thus, there will be winners and losers, but this is part of the process. However, considering the urgency to firmly address climate change mitigation challenge, this open approach might not be able to deliver in time.

It is also relevant to consider the impact that internal and external events not necessarily driven by factors relevant to the transition can have (e.g. geopolitical crises). Combining different political priorities (e.g. decarbonisation, energy security) might result in mixed signals to the market that contribute to additional uncertainty and lack of clarity.

Conclusion & scoring

This PA's approach provides little control on how to reduce uncertainty, this is considered a weakness. **Score: 2**

Green Industrial Policy

Assessment of understanding the challenge and instruments to address it

This PA follows the logic that transformative technological change does not usually come on its own and, thus, inputs by governments to shape markets and provide direction and clarity are needed. This means that innovation policies cannot be technology-neutral, although closing doors to other technologies should be avoided. According to this PA it is important to frontload decisions and the implementation of measures as much as possible to send clear and early signals to market participants and provide the time for cost reductions. The overarching instrument for coordinating the innovation efforts are "missions" each of which focuses on areas or technologies that are essential for transformation to climate neutrality. These "missions" are meant to bring together all involved stakeholders, including government, academia and the private sector. Within this "mission" framework the instruments that allow states to reduce uncertainty about future technological developments are a strong and directed RD&D funding scheme, setting standards, or providing research-related public goods, such as open data. In addition, the government can reduce uncertainty by guaranteeing demand for clean goods and services.

Assessment of ability to solve the challenge

The Green Industrial Policy PA gives providing direction a central role. Hence, a clear vision of how to achieve it both through strategic decision-making and through a specific set of instruments is defined. It is acknowledged by its proponents that it might not necessarily be the most efficient approach, but it should be the most effective. In this regard, the support of government and public resources is seen as necessary, but it is seen as something temporary that should lead to self-sufficient value chains.

Conclusion & scoring

The PA provides a solid approach to address the challenge. This is a major strength. **Score: 4**

Directed Transition

Assessment of understanding the challenge and instruments to address it

According to this policy avenue, directed technological change is the cornerstone for decarbonisation. Thus, governments need to actively direct it by making strategic choices regarding which technologies have more probability of success and can perform better. These decisions are informed by scientific knowledge, and thus, continuous exchange between science and policy is required. Although a clear direction is given to provide certainty, room for flexibility is necessary to allow for updates based on the results of monitoring of implemented solutions and their actual development. Planning (both economy-wide and sectoral), targets and standards are the core instruments to provide this clear direction. Although the general direction comes top-down from the EU level, Member States have a key role in the implementation of policies at lower levels.

Assessment of ability to solve the challenge

This PA seems to be well suited to solve the uncertainty challenge in innovation by providing clear direction. The PA implies implementing a policy mix that is responsive to socio-economic developments and changes in the political landscape, but at the same time continues to set a clear and shared long-term vision of the way forward. Some of the key instruments are sectoral roadmaps and standards. One of the premises of this PA is that most of the necessary solutions are already known. This idea might create some over confidence on the capacity of existing options and thus failing to pursue additional ones to the necessary extent. Possible risks of this approach to be considered are, on the one hand, the capacity to balance being as adaptive as needed while maintaining a clear long-term direction. Also related to this one, a clear scientific consensus won't be always available to give certainty on the right choices to make. On the other, this approach requires a complexity of instruments and measures at different levels (including coordination with and among Member States) that might prove challenging to run effectively without the bureaucratic load becoming a burden.

Conclusion & scoring

Providing clear direction is one of the core aspects of the directed transition PA. However, the approach is a little bit less clear on how to get there. This is considered overall as a strength. **Score: 3**

Sufficiency and Degrowth

Assessment of understanding the challenge and instruments to address it

The paradigm of reference for this policy avenue, unlike the previous three, does not consider viable decoupling economic activity from its climate impacts, thus considering the classic concept of economic growth not compatible with climate neutrality. This idea is reflected in an approach to innovation that goes beyond technological innovations and their markets, with a broadened scope to include social innovation, and that makes low-carbon lifestyles possible and attractive. The avenue provides clear direction about the principles guiding innovation needs. In this regard innovations that enable, or improve, circularity will be prioritised as well as those that allow for more efficient local approaches such as, for example, energy communities. Also, as addressing inequalities and wealth distribution is at the core of the paradigm, the innovation policy would also favour innovations that require less technology and resources and are more affordable, in line with the idea of frugal innovation. In terms of instruments, a mix of current instruments (i.e. EU ETS, targets, standards) with more stringent goals with additional supporting instruments is proposed.

Assessment of ability to solve the challenge

This policy avenue provides a clear innovation strategy but less detail is provided on how it would be put into practice. Focusing on less technology-intensive innovations and reducing the urgency of technological innovation by balancing with lower-consumption economies might remove some of the uncertainty and risk that characterises the constant need for breakthrough innovations. However there is also a risk of underestimating technological innovation requirements to decarbonize some basic needs that might not be possible to reduce via degrowth only (e.g. heating). However, it is an approach that is quite far from current political approaches to climate policy.

Conclusion & scoring

Although clear direction regarding innovation needs and how to attain them is provided, some feasibility concerns arise considering the status quo and the time frame. Overall this PA's approach to the challenge can be considered a strength, and some of its proposals could be integrated into a transformative policy mix. **Score: 3**

Indicator: Ability to support R&D into new inventions and technologies and bring them to a higher TRL (1-6)

Problem Statement

There is a strong consensus regarding the critical importance of the early stages of innovations and also about the elevated risks associated with them. Some sort of support is generally considered necessary as a lack of early support for innovations can lead to a low success rate for inventions to be taken any further. Also, this support needs to help mitigate to a certain degree the high risk levels. However, there is much less of an agreement on what form this support should take and with what public investment intensity. Both, more interventionist and more neutral approaches entail risks. The different PA provide different approaches to this.

Green Economic Liberalism

Assessment of understanding the challenge and instruments to address it

The Green Economic Liberalism PA acknowledges the limitations of carbon pricing alone in incentivising breakthrough innovations that involve fundamentally different ways of producing goods and delivering value to customers. Thus, additional market-compatible tools are needed to lower their costs and lead them toward market maturity. As risks in the first stages of innovation are high, it is difficult to attract private funding, and hence public innovation support is required. Also technology selection will to a certain extent be present in the form of avoiding fossil-fuel based solutions. However, the PA emphasises the need for these measures to be targeted and temporary. Also, they need to be implemented in a way that minimises possible market distortions.

Assessment of ability to solve the challenge

The PA identifies the risks of early stages of innovation and foresees specific measures to help moderate them through some public support although more limited than in other approaches. Also, the lack of top-down technology selection might cause this funding to have a more limited impact as it would potentially be spread among more contending technologies and approaches.

Conclusion & scoring

This less interventionist approach might bring some difficulties in mobilising funding at the necessary scale and the cost-effectiveness can be overly restrictive at this stage. This is considered a weakness.

Score: 2

Green Industrial Policy

Assessment of understanding the challenge and instruments to address it

Since technological transition is at the core of this PA's philosophy, supporting early-stage innovation is considered key. Although this PA advocates for the prioritisation of certain technologies, at this stage, enough room is to be provided for universities, research centres and companies to explore all technologies that can lead to breakthrough innovation. Creating an effective innovation ecosystem is necessary, and it needs to take into account the role of public and private stakeholders. This stage also requires abundant funding that should be channelled through base funding, project-based grants and loans to private companies to ensure that all actors involved can receive the needed support. To operationalise the innovation pathways a Transformation Fund is proposed that will build on and expand the current Horizon Europe Programme and the Innovation Fund.

Assessment of ability to solve the challenge

If properly managed, a well-funded R&D programme such as the one proposed in this PA can lead to the desired early-stage innovation results. It needs to be seen how well the technology selection works and whether the foreseen monitoring mechanisms to provide flexibility work efficiently. The public-private collaboration mechanisms should be a plus to foster breakthrough innovation; however, it needs to be seen how well private initiatives align with the proposed choices by the PA.

Conclusion & scoring

The PA proposes a strong strategy for early-stage innovation, with only minor doubts on its feasibility. This is considered a major strength. **Score: 4**

Directed Transition

Assessment of understanding the challenge and instruments to address it

The Directed Transition PA acknowledges that innovation involves taking risks and making investments in uncertain developments. Therefore, public investment and innovation go hand in hand. Governments should intervene to ensure that enough support is provided at the different stages of the technology lifecycle. This takes various forms. In the beginning, researchers and developers need high volumes of capital that allow for invention and experimentation. At this stage, public funding can have considerable leverage by directing funding to particular technologies. A prominent role is given to existing technologies. Technology-specific research and development funds (R&D) serve as an instrument to cover the high up-front costs for innovation and experimentation.

Assessment of ability to solve the challenge

In this PA the initial support is considered key to providing emerging technologies with the right environment to develop. Although private funding is taken into account, the primary role in this stage is given to public funds. Public funds allow to better steer in which direction and for which technologies support is prioritised. As mentioned previously, there is the risk of supporting solutions that do not manage to perform as expected which could delay and increase the cost of the carbon transition. The PA takes this risk into account and tries to mitigate it by close monitoring and ongoing dialogue between government and academia. However it is not clear that this can be as effective as expected as a mitigation measure. Also, the confidence in existing solutions might cause a reduced ambition in the promotion and support of early stage new technologies.

Conclusion & scoring

The PA has a clear strategy for the first stages of innovation and relies on mechanisms that already exist (R&D funding programmes) However there might be some risks to a directed approach in the form of making wrong decisions that can delay the development of effective and efficient breakthrough innovations. Also, the importance given to existing solutions might in certain circumstances hinder the development of new ones. Nonetheless, the approach is considered in general as a strength. **Score: 3**

Sufficiency and Degrowth

Assessment of understanding the challenge and instruments to address it

The Sufficiency and Degrowth understanding of innovation goes beyond technological innovation and focuses on system innovations. New inventions are only one of the many pieces needed to achieve the desired societal change and, thus, play a less prominent role than in other approaches. The importance of the development of these new technologies is linked to the extent to which they are instrumental in contributing to advancing towards low-carbon societies with better quality of life. In terms of instruments, the PA prescribes a combination of very stringent carbon pricing with directed public funding to R&D.

Assessment of ability to solve the challenge

The PA foresees public support for the emergence of technological innovations that align with the overall goal of advancing towards low-carbon and low-resource-use societies. This top-down approach can be effective in supporting a limited number of solutions. The availability of resources, though, might become a challenge. Although higher carbon prices should bring up available public funds, overall lower consumption might counter this effect. Considering the larger social agenda and the broad focus on environmental sustainability (including biodiversity and resource use), there might be limited resources to address the early-stage support needs.

Conclusion & scoring

Only moderate relevance is given to this aspect which is reflected in a less defined approach. However, the overall approach can still be considered a strength. **Score: 3**

Indicator: Ability to demonstrate promising technology fully (under real-life conditions and at scale), ability to form markets and let business models evolve in order for new technologies to survive the "valley of death" (TRLs 7 and above)

Problem Statement

Once a new technology's potential has been proved, and several TRL's have been achieved there still remains a critical phase related to the demonstration in real-time conditions and the capacity to scale up the technology and to attract a market for it. As in the previous phase, the divergence in criteria among paradigms and their associated PAs is not so much related to the need for some sort of support to help companies navigate past the "valley of death" but to the form it should take. Inadequate support can lead to insufficient development of prototypes into commercial products.

Green Economic Liberalism

Assessment of understanding the challenge and instruments to address it

As argued for previous indicators, according to the Green Economic Liberalism only the minimum required support should be provided. Choosing the right instruments is critical to avoiding inefficiencies and market distortions. In this sense, Carbon Contracts for Difference are a key instrument as they avoid overcompensating. An extended Innovation Fund would be implemented too. Supporting instruments like green procurement and quotas can also help in the later stages of this phase so to reach the maturity needed to compete with incumbent solutions. The aid schemes should prioritise performance over technology as a selection criterion to avoid biases that would favour certain technologies and, thus, create inefficiencies.

Assessment of ability to solve the challenge

If carbon prices are steadily high and the proposed support instruments are implemented, this approach might provide a fair chance for the technologies that can deliver decarbonisation in the most efficient way to be demonstrated and be ready to join an open market. However, there is very limited control to correct course along the way if needed.

Conclusion & scoring

The PA has a fairly strong approach to tackling this challenge and it is considered a strength.

Score: 3

Green Industrial Policy

Assessment of understanding the challenge and instruments to address it

This PA foresees different R&D support instruments for the different stages of the innovation process. In particular, for this stage, funding for demonstration projects should be provided. The mission approach plays a key role in this respect as it sets the specific goals to accomplish which can help bridge the gap between the initial developments of a technology and its full implementation. Also, this PA promotes a vision of shared risks. That is, risks related to bringing promising technologies to real-life scenarios, and the associated potential losses, should not be undertaken by private stakeholders alone, but neither by governments only. In this regard, partnerships are created through different instruments such as for example governments taking some equity of firms.

Assessment of ability to solve the challenge

This PA takes into consideration that there are different stages in the innovation processes and that specific instruments are needed to address them. The shared risk approach can be useful in providing some certainty and support in the "valley of death" phase.

Conclusion & scoring

The PA provides an overall strong approach to addressing this stage of innovation and the associated challenges. This is a major strength.

Score: 4

Directed Transition

Assessment of understanding the challenge and instruments to address it

Public funding is also at the core of the Directed Transition strategy for this stage of the innovation lifecycle. It provides the high up-front capital that is needed to move immature and uncertain technologies from niche markets into widespread deployment. In the demonstration phase, governments can accelerate the consolidation of breakthrough innovations, for instance, by supporting pilot and demonstration projects, real-life laboratories, or by creating lead markets for novel technologies. This allows for the development of technologies further and leads them to market maturity. This demonstration for projects can also be useful in harnessing private investment. Additionally, governments need to anticipate infrastructure needs and support its roll-out to enable the new solutions to develop.

Assessment of ability to solve the challenge

The PA takes into consideration both the need for public and private funds at this critical stage to ensure that maturity is gained Thus, it foresees allocating the needed amount of public support, but the strong directed approach might leave reduced toom for other instruments more targeted to mobilize private actors and that can create a pull effect from market demand. Also, it takes into account the need for enabling conditions for the deployment in real-life conditions such as the adaptation of existing or building of new infrastructure. Again, being technology-specific entails some risks, but certain mitigation strategies can be foreseen and some of the potential losses are assumed as unavoidable.

Conclusion & scoring

The PA provides an overall credible approach for this stage of the innovation life-cycle. This is considered a strength.

Score: 3

Sufficiency and Degrowth

Assessment of understanding the challenge and instruments to address it

The Sufficiency and Degrowth PA takes into account the need to support new technologies through the different steps towards their commercialisation and diffusion but with a somewhat narrower approach in terms of which technologies should be supported. Public support is instrumental in the demonstration of new innovations (social and technological).

Assessment of ability to solve the challenge

The challenge of the availability of resources and the lack of focus on technological innovation might create some challenges. However, the integrated view of the role of innovations in contributing to low-carbon societies as well to improved social equity can be helpful in ensuring that the supported ones manage to achieve the implementation at a real scale.

Conclusion & scoring

Although a framework to provide support is defined, and can be considered a strength, the broader approach to innovation somewhat blurs the focus on technological innovation. Together with the previous argument, the technological scepticism might also hamper the options to succeed in the most critical part of the innovation development process.

Score: 2

Indicator: Ability to deploy proven innovations and technologies and to enable their market penetration/diffusion

Problem Statement

Once a sufficient maturity level has been reached and demonstrated new technologies and solutions need to find a way to penetrate markets. One of the challenges in this stage is how to be competitive against incumbent solutions that can benefit from their longer presence in the market. Also whether the needed infrastructure to enable wide-spread diffusion is available. Although carbon pricing is a common element in most paradigms, the extent to which markets can deal with this on their own differs among them.

Green Economic Liberalism

Assessment of understanding the challenge and instruments to address it

As new technologies reach certain maturity levels, the support instruments should be phased out. At this stage, a strict approach to carbon pricing without interventions should be able to effectively allow new solutions to be more competitive than incumbent ones. The incumbent will either have been phased out or will have become more expensive and inconvenient.

Assessment of ability to solve the challenge

The challenges for the Green Economic Liberalism PA approach are more salient in the previous stages of innovation. Solutions that have reached the maturity level to be competitive should be able to scale up in a market that will have sufficient demand as they become the standard solutions. However, the right infrastructure needs to be in place to pave the way for the diffusion. Some uncertainty exists about the ability of this PA to ensure the necessary coordination for a timely roll-out of necessary infrastructures.

Conclusion & scoring

Strictly from an innovation diffusion perspective, a stringent enough carbon price with very limited support instruments should be able to deliver the desired results in an efficient way. This is considered a major strength.

Score: 4

Green Industrial Policy

Assessment of understanding the challenge and instruments to address it

The Green Industrial Policy PA believes in the need to combine supply-push support with demand-pull measures. These demand-creation measures are key for the last stage of innovation that requires the diffusion of the solutions. In this regard, the support should not be only for new innovations, but also it should serve to scale up existing solutions that need further diffusion. To achieve this, performance standards play a central role. Through the standards, the demand for newer technologies can be ramped up as the demand for more carbon-intensive solutions is phased down. Other specific support mechanisms are foreseen such as for example, green public procurement, subsidies or certification and labelling. Additionally, the PA foresees defining the infrastructure requirements needed to enable the scale-up and diffusion of technologies and solutions.

Assessment of ability to solve the challenge

The PA identifies the need for specific intervention in this consolidation phase of innovation. Additionally, there is an effort to coordinate both the different phases of innovation as well as the thematic priorities via missions and other coordinating schemes. However, one challenge to consider is the risk of subsiding too much for too long. The capacity to reduce public funding at the right time, and specifically being able to deal with the sectoral support groups pressure, is key.

Conclusion & scoring

The PA proposes a strong approach to overcome the challenges related to the deployment and diffusion of new technologies, but with some risk of having difficulties in the timely withdrawal of support. The overall approach is considered a major strength.

Score: 4

Directed Transition

Assessment of understanding the challenge and instruments to address it

For the last stage of the innovation lifecycle involving the commercialisation and uptake the Directed Transition PA relies on the capacity to generate network effects triggered by a "directed" implementation of an array of multi-sector policies and support mechanisms which drive down the cost of new technologies and their performance. In terms of instruments, standards should be able to have a major role in securing the phasing out of incumbent technologies and creating the necessary pull effect to allow the transition of new solutions.

Assessment of ability to solve the challenge

As in the previous phases of innovation, this PA proposes a directed and controlled approach. It takes into account that, to respond to technological and market developments, governance frameworks and policy mixes must be evaluated and adapted regularly. Also, the strong reliance on standards makes this PA somewhat less prone to the risk of regulatory capture, being able to solve better the phasing out of public support. A t the same time, however, standards might be less useful in helping overcome adoption barriers.

Conclusion & scoring

The PA provides a strong and adaptive approach to supporting the diffusion and uptake of new innovations. The more interventionist approach might lead to lower capacity to fully attract the market forces that are key at this stage. However, acknowledging some limitations, the approach his is considered a major strength.

Score: 3

Sufficiency and Degrowth

Assessment of understanding the challenge and instruments to address it

The sufficiency and degrowth approach to promote market uptake is linked to the stringent provisions to phase out carbon-intensive incumbent solutions thus creating demand for alternatives. Additionally, the solutions that align with the vision of circularity and low low-consumption and that enable low-carbon lifestyles are supported by public institutions including the creation of enabling public infrastructure conducive to low-carbon lifestyles and green public procurement.

Assessment of ability to solve the challenge

Diffusion of technologies linked to the creation of new markets is not a goal per se of this PA and there is clear hostility towards consumerism. The goal is to enable low-carbon lifestyles with reduced social inequalities. Also, since the sufficiency approach only searches to create the necessary demand, room for diffusion via enlarging demand will be more limited and available only, for the most part, for solutions that align with the overall vision of the PA. In terms of feasibility, it should be taken into account that this PAs approach relies on a shift of the collective mindset towards making quality of life a priority, which might be harder than approaches that are based on the diffusion based on affordability.

Conclusion & scoring

The lack of a clear strategy can be considered a weakness. The differences in the overall philosophy of the Sufficiency and Degrowth PA compared to other more conventional approaches make some of the identified gaps, such as this one, less relevant and thus the proposed solutions less convincing.

Score: 2

Indicator: Ability to disincentivise fossil-based technologies and value chains to support exnovation

Problem Statement

Fossil technologies are incompatible with climate neutrality. However, their widespread presence and dependence on them to keep or grow GDP levels have created strong path dependencies and the risk of lock-ins that need to be reverted. Additionally, as an intermediate solution in the absence of sufficient carbon-neutral solutions, the transition has depended on the switch to less carbon-intensive fossil fuel-based solutions (e.g. oil to liquid natural gas). The challenge is, how to effectively disincentivise and phase down fossil-fuel-based value chains, a requirement for the transition, considering the existing large inertias.

Green Economic Liberalism

Assessment of understanding the challenge and instruments to address it

If high carbon prices are sustained, the market should effectively address this challenge by, in a first stage, accelerating the replacement of carbon-intensive fuels with less carbon-intensive ones (i.e., switching from coal to gas) and then gradually eliminating fossil generation capacities. Additionally, any incentives for fossil fuel consumption such as subsidies, need to be removed, including temporary relief measures. Other instruments such as standards and bans should only be used in very particular cases and in a temporary way where carbon pricing instruments do not provide a sufficient long-term signal (e.g. EU ETS2 for oil and gas boilers).

Assessment of ability to solve the challenge

This PA relies on high enough carbon prices and caps set in the ETS that will efficiently disincentivise fossil-based technologies and value chains to support exnovation. Provided that carbon pricing stays high and firm caps are set and kept this PA can effectively address the fossil fuel phase out, albeit with some important potential social costs. Addressing these entails the risk of creating market distortions that should ideally be avoided according to this approach.

Conclusion & scoring

The PA defines how technology lock-ins can be avoided and fossil-fuel-based value chains disincentivised, this is considered a strength.

Score: 3

Green Industrial Policy

Assessment of understanding the challenge and instruments to address it

The PA highlights the need to create mechanisms to phase out incumbent fossil-fuel-based technologies to ensure that new technologies can thrive. In this respect standards are the key instrument. Negative technology standards provide an effective way to set specific dates to phase out carbon-intensive technologies. Additionally, performance standards will also contribute to accelerating the transition. Also, as a crucial first step, removing existing harmful subsidies is foreseen through the revision of the EU Energy Taxation Directive.

Assessment of ability to solve the challenge

This PA puts the focus more on the entry of new technologies rather than the phasing out of the incumbent. However, it still provides a credible pathway to exnovation using negative and positive measures implemented mainly via standards and carbon pricing. However, these standards need to be stringent enough to effectively achieve the set decarbonisation goals. In this regard pressures from economic sectors reluctant to an accelerated decarbonisation are to be expected.

Conclusion & scoring

The PA provides a clear understanding of the challenge but somewhat less defined response compared to other PA. Still it is considered a strength. **Score: 3**

Directed Transition

Assessment of understanding the challenge and instruments to address it

Governments need to direct this transition by creating the necessary regulatory pull effect, driving the phase-in of clean technologies and the phase-out of high-fossil incumbent ones through targets, standards, and mandates, and by providing the necessary infrastructure (D4.1). Additionally, long-term planning is a core element through which phase-out dates for fossil energy carriers and for fossil-based technologies and value chains are provided in advance. Also, the government cross-sectoral intervention in innovation is key to overcoming existing path dependencies that favour incumbent technologies.

Assessment of ability to solve the challenge

The Directed Transition paradigm understands the risks of lock-ins and defines specific mechanisms to try to avoid and overcome them. Additionally, evaluation and enforcement mechanisms are foreseen to ensure there are no delays and to mitigate the risk of a possible rollback towards fossil fuel technologies. Also, governments are in charge of deploying the necessary infrastructure to enable the timely replacement of fossil-fuel-based solutions. A risk to be aware of, though, is the importance of implementing a consistent approach, effectively managing to avoid sectoral interests lobbying and thus maintaining the credibility of the government in its commitment to address the problem.

Conclusion & scoring

A strong and coordinated approach is provided. This is a major strength. **Score: 4**

Sufficiency and Degrowth

Assessment of understanding the challenge and instruments to address it

Phasing out fossil-fuel-based technologies is at the core of this PA strategy. This is addressed in two main ways. First, the overall decrease in carbon-intensive economic activity promulgated by this paradigm should lead to lower usage of energy in general and fossil fuels in particular. Secondly, by actively regulating towards this goal. This includes a variety of instruments including immediate withdrawal of subsidies to the fossil fuel value chain, tighter carbon pricing and standards, bans, reformulation of the EU taxonomy for sustainable activities, specific measures to prevent rebound effects and active measures to promote greener alternatives.

Assessment of ability to solve the challenge

The overall approach and the variety of instruments proposed create a viable path to overcome this challenge. Although support for some of the harder instruments (e.g. bans) might prove harder to gain and there might be political costs associated to being more outspoken about the issue, the prioritisation of this issue makes the ability to achieve a timely phase-out credible.

Conclusion & scoring

Overall strong strategy and instruments to overcome the challenge. This is considered a major strength. **Score: 4**

Investment and finance

Indicator: Ability to undertake and mobilise investments, availability of sufficient support mechanisms

Problem Statement

The energy transition requires sufficient amount of (private and/or public) investments as sustainable technologies and other innovations need to become part of society. The question is whether the different policy avenues will commit sufficient public investments and incentivise private investments in the transition.

Green Economic Liberalism

Assessment of understanding the challenge and instruments to address it

In the green economic liberalism policy avenue, investments will usually take place once they are profitable (within a certain timeframe). Government's role in directing private investments is limited mostly to establishing the carbon price – in this case through the ETS. The assumption is, that investors fully factor the carbon price and its future development into their decision making. Whether or not this will mobilise sufficient private investments, depends on how high the carbon price will be and whether other market failures deter private investments. One acute challenge for carbon pricing, is myopia and the short-term pursuit of profit. Private investors may not fully

This policy avenue sees a very limited role for public investments, mostly directed at R&D and, in parts, in infrastructure. But direct public investments play a secondary role, as the allocation of resources should be mainly left to private actors.

Assessment of ability to solve the challenge

The primary tool for mobilising and directing private investment is the ETS, which establishes a carbon price. Whether or not this will mobilise sufficient private investments, depends on how high the carbon price will be and whether other market failures deter private investments. Generally, the correcting of market failures stemming from unpriced externalities can be expected to guide private investments.

However, one acute challenge for carbon pricing is myopia and the short-term pursuit of profit by market actors. This may lead to inefficient investments in the transition, as what is rationale in the long-term, may not be rationale in the short-term for individual investors. Moreover, fundamental uncertainty and coordination challenges may undermine the effectiveness of a transition strategy that centrally banks on private investments. Moreover, public investments will be necessary to support the transition even when effective carbon prices exist. For example, energy infrastructure is characterised by large sunk costs and high risk, deterring private investments. Within this policy avenue investments will be mainly private and to a limited extent public, which can result in overreliance on private investments and insufficient incentives to mobilise private investments. Furthermore, other market failures and non-price barriers may prevent the necessary amount of private investments.

Conclusion & scoring

We assign a **score of 2** to this indicator.

Green Industrial Policy

Assessment of understanding the challenge and instruments to address it

In the Green Industrial Policy avenue, the premise is that transitioning to a climate-neutral economy requires large-scale investments, and furthermore that private investors alone are unlikely to invest at the scale necessary. Therefore, the government has a more active role by directing private investments and committing public investments in the transition.

In this PA, the government will incentivise and de-risk private investments in different ways. Subsidies, tax credits, and loan guarantees can help private investors to overcome uncertainty and crowd-in private investments. The ETS will remain and thus direct private investments to some extent. Funds on both European and national level are an important means for supporting private investors. Moreover, an important indirect way of supporting private investments is the setting of standards and certification. In addition, this policy avenue uses green public procurement to create demand for low emission products and thus mobilise investments.

Next to these measures to direct private investments, the policy avenue commits direct public investments, especially in large-scale (energy) infrastructure. It moreover is open to taking stakes in companies and making investments in clean manufacturing, thus becoming an investor itself.

Assessment of ability to solve the challenge

The policy avenue has a comprehensive strategy for mobilising both private and public investments. It commits substantial public funds to this, which will likely crowd-in private investments and resolve some of the other market failures and coordination problems that plague a private-led transition.

A risk of the government guiding the transition in terms of investments, is that supported technologies or companies may not be viable in the long term. However, this is a risk this policy avenue is aware of and accepts.

And while it will be difficult to fully mitigate the risks, this may be a promising strategy, as the large scale investments will likely accelerate the transition.

Conclusion & scoring

Both public and private investments are important in this policy avenue, and there exists a plausible theory on how both are deployed and how they complement each other. We therefore assign a **score of 4** to this indicator.

Directed Transition

Assessment of understanding the challenge and instruments to address it

According to the Directed Transition policy avenue, market mechanisms alone are unable to deliver the transition to climate neutrality. This extends to investments. However, the policy avenue is much more focused on setting targets and phase-out dates for fossil technologies through standards, than it is on mobilising the necessary investments. Still, the policy avenue uses different mechanisms to make and mobilise investments in the transition. This is mostly focused at moving a technology from its early, pre-competitive phase into the commercialisation and to scale up deployment. Here, it mobilises the European Investment Bank, but also state investment banks and national tax credits can play a key role in guiding investments. Finally, green public procurement might be used to create green lead markets.

The policy avenue does make very limited use of carbon pricing to direct investments.

Assessment of ability to solve the challenge

The policy avenue does acknowledge the role of investments and mobilising private finance for the transition. It devises some measures that primarily focus on bringing novel technologies to the market. The exact mechanisms are less clear than in the GIP, however. Moreover, the primary focus of the policy avenue is on setting targets, phase-out dates, and legislation. It is less concerned of directing the market towards these targets in the short term and on mobilising the necessary investments.

Moreover, the policy avenue is very heavy-handed when it comes to regulation. While this can provide certainty to investors, there is a clear risk that "too much" prescription is a barrier and deterrent for private investment. Finally, as with GIP, there is a risk of supporting the wrong technologies. However, this is a risk that may be necessary to accept and that can be mitigated.

Conclusion & scoring

Overall, the policy avenue is less clear on its investment agenda with serious risk of not delivering sufficient investment. Therefore, we assign a **score of 2** to this indicator.

Sufficiency and Degrowth

Assessment of understanding the challenge and instruments to address it

The Sufficiency and Degrowth policy avenue focuses on reducing production and consumption as a solution to the socio-ecological crises. The reduction of consumption is initiated in several ways: lower or negative economic growth, redistributive measures in order to reach more equality and the emphasis on social innovation and behavioural solutions.

Assessment of ability to solve the challenge

The policy avenue is focused on reducing consumption and production. This would necessarily imply fundamental changes, given that profit expectations – a major guidepost for investment flows – will be substantially depressed.

It is important to note that, although less investments may be needed than in other policy avenues because overall demand will be lower and (financial) resources are redirected to only essential parts of the economy, also this avenue will need substantial public and private investments *inter alia* for deploying renewables and grid-level storage, for public transit, for grid upgrades, or for decarbonising heating.

While this policy avenue uses carbon pricing and environmental taxation to guide private investments, its focus on limiting overall economic output and strongly intervening in the core functions of markets will certainly depress private investments, including in the energy transition. It is moreover questionable, whether the policy avenue can compensate for the lack of private investments through public investments, given that the tax base will likely shrink in a shrinking economy.

Conclusion & scoring

The policy avenue is premised on fundamental different economic relations and a restructuring of the economy. It is doubtful, whether this can mobilise the necessary investments. Therefore, we assign this indicator a **score 2**.

Indicator: Ability to prevent any further investments in fossil-based assets and to mobilise investments in the transition of fossil-based assets

Problem Statement

In order to reduce greenhouse gas emissions, not only should assets based on renewable energy be taken up by society but also investments in fossil-based assets should be phased out. The question is whether the different policy avenues provide enough incentives for this phase-out.

Green Economic Liberalism

Assessment of understanding the challenge and instruments to address it

In the GEL policy avenue, price signals are the most important means to direct investments. Assuming an effective ETS with a stringent cap and an efficient market, permit (i.e., carbon) prices should reflect the long-term unprofitability and high operational expenditure of fossil assets. The price of carbon can be expected to rise over time, as the cap declines. Rational market actors would factor this into their investments and long-term expectations. In the GEL PA, fossil investments would be detered primarily through the price signal of the ETS. There would be no additional phase-out dates or bans.

Finally, the phase out of any remaining fossil fuel subsidies also plays an important role in this policy avenue.

Assessment of ability to solve the challenge

The ETS is an effective instrument for preventing (some) investments in fossil-based assets. It has already made coal power plants unprofitable in the medium-term, effectively deterring any new investments in coal power in Europe. However, carbon prices would need to be very high to *prevent* any investment in new fossil assets, and some persist to be profitable even with a carbon price, such as gas. Private actors may still continue to invest in fossil assets because they are profitable in the short-term, which the carbon price may not sufficiently address. Myopia, moreover, may result in inefficient investments in fossil assets, even when carbon prices reflects long-term climate effects and scarcity in permits. This may be a challenge, specifically for households, who do not have full information about the trajectory of carbon prices or may not be fully aware of them, leading to investments in fossil technologies that may not be cost-effective in the long-term.

Conclusion & scoring

The GEL policy avenue will effectively deter investments in fossil-based assets. There is certain a risk that price signals are insufficient to deter all fossil investments. Other market failures, such as incomplete information or myopia may undermine the effectiveness of the carbon price in preventing fossil investments. Moreover, the carbon price may not be able to address the short-term profitability of fossil assets. We therefore assign a **score of 3** to this indicator – phasing-out investments in fossil assets is a moderate strength.

Green Industrial Policy

Assessment of understanding the challenge and instruments to address it

This policy avenue is more focused on phasing-in low-emission technologies than it is on actively phasing-out the fossil technologies. However, it still disincentivises fossil technologies. First, the policy avenue does make use of carbon pricing through the ETS. It moreover phases out fossil fuel subsidies. Second, the policy avenue uses standards to direct markets and drive the substitution of fossil capital. Third, the policy avenue uses prudential regulation to align private financing flows of financial institutions with their decarbonisation strategies and requiring them to either finance the transition of their counterparties including the phase out of fossil assets or to divest from such counterparties. Finally, there will also be government support for exnovation of existing fossil-based technologies, such as an exnovation fund or dedicated credit programmes.

Assessment of ability to solve the challenge

The policy avenue uses multiple instruments to support the phase out of fossil-based assets. However, the policy avenue is much more focused on phasing-in clean technologies, than it is on phasing-out old technologies. While pricing and standards are used, the policy avenue bets on low-emission technologies becoming cheaper and better than fossil ones. However, as long as fossil-based assets are more profitable than sustainable assets, parties may still invest in them.

Conclusion & scoring

The policy avenue dedicates different instruments to discouraging investments in fossil assets and mobilises transition finance. But some risks remain as the focus is more on phasing-in the clean technologies than phasing-out the old. We assign a **score of 3** to this indicator.

Directed Transition

Assessment of understanding the challenge and instruments to address it

This policy avenue relies heavily on the direct phase-out of fossil-based assets. It does this by setting clear standards and phase-out dates for technologies and thus provide private investors with the necessary certainty to plan their investments accordingly. Also, there might be bans on fossil-based assets. Fossil fuel subsidies are phased out (both implicit and explicit ones). In this policy avenue there will also be government support for exnovation of existing fossil-based technologies, but the focus is on regulatory instruments such as standards rather than on financial instruments.

Assessment of ability to solve the challenge

As with in the green industrial policy avenue, governments are having an important role in this policy avenue. However, it is much more focused on and direct in phasing-out fossil technologies and assets.

They will also be more likely to using prudential regulation to align private financing flows of financial institutions with their decarbonisation strategies and requiring them to either finance the transition of their counterparties including the phase out of fossil assets or to divest from such counterparties.

Conclusion & scoring

The strong focus on phasing-out fossil fuels and the use of direct regulation such as bans makes this policy avenue very strong when it comes to preventing investments in fossil assets. We assign a **score of 4** to this indicator.

Sufficiency and Degrowth

Assessment of understanding the challenge and instruments to address it

The Sufficiency and Degrowth policy avenue is focused on shrinking emission-intensive sectors, such as the fossil fuel industry. It phases-out fossil subsidies and it uses standards and bans to phase-out fossil technologies. They will also be likely to use prudential regulation to align private financing flows of financial institutions with their degrowth-oriented decarbonisation strategies and requiring them to either finance the transition of their counterparties including the phase out of fossil assets or to divest from such counterparties.

Assessment of ability to solve the challenge

Governments are likely to effectively implement bans and standards to phase-out investments in fossil-based assets. The general inclination of this policy avenue gives a strong base to support the phase out of fossil-based assets. On the other hand, the instruments used are mostly directed at reducing consumption and steering behavioural choices, not necessarily explicitly at creating incentives to phase-out fossil assets. Moreover, the policy avenue favours the direct ban of a technology or fuel over a transition path, thereby overlooking the needed transition finance that some sectors may need.

Conclusion & scoring

The general inclination of this policy avenue gives a strong base to support the phase out of fossil-based assets. We assign a **score of 3** to this indicator.

Indicator: Ability to improve data collection and information distribution, and to address information-related market failures

Problem Statement

In order to address information-related market failures, transparency about the alignment of financial flows with climate goals is necessary. Asymmetries and information failures prevent financial markets from functioning efficiently and result in an under-estimation of financial risks. Incomplete information also compromises the management of the transition. This means there must be transparent information about who invests in what and the associated exposure of financial institutions to climate and transition risks.

Green Economic Liberalism

Assessment of understanding the challenge and instruments to address it

Though the role of the government is limited within this policy avenue, the goal of policy in this policy avenue is to correct market failures. While the primary market failure under consideration is the unpriced externality of GHG emissions, the goal to fix markets also extends to asymmetries and information failures. One can therefore expect that prudential regulation and much stronger disclosure requirements are compatible with this policy avenue.

Assessment of ability to solve the challenge

The policy avenue generally aims to correct markets, so they can function efficiently. This also extends to financial markets. One can therefore expect that prudential regulation and much stronger disclosure requirements will feature in this policy avenue. However, the policy avenue also wants to limit government interventions and give companies flexibility and it will depend how important information asymmetries and failures are perceived, i.e., whether financial markets are seen as inefficient or not. Policymakers may thus refrain from implementing very strong disclosure requirements, based on the assumption that carbon pricing is sufficient to correct prices.

Conclusion & scoring

Most likely there will be some regulation on data transparency to allow for tracking of financial flows, in order to be able to fix market failures related to incomplete information. However, one can question the stringency this will have. Therefore, we assign a **score of 3** to this indicator.

Green Industrial Policy

Assessment of understanding the challenge and instruments to address it

This policy avenue is based on the assumption that there are multiple, overlapping market failures that justify extensive government intervention. This includes information-related market failures. The policy avenue moreover questions the premise that financial markets are efficient and correspondingly dedicates different measures to correcting financial markets.

Assessment of ability to solve the challenge

Considering the important role of governments in this policy avenue, it will also be more likely that companies will be required to provide transparency on their investment flows through mandatory transition plans and other disclosure requirements.

Besides for transparency, other monetary policy is used by governments in order to direct investments of corporates and financial institutions to desirable sectors and activities. The European Central Bank could limit credits to fossil-intensive sectors and direct them to clean ones. The policy avenue thus foresees a very active monetary policy that is used to support the fiscal side in the transition to climate neutrality, this includes intervening in financial markets and requiring more transparency.

Conclusion & scoring

As government action can be very effective in reaching financial transparency, we assign a **score of 4** to this indicator.

Directed Transition

Assessment of understanding the challenge and instruments to address it

This policy avenue is much more sceptical towards markets and the role they play in the transition than GEL and GIP. Private investments are playing a less important role in this avenue. Given the scepticism towards financial markets and the efficiency, though, one can expect that the policy avenue will ensure more transparency about financial flows.

Assessment of ability to solve the challenge

Governments, having an important role in this policy avenue, will likely require companies to provide transparency on their investment flows through making transition plans mandatory for corporates. However, given the clear phase out policies that are likely to be part of the policy mix under this paradigm, a close tracking of financial and investment flows may be of less importance.

Conclusion & scoring

The Directed Transition policy avenue will likely mandate greater transparency. However, the financial sector is not seen as relevant and high level targets and phase-outs are assumed to do much of the work in this policy avenue. We assign a **score of 3** to this indicator.

Sufficiency and Degrowth

Assessment of understanding the challenge and instruments to address it

The policy avenue is very sceptical towards (financial) markets and their role in the transition. It does not merely employ a "market fixing" approach, but directly mandates phase-outs. The role of prudential regulation and transparency may thus be less relevant.

Assessment of ability to solve the challenge

All in all, governments have an important role in this policy avenue and will also be more likely to require companies to provide transparency on their investment flows through making transition plans mandatory for corporates.

Conclusion & scoring

While financial markets and their efficient operation are less relevant in this policy avenue, the policy avenue will likely mandate more disclosure and clear transition strategies from financial institutions. We assign a **score of 3** to this indicator.

Infrastructure

Indicator: Ability to deliver sufficient and timely financing and investment for infrastructure

Problem Statement

Infrastructure requires large investments at the time of construction. These investments typically are expected to pay off in the long term (decades) if the infrastructure is well used, i.e., well suited to the needs of its users. In the context of the energy transition there is considerable uncertainty as to which infrastructure, to what magnitude and in which locations will be necessary. Given this uncertainty, private investors are reluctant to take up the risk. At the same time the availability of public funding is far from guaranteed. Thus, lack of financing leads to delays in infrastructure construction, thus delaying the energy transition. As transportation is expected to increasingly electrify, transportation infrastructure is more and more linked with energy infrastructure and is affected by its uncertainties.

Green Economic Liberalism

Assessment of understanding the challenge and instruments to address it

The Green Economic Liberalism policy avenue places markets and market instruments at the centre of the way forward to address climate change. The policy avenues emphasises that markets provide the needed effectiveness and efficiency to mobilise private funds. Under this policy avenue, the bulk of the investments in infrastructure should be provided by private investments. Possible instruments to indicate the need for infrastructure are digitalisation; auctions; nodal pricing or other cost differentials to incentivise investments in large-scale infrastructure such as electricity transmission networks.

Assessment of ability to solve the challenge

Following the Green Economic Liberalism policy avenue, private parties are the ones to invest in and operate infrastructure. Given the complexity and the interdependency of infrastructure construction, the policy avenue does see a need for planning and coordination by a governmental authority. This should reduce the uncertainty and thus risk for private investments. However, the instruments to achieve planning and coordination are underspecified in this policy avenue (see further). Thus, specifically for infrastructure, uncertainty can remain large. Depending on the type of infrastructure, the effect of this uncertainty can play out differently. The larger and the more complex infrastructure is, the riskier the investments are. For some types of infrastructure, such as vehicle charging infrastructure, uncertainties are limited, and private funding are expected to come forward in practice. For others, such as hydrogen networks or additional transmission power lines (especially cross-border) the uncertainties of the energy transition are large, and private investments could turn out to be too risky, leading to insufficiency, delay and at times unavailability of financing and investment.

Conclusion & scoring

Depending on the type of infrastructure, sufficient and timely investments may or may not be realised. In particular, for large-scale, complex infrastructure projects – that are key for the energy transition in the EU – there is a realistic threat that risk averse private parties and public/private parties such as TSOs and DSOs will not timely, not sufficiently or not at all invest. Therefore, we assess the ability of the policy avenue to raise sufficient and timely funding for infrastructure specifically as a weakness and give it a **score 2**.

Green Industrial Policy

Assessment of understanding the challenge and instruments to address it

The Green Industrial Policy avenue assumes an active role for the government to build a green economy. Part of this active role is the availability of government funding to support and enable technological change. A new Transformation Fund is created to achieve this, with infrastructure being one of the three pillars of focus. The existing Connecting Europe Facility, currently the most important vehicle for infrastructure funding, is to be integrated in the Transformation Fund. Investments are thus one of the main types of instruments used in this policy avenue. The Green Industrial Policy avenue does not necessarily seek to be technologically neutral; it accepts that in some cases certain technological choices, and thus certain type of infrastructure will be accelerated through policies and governmental support.

Assessment of ability to solve the challenge

The government is seen as the main developer for infrastructure. This leads to reduction in uncertainty for private investors when private funding is also necessary. As the Transformation Fund provides public investments, it can act as a lever to foster private investments. Jointly public and private funding increases the likelihood to deliver sufficient and timely financing and investment for infrastructure.

Conclusion & scoring

The availability of public funding boosts investments, both directly and by leveraging private investments through the reduction of technological uncertainty. We assess this indicator to be a major strength under the Green Industrial Policy avenue and give it a **score 4**.

Directed Transition

Assessment of understanding the challenge and instruments to address it

The Directed Transition policy avenue is strongly geared towards standards and cross-sectoral roadmaps, which both send clear signals to private investors and, in case of energy infrastructure, to responsible parties such as TSOs and DSOs. Both standards and roadmaps thus reduce uncertainty and thus risks for private funding. The policy avenue is less explicit in the means to mobilises public investment funds. It assumes that public investment funds will indeed be available, and will help support the roll-out of necessary infrastructure. However, it is not entirely clear through which mechanisms how the public funds would work.

Assessment of ability to solve the challenge

The main mechanism is to plan the infrastructure and lay it out in roadmaps, this supports the timeliness of investments. Whether investments will be sufficient is less clear. The policy avenue sees a role for both public and private investing. Public investments should in general come from Member States, and can be supported by EU-level funds. The reduces risks through clarity of roadmaps are supposed to attract private investment. TSOs and DSOs are in addition incentivised through targets. This set of instruments provides certain support for sufficiency of investments, however, does not guarantee it.

Conclusion & scoring

This policy avenue acknowledges the large funding needs of infrastructure. Investments should come both from public (mostly national) and private funds. For private funds, the policy avenue seeks to reduce uncertainty and thus risks through cross-sectoral roadmaps. We consider the solution of the policy avenue a strength, however not a major strength as funding sufficiency is not guaranteed, thus yielding a **score 3**.

Sufficiency and Degrowth

Assessment of understanding the challenge and instruments to address it

In the Sufficiency and Degrowth policy avenue EU funding is geared towards low-consumption system. All infrastructure should support the envisioned low-carbon lifestyle. The policy avenue foresees reducing economic activity, and the extent of new infrastructure necessary is expected to be lower than in other policy avenues. The policy avenue also emphasises the phase-out of fossil infrastructure which can be expected to result in disinvestments. As the policy avenue is sceptic towards markets and GDP, and considers economic growth incompatible with decarbonsation, cost recovery of disinvestments is expected to be limited to nil. Given the scepticism towards markets, funding for infrastructure is mainly assumed to come from public sources. In addition, through policies, private funding should also be redirected towards the same goals and the same type of low-carbon infrastructure.

Assessment of ability to solve the challenge

The Sufficiency and Degrowth policy avenue has a general adverse stance towards markets and investments. It assumes funding for infrastructure, where necessary, to come from public funds, but does not detail how these public funds should be financed. The policy avenue does assume a strong role for the government, which could lead to timely decisions for investments. However, it is not clear whether sufficient funding would be available. The policy avenue primarily concerns itself with the types of infrastructure that are compatible with a decarbonised world (cycle paths, effective public railways, etc), not with the financial side of the transition. The financial perspective is limited to the assumption that public funding should be entirely geared towards supporting the foreseen low-carbon, sustainable types of infrastructure.

Conclusion & scoring

Although the overarching goals of this policy avenue are clear, the exact funding streams (both public and private) are less so. There is therefore as of yet uncertainty whether and how funding will be available for infrastructure. We consider this a weakness of the policy avenue and give it a **score 2**.

Indicator: Ability to support a timely choice for certain infrastructure / create a deliberate lock-in

Problem Statement

Infrastructure takes a long time to build and requires a long-term view. Availability or non-availability of certain infrastructure facilitates or inhibits the use of certain technologies. A chicken-and-egg-type of problem arises if a new technology (such as hydrogen, CCS, electrical vehicles) requires new infrastructure (hydrogen or CO_2 pipelines, EV charging infrastructure). Investments in infrastructure face high uncertainties because the extent of its future use is unknown. At the same time, the users await infrastructure before taking the leap into adopting a new technology. Overarching governance is needed to solve this type of problem.

Green Economic Liberalism

Assessment of understanding the challenge and instruments to address it

The Green Economic Liberalism policy avenue sees markets as the most efficient way to develop, scale up and roll out solutions for societal challenges, such as climate change. Under the policy avenue assumption that market mechanisms provide the right signals, market actors can choose how to respond. For instance, industrial plants can choose the most cost-efficient way to decarbonise their processes: to electrify, to employ green hydrogen, to adjust production, etc. The policy avenue is thus explicitly technology-neutral. It does therefore not address the chicken-or-the-egg type of problem. For a single industrial power plant it might be unclear which of the possible solutions is the most cost-efficient as some solutions need new infrastructure, but whether or not it will be built, depends on the choices of other market actors (power plants), who individually face the same challenge. Price-signals do not resolve this.

Assessment of ability to solve the challenge

Market signals work well if the market can quickly respond to increases, decreases or changes in supply or demand. However, as infrastructure requires long lead times to construct, market signals are muddied by the unavailability of infrastructure. They are thus an inadequate coordination mechanism to resolve the chicken-or-the-egg problem. The policy avenue inherently has limited instruments to address this challenge.

Conclusion & scoring

We conclude that this policy avenue is not suited to face the chicken-and-egg problem which may lead to long delays in decarbonisation efforts since end-users and infrastructure operators are waiting for each other. Therefore, we assess this as a strong weakness of the policy avenue and give it a **score 1**.

Green Industrial Policy

Assessment of understanding the challenge and instruments to address it

The Green Industrial Policy avenue explicitly assumes that markets on their own are insufficient to coordinate structural change. Governments need to shape markets and actively direct technological change. Governments are assumed to reduce uncertainty in this policy avenue. The main instruments of the policy avenue are so-called missions, these are coordinated efforts by public and private actors to achieve technological progress and implement change. The so-called Mission Coordination Board oversees, choses and/or advises on the missions. Through this coordination, demand for and supply of clean goods and services are brought together. In addition, instruments such as green public procurement and strong focus on product and service standards help solve the chicken-and-egg-type of problem by breaking the vicious circle.

Assessment of ability to solve the challenge

Infrastructure is explicitly acknowledged as an enabling and/or necessary condition through its inclusion in the "missions". The Mission Coordination Board is expected to identify structural needs and coordinate the development of infrastructure in close collaboration with Member States. This is a clear approach to solve the chicken-or-the-egg problem.

Conclusion & scoring

As governments take an active stance towards shaping markets, they are also actively shaping the demand for infrastructure. We consider this a strength of the policy avenue. We do not score this as a major strength because the policy avenue does not provide mandatory instruments to choose a given infrastructure, and therefore some uncertainty remains. Thus, we give it a **score 3**.

Directed Transition

Assessment of understanding the challenge and instruments to address it

The Directed Transition policy avenue assumes that market forces alone are insufficient to coordinate structural change. In that sense it is similar to the Green Industrial Policy avenue. Also here, governments are assumed to break the chicken-and-egg-type of problem by creating a regulatory and infrastructural pull effect to drive out fossil technologies and phase-in clean technologies. The EU and its Member States are to develop sectoral roadmaps to provide guidance, with infrastructure an integral part of these roadmaps. Again, similarly to the Green Industrial Policy avenue, Directed Transition is not necessarily technology neutral as roadmaps can benefit one technology more than others.

Assessment of ability to solve the challenge

The Directed Transition policy avenue makes explicit technological choices through sectoral roadmaps, thus creating path-dependencies, which resolve the chicken-or-the-egg-type problem. It should be noted that infrastructure lock-in is not guaranteed until the roadmaps are translated into actual infrastructure planning and implementation. However, as Member States are playing a key role in infrastructure development, a joint application of infrastructural planning and roadmaps can be expected.

Conclusion & scoring
As infrastructure is an integral part of cross-sectoral roadmaps in this policy avenue, we consider this a major strength to support timely choice for infrastructure and give it a **score 4**.

Sufficiency and Degrowth

Assessment of understanding the challenge and instruments to address it
The Sufficiency and Degrowth policy avenue sees climate change as a structural, system-wide failure. It sees strong and value-based governance as the correct solution to this problem. Thus, it postulates that certain technologies and life-style choices are not compatible with a carbon-neutral, sustainable world. It is thus explicitly not technology neutral. Where other policy avenues mostly favour some technologies as solutions, Sufficiency and Degrowth goes further in its technological choices and largely bans others. Public transportation is emphasised, private (electrical) vehicles strongly demotivated. The policy avenue emphasises the importance for infrastructure to be conducive for low-carbon lifestyles. As this policy avenue envisages a very different future and lifestyle than other policy avenues, we expect the types of infrastructure also to be different: more cycle paths, railways, and less charging infrastructure. The total extent and the local scale of energy infrastructure will be smaller under Sufficiency and Degrowth, however, some additional infrastructure to harness and transport energy will still be necessary.

Assessment of ability to solve the challenge
In this policy avenue we expect governments, both the EU and its Member States, to take on a key role in many coordination problems. As the policy avenue emphasises the urgency of the climate change crisis, under this policy avenue we expect swift choices for – or against – certain technologies. These choices provide a way out for chicken-or-the-egg-type of problems. However, infrastructure is as of yet a largely underexplored area in the school of sufficiency and degrowth[48].

Conclusion & scoring
Given the important role of governments in the system-wide turnaround of the economy, we expect the EU and Member States to play key coordinating roles in infrastructure choices. When choices are made, we expect them to be well-informed and based on strong values such as just transition and social equity. However, development of a framework for infrastructure within this policy avenue can create delays and uncertainties. Given this lack of clarity for implementation in practice, we score this as a weakness of the policy avenue, and give it a **score 2**.

[48] Pansera, Lloveras and Durrant. 2023. The Infrastructural Conditions of (De-)Growth: The Case of the Internet. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4435948

Indicator: Ability to accelerate planning, permitting and implementation of infrastructure projects

Problem Statement

Infrastructure often has considerable – mostly negative impacts on the local areas where it is constructed. It changes landscape views, affects natural environments and potentially creates nuisances such as noise, shadow, etc. At the same time infrastructure can have considerable, mostly positive impacts in general. It is important for the provision of (clean) energy, enhances security of energy supply, improves connectivity, etc. Planning and permitting processes are typically in place to weigh the local and the global (country or EU-wide) impacts. However, these processes can be very long and are not always transparent, just, and well-coordinated. As the energy transition requires swift changes, decision making processes regarding infrastructure need acceleration without losing key characteristics such as transparent decision-making. With the trio planning, permitting and implementation for most infrastructure the former two take most (say up to 80 or 90%) of the time, we therefore focus on these two phases.

Green Economic Liberalism

Assessment of understanding the challenge and instruments to address it

The solution of Green Economic Liberalism policy avenue to accelerate planning and permitting is to make procedures drastically simpler, so they require much less administrative capacity to implement. The policy avenue states that negative effects, such as ecologic damage, are factors that should be priced in. If that is the case, market signals should provide sufficient information to weigh local costs and global benefits of infrastructure. Given this paradigm, planning and permitting procedures that currently require strong government involvement can be made considerably leaner. The policy avenue does see a role for the government for planning infrastructure projects since it is a public good, but compared to the other policy avenues, the overall role of the government should be limited. Implementation of infrastructure projects is typically the fastest part of the process, and requires relatively little acceleration compared to planning and permitting.

Assessment of ability to solve the challenge

The challenge is to accelerate three steps of infrastructure project: planning, permitting and implementation. A lean take on the government can accelerate permitting given the assumption that the internalised pricing indeed correctly depicts all negative effects. In practice, correctly pricing in all externalities can prove to be exceedingly difficult. However, the planning step of infrastructure is a government activity. Green Economic Liberalism also describes it as such, however, provides little detail as to how it should be realised.

Conclusion & scoring

The policy avenue provides little detail for how the planning should be carried out by a government. In addition, permitting made leaner through pricing in externalities could in practice prove insufficiently adequate. For these two reasons, we assess the take of the Green Economic Liberalism on accelerating planning, permitting and implementation of infrastructure projects as a weakness and give it a **score 2**.

Green Industrial Policy

Assessment of understanding the challenge and instruments to address it

One of the main goals of the Green Industrial Policy avenue is accelerating technological change. The policy avenue further assumes that different industrial policies are aligned and integrated, using so-called "missions" as mechanisms for coordination. Member States will be mandated under this policy avenue to implement integrated infrastructure planning. The policy avenue assumes the creation of a Transformation Fund, with climate-neutral infrastructure as one of its three pillars, which is also expected to facilitate acceleration. In addition, the policy avenue assumes the creation of an EU-wide institution with the administrative capacity to accelerate the planning of infrastructure and to help avoid bottlenecks.

Assessment of ability to solve the challenge

The technological acceleration in the Green Industrial Policy avenue is in particular beneficial for the planning portion of the planning-permitting-implementation trio. As missions are integrated mechanisms, and include infrastructure, planning for infrastructure gains an important boost. The permitting portion is less clear, the Mission Coordination Board and the obligatory integrated planning by the Member States could help facilitate or speed the process, yet this is not a given.

Conclusion & scoring

The Green Industrial Policy avenue has a clear focus on acceleration of technological change as well as alignment and integration of policies. We consider this focus a strength. As the policy avenue is mainly geared towards technologies and still requires considerable coordination between various parties in the planning, permitting and implementation steps. The PA acknowledges the need for high administrative and planning capacity. However, it is unclear whether streamlining and fast-tracking would be part of this policy avenue, we therefore do not score this indicator at the highest level (major strength) and give it a **score 3**.

Directed Transition

Assessment of understanding the challenge and instruments to address it

The Directed Transition policy avenue sees a strong role for governments to address climate change. Cross-sectoral roadmaps are an important instrument of the policy avenue in this respect. The Directed Transition requires a capable public administration with a sizable capacity to realise the planning work required by the cross-sectoral roadmaps. If this capacity is indeed available as foreseen by the policy avenue, well-trained, capable and efficient, planning and permitting portions of infrastructure process can indeed be accelerated. These conditions are not necessarily guaranteed by this policy avenue.

Assessment of ability to solve the challenge

The ability of the Directed Transition policy avenue to accelerate the planning and permitting portions of infrastructure projects depends on the implementation of the public administration capacity. If public administration is well-oiled, having the important functions of planning and permitting can expedite the processes. If however, the implementation is inefficient and bureaucratic, and collaboration between different government levels or branches is not well-oiled, acceleration of infrastructure projects might be thwarted.

Conclusion & scoring

The policy avenue assumes a strong role for governments through the use of cross-sectoral roadmaps and a sizable public administration. If well-implemented, planning and permitting could be fast-tracked. This could be a major strength of the policy avenue. However, as efficiency is not guaranteed, we do not give the highest end-score, thus considering this indicator as strength, and therefore giving it a **score 3**.

Sufficiency and Degrowth

Assessment of understanding the challenge and instruments to address it

The Sufficiency and Degrowth policy avenue seeks to overhaul the entire approach to the economy, life-style, and consequentially decision-making process on infrastructure. Infrastructure is as of yet a largely underexplored area in the school of sufficiency and degrowth[49]. The policy avenue does emphasise a smaller economy with drastically reduced overall energy-use. However, from an energy balance perspective we still expect a larger role for electricity in this policy avenue than what the existing networks can provide, even though overall energy demand is expected to drastically decrease. More reliance on electricity will require more electrical infrastructure such as generation, storage, and transmission networks. Similarly, transportation is expected to undergo a drastic change, towards less mobility, with a high share of shared and public options. Similarly, this overhaul requires new infrastructure, for instance expanded railway or bus services with more bus charging facilities. It is however entirely unclear what the planning, permitting and implementation processes would look like in the overhauled system, and thus whether they will be faster or slower than in the current system.

Assessment of ability to solve the challenge

We do not know yet how this policy avenue will affect lead times. On the one hand, we can imagine that weighing positive overall effects of electrification and transportation and negative local effects of ecosystem disturbance will remain long and difficult processes. On the other hand, we can imagine that this policy avenue in time will provide clear guidelines as how to exactly do the weighing, which will greatly accelerate the processes. In addition, this policy avenue assumes a strong role for governments, which could accelerate planning, permitting and even implementation in the overhauled system. However, whether this would be the case under Sufficiency and Degrowth as of yet remains unclear.

Conclusion & scoring

As it is currently unclear whether Sufficiency and Degrowth would be able to accelerate planning, permitting and implementation of infrastructure, even infrastructure it deems compatible with the envisaged sustainable lifestyle, we score this as a weakness, and give it a **score 2**.

[49] Pansera, Lloveras and Durrant. 2023. The Infrastructural Conditions of (De-)Growth: The Case of the Internet. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4435948

Indicator: Ability to create strong & binding framework for transnational planning at EU scale

Problem Statement

Infrastructure has different scales and works optimally if all scales are well attuned to each other. The pan-European, trans-national scale currently has difficult governance, thus resulting in long and untransparent processes and sub-optimal choices. Improving the pan-European infrastructure planning has the potential to provide benefits such as higher security of supply, more flexibility and resilience and better connection at equal or lower costs. For this to happen, strong and binding frameworks for transnational planning at EU-scale are necessary.

Green Economic Liberalism

Assessment of understanding the challenge and instruments to address it

Although the Green Economic Liberalism policy avenue describes a need for planning and coordination, it, provides little guidance as how this should be achieved, as it focuses mainly on the design of market instruments such as taxes and emission caps (e.g., ETS). With this policy avenue, decisions for investments in transnational energy infrastructure are made on Member State level by individual Transmission System Operators (TSOs), based on market incentives. Some coordination on a European level may be present, like the existing Projects of Common Interests procedures and Ten Year Net Development Plans (TYNDP) from the European Network of TSOs (ENTSOs) for energy-infrastructure. But these processes are voluntary and there is no real pan-European view on planning embedded in MS and EU processes.

Assessment of ability to solve the challenge

The policy avenue describes the need for coordination across different governmental levels, including the international, European level. However, it does not provide specific instruments. Reliance on market-coordination and self-organisation for infrastructure is in the transnational context even more complicated. Differential prices zones and integrated international markets are possible, however insufficient. As these mechanisms do not solve the chicken-or-the-egg-type problem at the national level, they are even more so incapable of doing so transnationally.

Conclusion & scoring

This policy avenue is not suited to embed a pan-European view on planning of transnational infrastructure. So, we assess this as a weakness of the policy avenue and give it a **score 1**.

Green Industrial Policy

Assessment of understanding the challenge and instruments to address it

Coordination mechanisms and bodies are an essential part of the Green Industrial Policy avenue, they are translated into so-called “mission” mechanisms for coordinating the industrial policy mix. Missions can refer to infrastructure, including upgrading EU-wide transmission networks. An overseeing body, a so-called Mission Coordination Board is to be established given this policy avenue. This would be an intra-institutional body with an executive secretariat in an agency. Alternatively, an independent expert body is also a governance option. Specifically for infrastructure an EU-wide institution will be established to ensure the transnational coordination of national infrastructure plans, building further on the Trans-European Transport Network for transportation and for energy (TEN-T and TEN-E) and the Connecting Europe Facility. This type of governance structure, with some European-level mandate, but also a strong engagement of parties at Member States' level is well aligned with the Middle-of-the-Road policy option proposed in the energy case study in Work Package 4.2 of this study.

Assessment of ability to solve the challenge

Under this policy avenue the Mission Coordination Board will closely cooperate with Member States working towards integrated infrastructure planning. Depending on the power interplay between the Mission Coordination Board and the Member States, the result might be of a stronger or weaker pan-European nature. If the Mission Coordination Board is a strong institution with a pan-European view, the result might be indeed pan-European. In the other, possibly more likely, case, the Member States are stronger actors and their national interests prevail.

Conclusion & scoring

The Green Industrial Policy avenue coordination mechanisms and seeks for explicit governance approaches to facilitate efforts, such as infrastructure planning. We assess this as a strength of the policy avenue. We do not give it the highest score (major strength) because stronger, pan-European governance is thinkable. Therefore, for this policy avenue we give a **score 3**.

Directed Transition

Assessment of understanding the challenge and instruments to address it

The Directed Transition policy avenue assumes an overall important role for the EU, with far-reaching authorities and a focus on economy-wide long-term planning. At the same time, Member States remain in the lead for implementation. This is made tangible through cross-sectoral roadmaps, of which infrastructure is an integral part. The EU set targets, can issue guidance or control their implementation. Member States have leeway in the implementation depending on their country-specific energy mixes, geographical topology and other specifics. This is a strong basis for a clear and (partially) binding framework for infrastructure planning.

Assessment of ability to solve the challenge

Given the long-term and cross-sectoral planning which lies at the base of this policy avenue, we consider the pan-European infrastructural planning to be strongly imbedded in this policy avenue. Though Member States are in the lead for implementation, EU-level guidance and control can provide the pan-European view.

Conclusion & scoring

This policy avenue has a strong European focus and emphasises extensive and long-term planning. Therefore we consider the approach in this policy avenue a major strength to achieve a strong and binding framework for transnational infrastructure planning. We give it a **score 4**.

Sufficiency and Degrowth

Assessment of understanding the challenge and instruments to address it

The Sufficiency and Degrowth has a strong local well-being emphasis. It does fit the adagio "think globally, act locally", and thus has a pan-European, or even a worldwide context. However, the technologies the policy avenue favours are local, modular, smaller in scale and flexible, allowing for multi-purpose use. This view seems not well aligned with large-scale transnational networks. However, as infrastructure is an underexplored area in the policy avenue it is unclear how it would weigh more material-intensive solutions such as small-scale batteries versus large-scale transmission networks to achieve energy reliability in a carbon-free energy system.

Assessment of ability to solve the challenge

Given the preference of the policy avenue for local, smaller solutions and locally-oriented life choices, we expect that if transnational infrastructure would be necessary, its extent would be more limited. Depending on the level at which the policy avenue is implemented (locally, nationally or EU-wide) and the eventual take of the policy avenue on large scale infrastructure, the pan-European view could materialise to a smaller or larger extent.

Conclusion & scoring

As infrastructure is as of yet a largely underexplored area in the school of sufficiency and degrowth, it is also unclear how Sufficiency and Degrowth will affect the pan-European view on infrastructure planning. The focus of the policy avenue is on local well-being, not on transnational large-scale infrastructure. This uncertainty is a weakness of the policy avenue we thus give it a **score 2**.

Integration

Indicator: Ability to ensure adequate administrative and institutional capacity

Problem Statement

A major challenge for effective climate policy is administrative capacity. Administrations and institutions need to have the capabilities and capacities to be able to coordinate, plan, implement, monitor, and enforce comprehensive climate policy. The extent of the necessary capacities and capabilities depends on the instrumentation chosen – more detailed, interventionist approaches tend to require more skilled and extensive administrative capacities.

Green Economic Liberalism

In this PA, the role of policy is largely constrained to providing a framework for markets to operate efficiently. Governments primary role is to correct the functioning of markets where they fail to reach an efficient allocation of resources, and hence maximisation of welfare. The primary policy instrument is carbon pricing in the form of emission trading systems. While these require some administrative capacity to operate effectively, they (are seen to) require less of it than conceivable alternatives. Generally speaking, administrative, and institutional capacity are not perceived as major challenges for the transformation to climate neutrality in this policy avenue, also since the approach seeks to deliver the instrumentation that requires least on state intervention. Consequently, there are few instruments and measures devised to address it. The PA acknowledges a need for "coordination of efforts", but improving administrative capacity is not a direct policy need. "Coordination of efforts" is reduced to a political agreement on a "comprehensive vision of the transformation" (p. 39) which is non-prescriptive and meant as guidance for economic actors.

Assessment of ability to solve the challenge

There is limited recognition for the need for an agile and capable administration for implementing effective climate policy. The primary task of the administration is to effectively enforce the main tool, i.e. carbon pricing / ETS. However, there will also be less need for administrative capacity in this PA than in other PA's that foresee a more active and interventionist role of the state: the main instrument in the GEL PA, carbon pricing, by relying more on market dynamics and private initiative to reduce emissions, comes with fewer and less detailed rules and regulations that need to be implemented and enforced. At the same time, the PA does not acknowledge that even under a regime that relies mainly on carbon pricing regime, many issues remain that need to be addressed by administrations, such as urban planning, infrastructure development, or permitting.

Conclusion & scoring

We consider this ability a weakness and assign a **score 2**.

Green Industrial Policy

Assessment of understanding the challenge and instruments to address it

The fundamental idea of this PA is that the *state* must build a green and climate neutral economy. That means, the state must shape markets and direct change. It therefore puts a lot of emphasis on non-market coordination and capable administrations to implement industrial policy. The policy avenue sees administrative and institutional capacity as a basic prerequisite for successful climate policy.

Assessment of ability to solve the challenge

The PA involves substantial planning and coordination. It moreover employs various standards, integrated planning of so-called "missions"[50], the coordination of investments, and infrastructure planning. The importance of coordination between different economic actors and between levels of government is explicitly

[50] The report defines missions as follows (Görlach, Martini, et al., 2022, p. 43): "A mission can be understood as a coordinated effort by public and private actors to achieve progress in a certain (technological) area that is identified as central in the transformation to climate neutrality. A mission can refer to a technology area, such as carbon capture and storage (CCS) or heat pumps; to an end use, such as decarbonisation of industrial heat; or to a piece of infrastructure, such as an EU-wide charging infrastructure for electric vehicles or upgrading EU-wide electricity transmission. Missions are not limited to R&D or the "invention" of new solutions, they will also augment existing solutions and drive their deployment and commercialisation. For something to qualify as a mission, (a) it should have the potential to significantly reduce emissions and (b) markets must be incapable of developing or scaling the solution on their own. A mission is considered successful if the industry or technology makes an important contribution to climate neutrality and becomes competitive without any direct government support."

acknowledged and also a founding assumption of the underlying paradigm: the state acts as an agent of change, but the process also includes private actors and private, profit-seeking investment. Coordination needs under this PA are therefore much higher than in in other policy avenues. The PA does acknowledge that its approach requires a capable administration and institutions as pre-requisites and implies that these will be provided: in particular, the administration must be enabled to assume the role of leading markets into the desired direction in partnership with private actors. The PA assumed that a body for high-level planning of the industrial strategy is established at the EU level, the Mission Coordination Board (MCB). The task of a forum such as the MCB is to coordinate, plan, monitor, and adjust climate policy. The task of the MCB is to also identify the needs for achieving a mission, and therefore the administrative capacity.

One critique of this PA is that it relies heavily on a capable and agile administration. There are risks associated with relying too much on the decisions and abilities of a central planner, such as making the wrong decisions, developing path dependencies, not being adaptive, or being prone to regulatory capture etc. While this policy avenue tries to pre-empt these risks by developing capable public institutions and administration, they are difficult to fully mitigate.

In sum, though, the PA builds on a strong and capable state capacity to plan and implement industrial strategy, this is counterbalanced by relatively high coordination and administration needs.

Conclusion & scoring

We consider this ability a strength and assign a **score 3**.

Directed Transition

Assessment of understanding the challenge and instruments to address it

The policy avenue relies heavily on binding legislation and planning. Binding legislation implies using binding instruments to mandate binding outcomes. The PA relies less on market-mechanisms, but instead on standards and targets as key policy instruments to direct and orchestrate the transformation. It consequently requires a high administrative and institutional capacity to identify the right solutions and strategies and implement policies to deliver them. The policy avenue is based on the assumption that market-coordination is insufficient to break out of lock-ins such as physical infrastructure and will not achieve the transition effectively and quickly enough. Instead, regulators plan and mandate specific transition outcomes, and predefine specific outcomes. It has much more faith in regulators, who are assumed to have the ability to plan and steer the transition centrally than the Green Economic Liberalism and also the Green Industrial policy avenue.

Assessment of ability to solve the challenge

Because the policy avenue is based on detailed prescriptions about sectoral developments and technological choices, administrators must have detailed knowledge about sectoral, technological, and market trends. Accumulating and acting on this information is a challenge. The policy avenue relies heavily on strategies. The day-to-day implementation, translating the strategy into standards, and enforcing them would require substantial administrative capacity. This is acknowledged in the policy avenue: "This avenue requires a capable public administration, with significant capacity to carry out the (in part) detailed, cross-sectoral planning processes, and ensure effective implementation, as well as compliance monitoring and enforcement" (57).

While it is not specified how exactly the strategies are implemented and administrative capacity is in part reduced to the availability of knowledge for regulators, the PA is clear about the administrative needs necessary. However, given that regulators would prescribe much more and engage in a detailed management of the transition, the risks of government failure are larger than in the GEL and GIP policy avenues.

The policy avenue, moreover, delegates a large extent of the implementation of strategies, including the definition of standards and infrastructure development, to member states. There is a risk that this delegation will result in heterogenous outcomes across member states, as the administrative capacities are dissimilar. Moreover, it is unclear if member states have the capacities to act on the EU-level strategies and implement them effectively.

In sum, this policy avenue relies heavily on a capable administration to plan the transition and implement legislation, but there are risks that the policy avenue cannot fully deliver in this respect.

Conclusion & scoring

Given the above, we consider this a weakness of the Directed Transition and therefore assign a **score 2**.

Sufficiency and Degrowth

Assessment of understanding the challenge and instruments to address it

The challenge of administrative capacity is not acknowledged in the policy avenue. While climate action and the transformation to climate neutrality is understood as a societal challenge, it is primarily understood as one of lifestyles and bottom-up change with less emphasis on a capable bureaucracy.

Assessment of ability to solve the challenge

The PA does not make explicit statements about administrative and institutional capacity. It assumes high capacities for change and action within society and communities. However, while this bottom-up change logic implies first and foremost a high capacity and commitment by non-state actors to get involved, this does not replace the agile and capable state: the public administration will, in some instances, be needed to initiate or coordinate bottom-up-action, and above all to ensure the outcomes of bottom-up action remain aligned with each other and the common transformation goals. This is not a trivial task, and requires substantial capabilities for an inclusive, participatory form of governance – which are not widely available at current.

Conclusion & scoring

We consider this a weakness of the Sufficiency and Degrowth Policy Avenue and assig a **score 2**.

Indicator: Requirement to mainstream climate policy in all relevant policy areas and effective mandates, tools and mechanisms for mainstreaming

Problem Statement

Insufficient legal mandates and mechanisms to mainstream climate in all policy areas is a major challenge for climate policy integration, potentially resulting in contradictory outcomes and incoherent policy.

Green Economic Liberalism

Assessment of understanding the challenge and instruments to address it

The carbon price is the central vehicle to ensure climate considerations are integrated into the decision-making of all actors – policymakers and private actors. In addition, a comprehensive vision is supposed to be formulated, to provide orientation for market actors.

Assessment of ability to solve the challenge

The primary mechanism for mainstreaming climate into other policy objectives and throughout the policymaking process is the carbon price. Ideally, this takes the form a single ETS that covers all sectors and establishes a uniform carbon price. The carbon price thus integrates climate considerations in the decision-making of all private and public actors and serves as a form of mainstreaming climate into different sectors, as well as distributing the mitigation effort across sectors. Yet, a single ETS is only envisioned for the long-term, maintaining the existing sectoral boundaries in the short-term. Since the single ETS cap with a uniform carbon price would be inconsistent with sectoral sub-targets, there are no (legal) requirements beyond the carbon price *for policymakers* to consider climate in their decision-making. The single cap is therefore also the (only) safeguard to ensure policy outcomes do not contradict climate policy objectives.

Conclusion & scoring

Given the above, we assign a **score 3** (strength).

Green Industrial Policy

Assessment of understanding the challenge and instruments to address it

The PA assumes a need for high-level coordination and planning of green industrial policy to align different policy subsystems and industrial policies. To this end, it devises different coordination mechanisms and bodies. The PA understands climate policy mainstreaming as an institutional and governmental task but does not say anything about legal mandates explicitly.

Assessment of ability to solve the challenge

Climate neutrality is framed as a challenge for all of government in this PA. The underlying idea is that the state must direct the economy be the main actor for building a climate-neutral economy. Given this assumption, the policy avenue employs an "all of government" approach to climate policymaking. Institutional arrangements such as the Mission Coordination Board or the Transformation Fund are meant to coordinate the different policy sub-systems, so that policy is coordinated and aligned. One drawback is that the main tool for organising policymaking are missions and a tendency to focus more on some sectors (power, industry, circular economy) than others (agriculture, land-use), and more on building the new rather than phasing out the old. While this ensures that certain climate-neutrality challenges are addressed in a systematic and holistic way, it brings the risk that areas of policymaking that are not part of missions may not get the attention they need. Moreover, while climate neutrality and a green industrial strategy emerge as the reason of state intervention and the goal of all policymaking, the PA does not explicitly frame this in terms of legal requirements. Consequently, the policy avenue employs an "all of government" approach but brings the risk that some areas may not receive the attention they need in the absence of legal mandates for all policymaking.

Conclusion & scoring

We consider this a weakness of the Green Industrial Policy Avenue and assign a **score 2**.

Directed Transition

Assessment of understanding the challenge and instruments to address it

The policy avenue understands climate policymaking as an issue for all areas of government. To this end, it relies on comprehensive planning of the transformation process. Binding targets ensure that all areas and levels of governance are comprehensively integrated and aligned with the goal of climate-neutrality.

Assessment of ability to solve the challenge

Comprehensive strategies and planning are meant to ensure that all areas and all level of government integrate climate into their decision-making. Moreover, the PA sets binding sectoral emission targets. The policy avenue therefore takes an all-of-government approach to climate policymaking. At the same time, member states are in the lead. Sectoral strategies are meant to be flexibly implemented by member states to "enable experimentation and (…) help find effective policies" (55). Given the binding targets and mandates, this flexibility does not undermine climate policy mainstreaming but allows context-specific solutions.

Conclusion & scoring

Also for Directed Transition, this is considered a strength and a **score 3** is assigned.

Sufficiency and Degrowth

Assessment of understanding the challenge and instruments to address it

While climate action is understood as a systemic challenge that requires structural change, there are no explicit or legal requirements to mainstream climate in policy in this policy avenues. At the same time, policymaking is reoriented towards the goal of societal wellbeing within planetary boundaries. Delivering this requires a fundamental overhaul and reorientation not only of climate policy, but particularly economic and fiscal policy.

Assessment of ability to solve the challenge

The goal of the policy avenue is to promote low-emission and low-consumption lifestyles. This necessitates systemic action. All of government is focused on restructuring the economy so that it delivers societal wellbeing within planetary boundaries. Climate is treated as a cross-cutting, societal challenge. However, given the emphasis on bottom-up climate action and place-based solutions, there is a risk that these do not aggregate to sufficiently transformative changes on the systemic level.

Conclusion & scoring

Given the above, a **score 3** is assigned (strength).

Indicator: Ability to integrate and coordinate investment, innvoation, and infrastructure

Problem Statement

For transformative change innovation, investment and infrastructure policies need to be well coordinated. Likewise, progress on one of the challenges is dependent on the other. Therefore, they require integration of investment, innovation, and infrastructure.

Green Economic Liberalism

Assessment of understanding the challenge and instruments to address it

The coordination of innovation, investment, and infrastructure is only partially acknowledged – primarily with regards to the need for the right infrastructure as a prerequisite for investments and the importance of governments for planning it. But the primary coordination mechanism is the carbon price (in the form of emissions trading), which is seen as the central incentive to drive and coordinate investments and innovation. While the PA acknowledges that additional market failures require targeted companion policies that specifically address innovation, investment and infrastructure, it relies on the carbon price as the central coordinating mechanism across the 4i
challenges and across sectors.

Assessment of ability to solve the challenge

The primary coordination mechanism is the ETS and the carbon price, which is assumed to incentivise and determine investments and innovation. Integrated infrastructure planning is supposed to ensure the roll-out of infrastructure.

A few mechanisms are foreseen to support the carbon price, recognising that other market failures may keep it from delivering (sufficiently). Regarding innovation (especially R&D), given other market failures such as spill-over effects or fundamental uncertainty, the carbon price alone is unlikely to deliver the necessary change. Similar constraints apply to transformative investments. In this way, the PA does formulate a clear rationale for when additional policies are called for, and which function they would be expected to serve. However, these companion policies are themselves separate patches that are meant to compensate deficits of the main mechanism, the carbon price – yet (beyond the carbon price) there is little in the way of a central coordinating mechanism to ensure that the companion policies are aligned.

Conclusion & scoring

This ability is considered a strength for Green Economic Liberalism – **score 2**.

Green Industrial Policy

Assessment of understanding the challenge and instruments to address it

The PA centrally acknowledges the coordination challenge of different actors, sectors, and technologies. It understands that the transformation of the economy to a climate neutral one requires the alignment and integration of different policies. Its logic of intervention states that "transformative investments cannot be successful if, e.g., regulatory standards are not aligned and pull in the other direction" (D4.1, p. 41). In particular, the various interactions between investment, innovation, and infrastructure are explicitly acknowledged and addressed in the main coordination mechanisms: the Mission Coordination Board and the Transformation Fund.

Assessment of ability to solve the challenge

The main instrument for integrating investment, innovation, and infrastructure is the Mission Coordination Board. It identifies "climate neutrality missions, defines standards, and sets targets. It identifies infrastructural needs and coordinates the efforts that are happening in different sectors. The high-level planning ensures that all potentials of sector coupling are realised, and measures are taken that are efficient from the perspective of the system as a whole."

The central tool for investments is the Transformation Fund, "it streamlines what used to be isolated funding mechanisms into one integrated mechanism for strategic investments in climate neutrality" (D4.1, p. 44). The Fund – the main investment vehicle – has three pillars (D4.1, p. 44), which reflect the coordination of investment, innovation, and infrastructure. The first pillar tackles research, development, and demonstration (RD&D). The second pillar addresses the deployment of clean technologies. Combined, the two pillars tackle the supply and demand for and of clean technologies and therefore the full innovation chain. The third pillar is devoted to climate-neutral infrastructure. As all three pillars are streamlined and coordinated in one fund, there is a close integration of the three challenges. The MCB and sunset-agreements ensure that the policy avenue is responsive to changes and corrected on an ongoing basis.

Conclusion & scoring

This ability is considered a major strength for the Green Industrial Policy Avenue, so a **score 4** is assigned.

Directed Transition

Assessment of understanding the challenge and instruments to address it

The policy avenue acknowledges the challenges involved in technological change and the complicated coordination of innovation, investment, and infrastructure. Its response is the extensive planning across sectors and levels of government. Economy-wide strategies and sectoral planning are meant to provide guidance and clear signals to market actors and ensure that innovation, investment, and infrastructure are coordinated.

Assessment of ability to solve the challenge

As stated previously, the flexible nature of the strategies may complicate the effective coordination of innovation, investment, and infrastructure. Implementation of strategies takes place mostly at member state level. There is no explicit connection between the investment instruments and the strategy – the extent to which the funding mechanisms act upon the strategies and are implemented in these is unclear. Standards are meant to function as important signalling devices to (help) direct innovation and investment. Infrastructure development should closely mirror standards, and thus enable technological change. Hence, the integration of innovation, investment, and infrastructure is visible, but the mechanisms are not entirely clear. One main weakness is that while the PA acknowledges the crucial importance of integrated planning, it is less explicit about the institutional solutions that should deliver this (considerable) effort.

Conclusion & scoring

We consider this a strength of the Directed Transition PA, **score 3**.

Sufficiency and Degrowth

Assessment of understanding the challenge and instruments to address it

The integration of innovation, investment, and infrastructure is inconsistent in this policy avenue. One the one hand, the focus on enabling sustainable lifestyles through systems innovation and high levels of public goods / infrastructure implies a high need to coordinate the different areas of change. Yet since the PA focuses primarily on enabling sustainable lifestyles, it is less explicit on energy systems or industrial value chains, where most of the investment and infrastructure needs are concentrated.

Assessment of ability to solve the challenge

The policy avenue focuses on lifestyles and behavioural change as well as resource efficiency / circular economy. While this includes infrastructure aspects (e.g., regarding urban and regional planning, public transportation or recycling infrastructure), there is less emphasis on other challenges including technological innovation, industry decarbonisation, energy system integration, etc. – all of which require the integration and coordination of innovation, investment, and infrastructure.

Moreover, overall investment volumes should fall in this policy avenue, and it suggests a lower overall need for infrastructure. In sum, this calls into question to what extent the policy avenue will be able to coordinate innovation, investment, and infrastructure.

Conclusion & scoring

We consider this a major weakness of the Sufficiency and Degrowth PA, **score 1.**

Indicator: Capacities and mechanism to ensure cross-sectoral governance of coupled sectors

Problem Statement

Sector coupling is a crucial prerequisite for harnessing the potentials of a renewable energy system and for maximising efficiency. Insufficient mechanisms to couple different sectors can thus be a major problem for realising transformative change to climate neutrality

Green Economic Liberalism

Assessment of understanding the challenge and instruments to address it

The carbon price is a key enabler for sector coupling: at current, several instances of sector coupling are held back by diverging carbon prices (or lack of a carbon price) in different sectors; in particular since electricity in the EU includes a carbon price, whereas space heating and road transport do not, creating a distortion that works against sector coupling. Universal coverage by a single carbon price is therefore key to enable sector coupling (where it makes economic sense).

Assessment of ability to solve the challenge

The main coordination mechanism is the carbon price. In addition, a "comprehensive vision" of the transition is supposed to be developed, but mostly as orientation. Moreover, integrated infrastructure planning of different infrastructures and between member states is supposed to ensure that infrastructure planning supports market demands and outcomes. It is unclear, however, to what extent the single carbon price would suffice as an enabler for sector coupling. In addition, the policy avenue foresees that ETS systems for power and industry, and transportation and buildings still remain separate in the medium term. This means that carbon prices will continue to diverge for the foreseeable future, undermining the potential of the (envisaged) main instrument to bring about sector coupling.

Conclusion & scoring

Because of these barriers, we assign a **score 2** (weakness).

Green Industrial Policy

Assessment of understanding the challenge and instruments to address it

The PA understands the challenges of sector coupling and sees a strong need for governments to plan and coordinate developments in different sectors to realise its potentials.

Assessment of ability to solve the challenge

The PA devises instruments and mechanism to the challenge of sector coupling. As an industrial strategy, the PA breaks up sectoral boundaries and orients planning around the goal of restructuring the economy in a climate-neutral way. High-level planning is intended to ensure that all potentials of sector coupling are realised, and that any measures are efficient from the perspective of the system as a whole. Through its strategic approach, the PA is also well-positioned to identify where sector coupling may be of strategic significance (e.g. allocating scarce green hydrogen potentials between competing sectoral uses). To facilitate the roll-out of the necessary infrastructure for sector coupling, an EU-wide institution is supposed to ensure the transboundary coordination of national infrastructure plans building on the Trans-European Transport Network (TEN-T) and the Connecting Europe Facility. However, it is an own institution with administrative capacity to coordinate the necessary infrastructure, and if necessary, also accelerate the planning and deployment of infrastructure to avoid bottlenecks.

Conclusion & scoring

The Green Industrial Policy Avenue is well positioned to include the facilitation of sector coupling, particularly where it is of strategic significance for the decarbonisation process. Therefore, we consider this a major strength of the Policy Avenue and assign a **score 3**.

Directed Transition

Assessment of understanding the challenge and instruments to address it

The policy avenue acknowledges the challenges and potentials of sector coupling. The primary instrument for identifying the potentials of sector coupling are economy-wide strategies that are downscaled to sectoral roadmaps, which are supposed to identify the potentials and needs for sector coupling.

Assessment of ability to solve the challenge

To address sector coupling in energy system integration and infrastructure, the PA sets targets for grid operators and defines infrastructural requirements. Moreover, sectoral roadmaps are based on integrated infrastructure planning. Projects of common interest should be identified to facilitate the transboundary coordination of infrastructure.

One challenge in this policy avenue is the fact that sector coupling is explicated in sectoral roadmaps, which are by definition sector specific. To what extent there will be sufficient coordination between the relevant sectoral actors and what mechanisms will facilitate sector-coupling beyond the (evolving) strategies is unclear, and constitutes a governance challenge. Moreover, given the higher level of decentralisation in this PA, there are risks that transboundary coordination will be challenging as different countries pursue diverging strategies, e.g. with regard to the pace of electrification in key sectors, or the use of green hydrogen.

In consequence, the PA acknowledges the need for planning and coordination to yield the potentials of sector coupling, while there may be risks stemming from the focus on sectoral roadmaps and delegation to MS level.

Conclusion & scoring

We consider this a strength of the Directed Transition PA – **score 3**.

Sufficiency and Degrowth

Assessment of understanding the challenge and instruments to address it

Sector coupling is not a primary focus of this policy avenue and not explicitly acknowledged. Energy system integration is primarily targeted at integrating a high share of renewable energies, not at coupling different industry and transport with the power sector. The production and manufacturing side is moreover a blind spot in this policy avenue.

Assessment of ability to solve the challenge

There are no explicit mechanisms beyond the power sector and renewables integration.

Conclusion & scoring

As the relevant mechanisms lack, we consider this a strong weakness and assign a **score 1**.

Assessment Opportunities and Threats

Green Economic Liberalism policy avenue

Political attainability

This policy avenue is largely market-based, building centrally on the ETS 1, ETS 2, and new pricing instruments for the remaining sectors. This is largely in line with much of the current EU climate and energy policy. Emissions trading has already been applied to power generation, aviation, and industry, and is set to be extended to the building and transport sector, as well as shipping. In this sense, carbon pricing is already a central policy instrument of EU policymaking. The policy avenue would thus be largely compatible with the institutional set-up of the EU and can build on existing expertise and structures.

However, this policy avenue foresees a stronger and more central role of carbon pricing, increasing the scope and its stringency, while other instruments in the EU policy mix will need to be justified in relation to the carbon price: in what way they serve to enhance the functioning of carbon pricing. If carbon prices assume a greater role in the policy mix, this also translates into higher carbon prices. Given their distributional effects, this may prove politically challenging.

While the increased revenue could be used to offset some of the social effects of higher carbon prices, public opposition to higher prices for energy and other goods are persistent and easy to mobilise by political opponents and vested interests. The political sensitivity of energy prices, for example, was well visible during the energy price shock after Russia invaded Ukraine.

Another major barrier to the extension of carbon pricing and more stringency in existing pricing systems is the opposition of vested interests. This had been a major problem with the EU ETS, where loopholes and generous free allocation initially undermined the functioning of the market and required several rounds of reforms. For incumbent parties, investing in sustainable technologies is only interesting in case there will a business-case and they will keep investing in fossil-based assets as long as these are profitable. Carbon pricing, which is a core element of the economic liberalism policy avenue, will reduce this business-case. To implement and increase carbon prices, a certain willingness of stakeholders to cooperate is indeed necessary. This willingness is uncertain since stakeholders' profitability is directly affected. This political opposition will likely be transferrable to other sectors (such as agriculture, forestry, and shipping).

Next to the ETS, this policy avenue would remove (implicit and explicit) fossil subsidies and align energy taxation. Phasing-out fossil fuel subsidies has proven extremely difficult across the EU. Taxation, moreover, is not an EU competency. The proposed revision of the Energy Taxation Directive which has been part of the Green Deal and would have aligned energy taxation with their emission intensity, was unsuccessful to date.

A liberal climate policy, building on the ETS as the key climate policy instruments used to have high ideological support and still does in the EU. The existing ETS was reformed and its stringency increased as part of the Green Deal. However, the EU's climate policy has become much more heterogenous, and carbon pricing is no longer seen as the silver bullet. It will moreover be unlikely that key pro-climate actors will agree to ending or reforming some of the key climate policy legislation (such as the RED, EPBD, or the vehicle emissions standards) that this policy avenue would de-emphasise for the benefit of a leaner policy mix focused on carbon pricing.

In sum, economic liberalism is a well-embedded ideological position in the EU and especially in key institutions. However, EU climate policy has become more complex and the role of government intervention (on all levels) has increased substantially. Some necessary changes are substantial and therefore we give this indicator a score of 3.

International attainability

With the extension of the EU ETS to cover almost all (sub)sectors, the CBAM is an important measure to make sure that EU market parties will not lose their competitiveness within the EU. The result of introducing CBAM might be that market parties outside of the EU will choose to export less to the EU as export prices become higher. These developments could result in trade tensions with third parties. A consequence could be the reduced international trade of goods and services, including low-emission technologies, which could undermine the (technological) transition.

However, as most countries outside of the EU have climate policies nowadays, there is a realistic chance that fossil-based assets will become more expensive outside of the EU as well. As a result of the CBAM, countries might also implement carbon pricing as this will reduce an outflow of money towards Europe. This would improve the competitiveness with parties outside of Europe again. Therefore, we assign a score of 2 to this indicator.

Achievement of socio-economic goals

The ETS and other ways of carbon pricing will increase the price of fossil-fuel based products, including products used for basic needs like heating houses or for mobility. Therefore, a fund should be used to provide social compensation and targeted support for vulnerable groups. The existing Social Climate Fund could be used for this purpose, even though there will be a risk that funds will not be enough to fully compensate. In the absence of effective social measures, a price-based transition will likely create social hardship for many households and affected sectors, potentially aggravating existing inequalities.

Carbon pricing – if prices fully reflect external costs – can, in principle, lead to economically efficient outcomes. So, in theory they could minimise the economic cost of the transition to net-zero. However, this assumes such prices can be reached and other barriers (political, economic, etc.) do not interfere.

While this policy avenue can theoretically lead to an economically efficient transition, there are serious social risks that must be mediated. It is questionable if the policy avenue can manage to mediate these risks without foregoing the core idea of the policy avenue: the government should intervene as little as possible in the (emissions) market. Therefore, we assign a score of 2 to this indicator.

Green Industrial Policy avenue

Political attainability

The EU currently relies on a policy mix that incentivises the adoption of greener technologies through framework laws such as the Renewable Energy Directive, through standards to direct technological change (CO_2 emission standards for cars, energy efficiency standards, etc.), and through carbon pricing (ETS 1 and 2). However, policies to support the development of green industries are more recent, fewer, and less impactful: in particular, this pertains to instruments to support investments in clean technologies (Innovation Fund, Invest EU, Modernisation Fund). Vertical industrial policy – the targeted promotion of certain sectors considered to be of strategic importance – has not been a core element of EU policy. Instead, the EU focused on horizontal industrial policy, gearing rules and institutions toward safeguarding competition in the single market. Despite recent efforts into this direction (in particular the proposed Net Zero Industry Act), the historically developed climate policy mix therefore does not amount to a coordinated industrial strategy, as envisaged in the Green Industrial Policy Avenue.

The Green Industrial Policy Avenue would require to significantly ramp up the competencies of the EU for such vertical industrial policy, and to direct these towards creating a green economy. Current market-based policies like the EU ETS would continue to exist and the market would remain an important coordination mechanism. However, the policy avenue would also involve a stronger role for public authorities, in particularly to foster and support substantial investments in a low-emission economy. This requires additional financial resources – at current, but also a firm and credible commitment to sustain them in future: private investors will only be convinced if they expect that the support will be upheld over the economic lifetime of the investment. Entering into this commitment in a way that survives electoral changes and budgetary cuts is therefore one of the most challenging aspects of industrial policy.

One way to ensure a lasting, credible supply of public funding would be to endow the EU (or a dedicated fund at EU level) with fiscal capacities, either by earmarking a certain share of revenues (e.g. from the ETS), and/or to allow debt funding. This has been very challenging in the EU for many years – with fierce resistance against common borrowing (as can be seen with regards to the Recovery and Resilience Facility). Similarly challenging is the reform of the fiscal rules that apply to member states, which would allow them to borrow more to finance the transition. Reforms of the Stability and Growth Pact have proven very difficult. EU investments in the transition are expected to decrease in the medium-term.[51]

This difficulty became evident when the EU proposed the GDIP. The investment arm of the GDIP, the Sovereignty Fund, merely repackaged existing funds. Instead, the Commission loosened the Stat Aid Framework, which allows member states to support their industries more. This in turn has created tension among member states, as some are more able to support their industries than others. This approach moreover risks fragmentation in the single market and consequently, a fragmented transition. The political feasibility of ramped-up investments in the EU are therefore questionable.

Beyond the fiscal question, the interventionist turn this PA implies is highly questionable and will likely prompt strong political opposition. Increasing direct financial support to certain sectors and introducing more ambitious standards will likely be opposed by many stakeholders, as can be seen with the Construction Products Regulation or the Ecodesign for Sustainable Products Regulation.

With regards to public opinion, this policy avenue may be more promising, as the policy avenue aims to make clean technologies cheaper and support their adoption. The costs of this strategy may thus be more hidden than they are in a strategy that relies more on carbon pricing. However, as could be seen with regards to a fossil boiler phase-out policy in Germany, the potential risks of standards can also be effectively mobilised by political opponents. In general, however, this policy avenue tries to create new, low-emission jobs and growth, potentially creating new coalitions and generating long-term support for the transition.

Overall, the EU currently relies on a policy mix of market-based instruments and standards, with a limited role for investment support. While the EU has recently taken steps towards a more concerted promotion of strategic industries and technologies (such as the envisaged Net-Zero Industry Act and the EU Innovation Fund), these are relatively recent additions to the policy mix, and fall short of a full industrial policy as practised in other world regions. There are numerous challenges for an ambitious EU industrial strategy, chief among them the challenges related to an EU fiscal capacity, the ability to deliver an effective industrial policy at EU level, fragmentation in the single market, and ideological opposition to a more interventionist EU. The political attainability of this PA is therefore challenging, and we assess it to be a (moderate) weakness.

International attainability

Public support for the green industrial transition will improve the competitiveness of sustainable technologies in the EU either in the innovation or implementation phase (depending on the specific

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support). This is intended to improve the competitive position of EU industries in the growing markets for green technologies, both inside and outside the EU.

Internationally, the move towards a more interventionist, directed industrial policy in the EU is very much influenced by developments in other countries, above all the Inflation Reduction Act adopted by the USA, but also China's industrial policy towards key sectors and technologies deemed critical for the transition to climate neutrality – such as solar PV, wind, batteries, and EVs. The fact that other world regions offer strong support for green industries, and that the EU needs to match these efforts to stay in the race, is a strong driver for industrial policies in Europe.

At the same time, the substantial support to domestic industries that this policy avenue involves may give rise to trade tensions with third states, as witnessed with the Chinese state support to EVs or the USA's Inflation Reduction Act has shown. Countries that are not willing or able to offer similar levels of support to their own green industries, including developing countries, may perceive some of the industrial support measures as protectionist and conflicting with their own development aspirations. While these issues can be mitigated through diplomacy, trade policy and development cooperation, they will need to be carefully managed.

Although there are indeed some risks, there are significant opportunities for international cooperation as well and we assign a score of 3 to this indicator.

Achievement of socio-economic goals

Governmental support for green technologies will create opportunities for jobs in this field. But the substantial support for businesses may also create new economic inequalities and the support of industry may come on the cost of households. However, these effects could be prevented if there are effective strategies for sharing the costs of the support schemes with the private sector, such as corporate taxation, governments taking stake in in companies themselves, or through new approaches to sharing the intellectual property created. Therefore, we assign a score of 3 to this indicator.

Directed Transition policy avenue

Political attainability

In the Directed Transition PA, state and science combine their forces to explicitly prescribe how the transition towards a climate-neutral economy should take place. Binding emission reduction targets are set, and sectoral roadmaps are devised supported by instruments like carbon budgets, performance standards and technology bans. The development of new, clean technologies is heavily supported, and the most effective ones are selected for further roll-out, creating lock-ins on purpose in order to bring clarity to investors. Targets and other instruments are regularly revisited based on the newest scientific insights.

Elements of this approach are recognizable in the current political context. As we have described in Chapter 3, the EU has historically relied heavily on direct regulation, standards, and limits in their environmental policy. This has changed over the years, as more market-liberal approaches were devised. Still, the EU uses standards and targets throughout their policy mix.

However, the strong role of the state that characterizes the Directed Transition does not line up well with the existing political economy. It is to be expected that both private interests and the market-liberal political factions would have serious objections against strengthening the role of the state to this extent and would prefer to see a stronger role for market forces and technological openness, for instance in selecting clean technologies. Also, some instruments that are typical for the Directed Transition approach, such as sectoral carbon budgets, standards and technology bans, would probably meet resistance from significant parts of the stakeholder arena. They would argue that carbon prices are also able to deliver a technological shift while being more investor-friendly. On the other hand, forcing the phasing out of certain incumbent technologies is not something completely alien to the current situation, as shown by the de facto ban on the sale of new cars with combustion engines by 2035.

The enhanced involvement of science may be less of a problem, both for public support and for political backing, as it provides a clear, relatively independent source for the general direction of the transition. Public opinion might actually largely support this aspect of the Directed Transition, as it provides reassurances that the government will do what is necessary to avert the most adverse impacts of climate change. However, if regular updating of the policies based on the newest scientific insights would lead to frequently changing of targets and carbon budgets etc., this would be received less positively by companies and investors. Science, moreover, is not always unanimous in its findings and policy implications, complicating policymaking in this regard.

The combination of a need for high levels of administrative capacity and the fact that Member States play a large role in this Policy Avenue forms a risk for the realisation of the Directed Transition. While some Northwest European Member States can probably live up to the high expectations for administrative capacity of this PA, as well as the Commission itself, this may be less true for newer Member States, which may not be well positioned for all the coordination, implementation and monitoring that comes with this particular approach.

All in all, although some elements of the Directed Transition are already present in the current policy mix, the massive involvement of the state in all sectors both could count on significant resistance from vested interests and certain political factions and would mean a serious deviation of the current policy approach. Therefore, we consider its political attainability as a weakness (score 2).

International attainability

In general, for most third countries outside the EU, a Directed Transition approach would be considered at least as much of a change in direction as it would be in the EU itself. In some strongly market oriented countries, such as the USA, it would be virtually unthinkable. Strict bans and standards in the EU would, furthermore, complicate exports from third countries towards the EU, as those countries would in general not apply the same level of standards for their products. To protect its industries, the EU may install import levies based on climate criteria, like the CBAM does for the CO_2 content of certain products, but as a growing number of standards could lead to a proliferation of different border adjustment instruments or other import barriers, this will probably increase discontent among the EU's main trading partners. Also, international agreements such as under the World Trade Organisation are not conducive for this type of measures.

For the above reasons, chances are high that third countries' policies and the international context would not be supportive for a Directed Transition approach, which is why we consider this as a strong weakness of the PA (score 1).

Achievement of socio-economic goals

The Directed Transition reflects a whole-of-government approach geared towards one overarching goal: the achievement of the energy transition leading to a climate neutral economy and society. This may entail the risk that there is less attention and capacity for socio-economic issues that are not climate related.

Also, in the short run, tightening standards and targets can increase the costs of for instance heating or mobility for citizens. The Directed Transition does recognize that and provides financial support and/or feasible alternatives for low income households. However, as this PA involves massive upfront investments to set the transition in motion, there remains the risk that financial resources for social support are limited or citizens' financial burden is raising through increasing taxes and stringent standards. So, although the achievement of the transition will certainly go hand in hand with many positive side-effects such as less air polution, this PA seems not particularly helpful for objectives outside the realm of climate and energy. Therefore we assign a score of 2 to this aspect (weakness).

Sufficiency and Degrowth policy avenue

Political attainability

The political philosophy of sufficiency and degrowth is slowly gaining ground at the edges of the political spectrum but remains squarely outside the mainstream political movements of today's Europe. Indeed, even the Green Deal itself stresses that economic growth could go hand in hand with the achievement of climate neutrality, the negation of which is basically the central assumption of the Sufficiency and Degrowth Policy Avenue.

Adoption of this Policy Avenue would not only mean a movement away from economic growth as an (implicit or even explicit) policy objective, but also from technological innovation as an important driver of the transition, from the belief that efficiency is an important criterium for policy instruments, and from the norm that governments should be very reluctant in steering citizens' personal consumption choices, among other things. Likewise, the strong anti-business sentiment of degrowth will likely result in strong opposition by the private sector. The core of this PA is a structural change of the way our economy and society has been organised for centuries – if not longer – and that is exactly why the establishment of Sufficiency and Degrowth as the main way of organising climate policy is very unlikely in the near future – and only slightly less so over the next decades. A democratic shift to degrowth has not been described and seems difficult at present. Therefore, we consider its political attainability as a strong weakness (score 1).

International attainability

Outside Europe, the body of thought related to Sufficiency and Degrowth has come to the surface in a few countries, such as Bhutan and New Zealand, but in general GDP has not been challenged significantly by the creation of alternative measures of wellbeing, lest become the core guidepost for policymaking. Apart from the economies of some individual countries, also the international arena is firmly governed by notions of free market, consumption, and growth (such as the G20).

At the same time, the EU has been leading globally in its relatively ambitious climate policies thus far, and it cannot be excluded that other countries or blocs would follow if the EU would make some steps towards debating long-standing assumptions on the merits of growth or consumption. Likewise, there have been calls by actors from the Global South for more redistribution from rich to poorer countries, and from historical emitters to those that have not emitted as much. Since degrowth tends to incorporate a strong social justice component, the shift to degrowth may improve international climate diplomacy, unless the downsides of less global growth outweigh.

However, since also in the international context there is very little that would make a move towards the systemic change associated with Sufficiency and Degrowth plausible in the foreseeable future, we consider its international attainability as a weakness (score 2).

Achievement of socio-economic goals

The socio-economic benefits of Sufficiency and Degrowth are highly uncertain. Theoretically, more than any other PA, Sufficiency and Degrowth could bring along significant and diverse advantages in many socio-economic aspects. It is actually directed at increasing human wellbeing by limiting environmental pressure, respecting the Earth's boundaries and reorganising society to ensure social justice and equity. The work-life balance would improve, public goods and universal services provided, and taxes would decrease. According to the PA's philosophy, this would increase health, happiness and social fabric, in a balance with the environment.

However, critics point out the high risks for human wellbeing in a degrowth strategy. The contraction of the economy – even if planned and sectorally selective – can create massive social hardship. Today's welfare systems rely on economic growth and the reorganisation of society brings many risks.

While the outcomes of this PA are much more uncertain than any others, degrowth is centrally concerned about creating a society based on well-being and justice. We consider these impacts a strength of this Policy Avenue (score 3).

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

Ecologic, VUB Brussels School of Governance, Climate Analytics, CE Delft, I4CE Institute for Climate Economics, University of Eastern Finland, Wageningen University & Research, WiseEuropa, rede research group in energy, innovation and environment

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