

STUDY

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Roadmap for Reallocation

A critical assessment of the Green Deal's growth, financial and regulatory challenges



Policy Department for Economic, Scientific and Quality of Life Policies
Directorate-General for Internal Policies
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Abstract

The aim of this study is to critically assess the proposed Green Deal's growth, financing and regulatory challenges. The study discusses the need for extended Shared Socio-economic Pathways. It examines the key growth drivers of the Green Deal and the green investment gap, the optimal mix of taxation and command-and-control measures, trade and competition policy and the implications for macroprudential supervision.

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AIFMD	The Alternative Investment Fund Managers Directive (2011/61/EU)
BCA	Border Carbon Adjustment
BECCS	Bio-Energy with Carbon Capture and Sequestration
CCS	Carbon Capture and Storage
CICES	Common International Classification of Ecosystem Services
CO₂	Carbon dioxide
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
EBRD	European Bank for Reconstruction and Development
EEA	European Environment Agency
EIB	European Investment Bank
ESG	Environmental, Social and Governance
ESSP	Extended Shared Socio-economic Pathway
ETS	Emissions Trading System
EU	European Union
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
GNI	Gross National Income
ICAO	International Civil Aviation Organization
IDD	Insurance Distribution Directive (2016/97/EU)
IEA	International Energy Agency
IORP	Institutions for occupational retirement provision (Directive 2003/41/EC)
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency

KPI	Key Performance Indicator
LCoE	Levelized Cost of Electricity
MiFID II	Markets in financial instruments directive (2014/65/EU)
NEET	Not in Education, Employment, or Training
NUTS	Nomenclature of territorial units for statistics
OECD	Organisation for Economic Co-operation and Development
RCP	Representative Concentration Pathway
R&D	Research and development
SCP	Sustainable Consumption and Production
SDG	Sustainable Development Goals
SMEs	Small and medium-sized enterprises
SPA	Shared (climate) Policy Assumption
SRES	Special Report on Emissions Scenarios
SSP	Shared Socio-economic Pathway
TCRE	Transient climate response to cumulative emissions of CO ₂
TEG	Technical Expert Group on Sustainable Finance
UCITS	Undertakings for Collective Investments in Transferable Securities (Directive 2009/65/EC)
ULCOS	Ultra-low CO ₂ steelmaking
WTO	World Trade Organization

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EXECUTIVE SUMMARY

Background

This paper critically examines the financing and regulatory aspects of potential economic growth opportunities deriving from Europe's commitment to achieve net-zero greenhouse gas emissions by 2050 through a socially-fair transition in a cost-efficient manner, as exemplified by *A Clean Planet for all* strategy or the "European Green Deal" currently in development by the newly appointed Commission.

Aim

The European Green Deal represents a total make-over of the European economy, with considerable impact on society at large, in a comprehensive effort to achieve a climate neutral Union by 2050. In the process, two so-called externalities must be addressed. There is the negative externality of human-induced climate change, saddling other people with the societal costs of our fossil fuel use for example. At the same time, innovation towards cleaner technologies brings positive spill-overs, generating 'free' opportunities for others to further build on and exploit an inventor's original idea.

The success of the far-reaching transformation hinges on the behavioural changes it can induce among consumers, workers, producers or investors to minimise the negative climate change externality while maximising the innovation externality. Putting a price on greenhouse gas emissions, whether explicitly through an emissions trading system or carbon taxes, or implicitly in the form of regulation, is necessary to have producers and consumers take into account the effect of their behaviour on others. But such price signalling may not be sufficient to spur innovation and productivity. Neither will temperature-rise or carbon-budget milestones placed at convenient decadal intervals by themselves generate society-wide support for the Green Deal.

The main challenge to the framework for achieving climate-neutrality is how to coordinate and harness individual member states', producers' or investors' efforts in a Union-wide pathway that embodies the common but differentiated responsibilities of the United Nations Framework Convention on Climate Change. We recommend creating and disseminating comprehensive socio-economic narratives, called extended Shared Socio-economic Pathway(s), for the European Union, together with the associated Shared climate Policy Assumption(s), that can accommodate each of the individual climate actions in a consistent perspective for consumers, producers or investors. These pathways include but are not limited to technological choices and transcend isolated economic activities. They represent an interactive story for the Green Deal if you will that may appeal to the European citizens, setting out the signposts along the road ahead while providing sufficient degrees of freedom for individual economic and social actors.

The Green Deal's four transformation drivers are not unique to the European Union. The electrification of power generation, with its intertwined need for flexible grid infrastructure and the replacement of fossil fuels with renewable energy sources; the electrification and coupling of the construction, industrial and transport sectors, incentivised to maximally reduce emissions; a more efficient (effective) use of energy and natural resources, in particular materials; and measures to promote safeguarding and strengthening of natural sinks apply equally across the globe. What may prove to be unique to the Green Deal, is the manner in which the Union resolves these challenges.

Whereas *A Clean Planet for all* is "meant to set the direction of travel of EU climate and energy policy," it presents a number of "portfolios of mitigation options" in a concern not to succumb to 'picking the winners.' However, portfolios have to be managed as well, and the language of (financial) options is an

apt description of best practice industrial policy: maximal resolution of uncertainty in the minimum possible time is the key driver propelling the transformation along its pathway(s).

These pathways offer a tangible and richer handle on the important timing aspect of the Green Deal transformation than the 2030 or 2050 static targets can offer. To maintain momentum and direct investments to where they are most effective, quantitative indicators such as the social cost of carbon or the (remaining) carbon budget can feature as arrow of time, or digit on the clock. They indicate at each point along the roadmap which abatement efforts or adaptation strategy is most appropriate, and how the trade-off between competing technologies can be assessed in the light of the combined economic, environmental and social objectives of the Green Deal. In particular, these narratives allow for the integration of the system-wide objectives and progress indicators of the Sustainable Development Goals that cannot easily be captured in a taxonomy of individual activities.

The additional annual investment required to bridge the green investment gap – 250 to 300 billion EUR – is comparable in size to both the fossil-fuel imports of the European Union as well as the (post-tax) fossil-fuel subsidies, i.e. including the estimated damages from climate change and related impacts such as traffic congestion or air pollution. The effect of carbon taxation in the European Union – whether in the form of explicit carbon pricing or through implicit-price regulation – is partially or even fully compensated when the fiscal revenues are recycled to remove distortions in, say, personal income taxation or fiscal targeting of vulnerable population groups. The Green Deal is best perceived then as a reallocation of investment and consumption, rather than a net additional investment, with a positive net effect on sustainable development. Any design of carbon taxation, and its presentation to the public, must incorporate both the sources and uses (the recycling) of the fiscal funds. The currently proposed Just Transition Mechanism then arguably reduces to a miniature version of the Green Deal with added geographical targeting. Its design could be improved by focusing only on unemployment support and reskilling measures.

If the absolute size of the green investment gap does not pose an impossible task, and demand for green investments appears insatiable, the key to a successful European Green Deal Investment Plan will be the ability to match supply and demand. The mismatch between demand and supply can be remedied by appropriate segmentation, securitisation and synchronisation of the “environmentally sustainable” activities in the EU Taxonomy, facilitated in particular by credit enhancement and guarantee programmes such as InvestEU and intermediation by the European Investment Bank.

From an international perspective, the risk of carbon leakage may, at least at present, have been overstated. There is however a risk of a race to the bottom as (foreign) fossil-fuel producers would ramp up production in an effort to extract maximal value and avoid stranding reserves – known as the Green Paradox. The European Union could take its cue from Ostrom’s management principles of common pool resources to foster global governance and counter trade issues. Its most effective way to promote an international level-playing field may be by exporting Europe’s high standards, leveraging on the attractiveness of its single market. The forthcoming assessment of a Border Carbon Adjustment will need to consider the impact on multiple interrelated domains.

The pace of the pathways finally will largely determine the risks to macro-economic and financial stability. Too fast a transition to a climate-neutral Europe may shock the financial system with stranded assets, too slow risks damages to exceed regions’ resilience – again calling on central banks as a “lender of last resort.” Appropriate policy is to avoid abrupt shocks by embedding the value dynamics of assets in the roadmap, transparently indicating to what extent projected economic lives could be impacted by climate change and/or climate action. The debate will continue whether in particular central banks have an active participatory role to play in these complex systems, through fiscal-cum-monetary-cum-prudential policy, or that they need to stand back as a watchful observer and regulator. At the very

least, the drive to promote sustainable investment suggests an active system-wide reallocation towards "green" investments that will need to be carefully monitored - by those same central banks.

The introduction in that respect of climate-related disclosures and in particular natural capital accounting comes with a non-trivial complication that tends to be underestimated. There exists a fundamental asymmetry between inherently reversible, fungible, individualised money transactions and the often irreversible, unique, systemic changes in "natural" capital. Simply stated, one cannot simply add or exchange natural and financial capital. That makes evaluating the trade-off between the two essentially incommensurable 'worlds' a delicate exercise. On the other hand, keeping separate tabs on the economy or the financial system versus the social and natural environment - as in the naive approach to ESG investing or sustainable development - decouples the links between the economic, environmental and social objectives of the Green Deal. The comprehensive pathways proposed earlier attempt to capture these links and trade-offs in a consistent dynamic framework.

1. A NARRATIVE FOR EUROPE

KEY FINDINGS

The European Green Deal represents a total make-over of the European economy, with considerable impact on society at large. The measures announced in the programme are not only related to the target of climate neutrality but tackle the entire catalogue of fall-out of our current global production system: pollution, waste, land and water degradation, the loss of biodiversity, and social inequality. In fact, pivoting towards a sustainable economy might arguably make sense irrespective of climate change.

The Green Deal's multiple-objective programme will in general not have a single solution that is optimal in terms of economic efficiency, social equity and ecological sustainability. Any solution will thus be a so-called *second-best* solution, where the first-best solution of simultaneously checking all of the boxes may be unavailable. The overriding concern is that policy choices and their impact must be designed and assessed on a system-wide basis. Piecemeal politics, optimising economic activities or sectors on a separate basis and abstracting from their links to other parts of the system, risks to end up with suboptimal outcomes.

The European Commission ought to extend its portfolio scenarios in *A Clean Planet for all* to building and disseminating Extended Socio-Economic Pathways (SSPs) for Europe. This comprehensive storytelling can act as a travel guide along the various potential paths from now to 2050. In particular, these narratives allow for the integration of the system-wide objectives and progress indicators of the Sustainable Development Goals that cannot easily be captured in a taxonomy of individual activities.

The key advantage of dynamic roadmaps with explicit decision rules is that they "free" policy makers to some extent from their degrees of freedom – and allow them to credibly commit to the optimal policies. The European Climate Law will need to provide for a framework that allows policymakers to credibly commit to the 2030 and 2050 targets, steering clear in particular from a naïve country-by-country pledge-and-review process. Union-wide climate neutrality in 2050 implies that free-riding remains a possibility for decades to come, which requires a climate governance system in which the mutual gains from cooperation are enhanced.

1.1. A European make-over

The European Green Deal proposed by the newly instated European Commission consists of a wide range of actions to make Europe climate-neutral by 2050, with due regard for the continent's competitiveness and for the regions and workers impacted during the transition. The Green Deal follows up on the 2018 Commission *A Clean Planet for all* strategy. Based on the Commission's communications the programme envisions, at least¹,

- a European Climate Law, enshrining the 2050 climate-neutrality target in law;
- a European Climate Pact and EU Strategy on Adaptation to Climate Change, with a proposal for an 8th Environmental Action Programme;

¹ European Commission 2019d, 2020a.

- a comprehensive plan to increase the EU emissions reduction target for 2030 towards 55% in a responsible way, while ensuring a level playing field and stimulate innovation, competitiveness and jobs, based on social, economic and environmental impact assessments;
- a smart sector integration strategy, with a hydrogen and offshore wind strategy;
- a new industrial strategy or Circular Economy Action Plan to make the EU a world leader in the circular economy and clean technologies, promote sustainable use of resources and reduce or reuse waste, especially in resource-intensive sectors with high environmental impact, such as textiles, electronics and batteries, or construction (with a Renovation Wave initiative for the building sector), and to decarbonise energy-intensive industries such as steel-making. Europe should lead on the issue of single-use plastics, and extend the fight against plastic waste to micro-plastics;
- a sustainable and smart mobility strategy, including the reduction of the carbon footprint of the transport sector and striving for Europe to have the best transportation system in the world, with emission-free cars and clean public transport, the promotion of production and supply of sustainable alternative fuels such as third-generation biofuels, batteries and investment in railways, inland waterways and an alternative fuels infrastructure with public recharging and refuelling points;
- the proposal to extend the EU Emissions Trading System to the maritime sector and reduce the free allowances allocated to airlines over time; and to extend this further to cover traffic and construction;
- a Border Carbon Adjustment for selected sectors;
- a review of the Energy Taxation Directive; Effort Sharing Regulation; Land use, land use change and forestry Regulation; Energy Efficiency Directive; Trans-European Network – Energy Regulation and Transport Regulation; Alternative Fuels Infrastructure Directive; Renewable Energy Directive; CO₂ emissions performance standards for cars and vans;
- a strategy for green financing and budgeting practices, and a Sustainable Europe Investment Plan, integrating the Sustainable Development Goals in the European Semester; with a review of the Non-Financial Reporting Directive and a review of the relevant (environment and energy) State aid guidelines;
- public funds investment programmes in advanced research and innovation;
- the proposal to turn parts of the European Investment Bank into Europe's climate bank;
- ensuring that the blue economy contributes to climate objectives;
- greening the Common Agricultural Policy, including the Farm to Fork Strategy on sustainable food along the whole value chain, together with the promotion of animal welfare and measures to reduce the use and risk of chemical pesticides, as well as the use of fertilizers and antibiotics;
- cross-cutting strategy to protect citizens' health from environmental degradation and pollution, including a Chemicals strategy for sustainability, a zero pollution action plan for water, air and soil;
- the Biodiversity Strategy for 2030, mainstreaming biodiversity across all policy areas. Europe should lead the world at the 2020 Conference of the Parties to the Convention on Biological Diversity;
- a new EU Forest strategy for reforestation towards a system to reassure consumers that imported products are not linked to deforestation;

- the new Just Transition Fund that cuts across different funds and instruments and also attracts private investment; and
- the EU to continue to lead the international climate and biodiversity negotiations, further strengthening the international policy framework through bilateral efforts and the Green Deal Diplomacy in cooperation with Member States.

It is not much of an exaggeration then to say that the European Green Deal aims for a total make-over of Europe's economy. The above list reads as the catalogue of fall-out of our current global production system: greenhouse gas emissions and pollution, the accumulation of waste and plastics, systemic land and water degradation, disruption of the nitrogen and phosphorous cycle, the loss of biodiversity, and social inequality. "Not a single country has been able, so far, to enhance the welfare of its citizens without increasingly depleting its resource base"². A total make-over is due. In fact, pivoting towards a sustainable economy might arguably make sense irrespective of climate change.

Primary cause of these effects is a deficient price system saddling consumers, investors and producers with misguided incentives as time evolves. The world's preferred signalling mechanism – the market – in many instances fails to send out the proper message that would allocate the planet's resources in an efficient yet sustainable manner to current and future users. Most egregiously, the market fails to account for the social (ecological) cost of fossil fuel use. Producers and investors in clean but expensive technologies that are of tremendous benefit to society at large, are faced with private returns that lie significantly below social returns and below the private returns of their competitors that resort to the incumbent fossil-fuel technology. The result, inevitably, is underinvestment.

Other than privatising the planet's resources, pricing their use at the efficient price would lead to closing the gap between private and social returns. A (more) complete market will properly incentivise consumers, oil & gas explorers, inventors or farmers to find the most cost-effective way to cater to their needs and desires. Cap-and-trade systems explicitly limit the total 'carbon' budget that can be spent if humanity is to maintain "a safe operating space"³ and allow users to trade these spending rights among one another. Carbon taxes attempt to discourage the use of greenhouse gas resources but do not guarantee an upper limit to the use. Although relatively easy to implement, polluter taxes can fall short of ethical standards: the mere possibility of buying off the right to pollute may be considered morally reprehensible.

The Green Deal's mission is further aggravated by the fact that putting a price on greenhouse gas emissions is not the only issue. The market fails to account for more so-called externalities that drive a wedge between private and social returns. Innovation into sustainable technologies and their business models is severely hampered when the pioneers see insufficient opportunity to capture themselves the pay-off from the often-manifold use of these technologies. Welfare in general may well be enhanced from the *knowledge spill-overs* into diverse industries and applications of the original idea; if the originators' private return falls short of the social return, there is no proper incentive to engage in privately financed research and development.

The market finds it difficult to resolve *coordination problems* as well. The electrification of the vehicle industry implies the coordinated complementary investment in a network of battery or fuel cell rechargers for instance. Such systemic change is unlikely to initiate without government intervention, whether by means of public procurement, public investments in infrastructure or the appropriate design of fiscal and behavioural incentives. Particularly investments in transportation are relatively

² Altenburg 2017.

³ Rockström 2009.

insensitive to price signals as the general public regards such infrastructure as ‘free’ public goods. The interlocked nature of the key drivers of the Green Deal transformation, exemplified by the coupling of the building, industry or transport sector with electrified power generation, strengthens the need for coordination.

The *co-benefits* of climate change action are also left largely unpriced. An increase in the quality of water, soil, and air, leading to improvements in health and well-being, a more robust biodiversity or the preservation of natural carbon sinks each represent valuable ecosystem services that are too often left out of the equation.

Finally, the wedge between private and social returns is not confined to the borders of a single country or region. *Negative externalities* such as the unbridled emission of greenhouse gases do not stop at the border and neither do *positive externalities* like the knowledge spill-overs we saw earlier. The global nature of the greenhouse effect implies that there can theoretically be only one worldwide carbon price. The global nature of great ideas implies that the fruits of the innovation in one country can quite easily be harvested by another country or region. Germany’s successful solar energy policy was ultimately captured by Chinese low-cost manufacturers. Inversely, Asia’s appetite for electrified cars may rapidly lower their cost to the benefit of German car manufacturers.

Arguably the largest policy issue is the public good character of climate change mitigation and adaptation. Any country or region benefits from any other’s reduction of emissions with no straightforward possibility to exclude anyone from enjoying this benefit. Public goods invite agents, from individuals to entire continents, to free-ride on others’ efforts. Climate change mitigation and adaptation may then quite easily degenerate into a game of strategy: how to minimise positive spill-overs over one’s borders while maximising climate change free-riding; how to tilt terms of trade to capture as much as possible of the rents.

Few observers will question the need for public intervention – industrial policy – to negotiate the life-changing transition to a sustainable European (and global) economy. Despite the fact that the overall direction ought to be clear, much uncertainty surrounds the roadmap towards the objective. Which technologies are most appropriate, and what are the trade-offs of choosing a particular technological path? Are biofuels a worthwhile alternative to fossil fuels if they jeopardise biodiversity and food production? Is nuclear energy or geo-engineering⁴ worth the risk? How to resolve the trade-off between developing countries that will want more resources earmarked for adaptation whereas more developed states stand to benefit most from mitigation?

The complex interdependence of the ecological, the social and the economic aspects of climate change and our policy response requires the use of integrated assessment models to guide our long-term outlook. Recent studies suggest that our model of the physics of climate change is quite robust despite gaps in our understanding of, say, cloud formation or aerosol dynamics. The critical model input however is well outside the reach of physicists, or economists for that matter: public policy and human behaviour. Policymakers and consumers in particular are known for being insensitive to price signals. Lack of information and behavioural biases will require a careful design of incentives to nudge all of us onwards on a sustainable pathway.

⁴ Geo-engineering refers to human direct interference with the Earth’s ‘control’ variables, in particular the incoming solar radiation and the concentration of CO₂ and other greenhouse gases in the atmosphere or the oceans. Geo-engineering is contested largely because it is unclear whether its impact can be reversed without pushing climate change on an accelerating trajectory. In a precise sense, the economics of climate change is the economics of exhaustible resources, of sunlight captured millions of years ago by plants that turned to the fossil hydrocarbon fuels over millions of years, only to be released back into the atmosphere in the blink of an eye, geologically speaking. The debate makes clear that rather than climate change per se, it is the pace of current change that poses risk.

The urgency of climate action cannot but cloud the value judgments to be made. The effect of the atmosphere's constituents – water vapour and CO₂ in particular – on Earth's temperature was already known by the middle of the nineteenth century⁵ and the anthropogenic impact on global warming was identified at least as early as the thirties of the twentieth century⁶. Yet since the ratification of the *United Nations Framework Convention on Climate Change* at the Earth Summit in Rio in 1992, humans still emitted half of all of the CO₂ present in the atmosphere. Still, it is estimated that if existing carbon-intensive infrastructure is phased out at the end of its design lifetime, there is a 64% chance that peak global mean temperature rise remains below 1.5°C⁷. But we may not have the luxury of sitting back comfortably and relying on the natural evolution of 'creative destruction', of the phasing in of clean and the fading out of emitter technologies.

To a first approximation, global warming is proportional to the total amount of CO₂ released into the atmosphere⁸. As a result, one can define a carbon budget⁹, i.e. the total amount of (anthropogenic) CO₂ that can still be emitted if global average surface air temperature is to remain below the Paris Agreement target(s). The caveat is that non-linear processes, notably the crossing of tipping points such as the thawing point of permafrost, and the impact of much more powerful greenhouse gases such as methane and fluorinated gases, as well as aerosols, interfere with the proportionality of temperature with budget.

If, in the extreme case, we exceed the planetary boundaries too far and risk tipping climate change into an irreversible trajectory towards a habitat that is no longer safe, all normal cost-benefit analyses and impact assessments will have become useless. Whereas we have at least a limited understanding of other ecosystem processes and believe in having some grip on the 'confidence interval' around an expected trajectory, we are at a loss when it comes to these tipping points¹⁰. Any climate change mitigation or adaptation measures, including the European Green Deal, must then be construed as mere insurance premia in an attempt to ward off catastrophic 'tail events'¹¹.

Consequently, scenario analysis, typically informed by multiple integrated assessment models is best treated with caution¹². If, say, two out of eight scenarios achieve a specific target without a technology such as bioenergy with carbon capture and sequestration (BECCS) while the others do, that does not mean that the probability of reaching the target with BECCS is 25% but rather that the roadmap will crucially depend on how a society chooses to go ahead. Neither do averages or medians tell the whole story.

Furthermore, it depends on the precise objectives used in the model as to how its outcomes must be interpreted. Models that aim to optimise environmental or technological objectives do not necessarily tell us how to deal with the distributional social consequences of their actions. In view of the comprehensive nature of the Green Deal, there can be no question then that at its core must lie a dynamic roadmap that incorporates not only environmental and technological aspects but a detailed socio-economic pathway as well.

⁵ Fourier 1824, Tyndall 1861.

⁶ Ekholm 1901, Callendar 1938.

⁷ Smith 2019.

⁸ The coefficient is called the transient climate response to cumulative emissions of CO₂ (TCRE) and is estimated by the IPCC to fall within the range of 0.2–0.7°C per 1 000 Gt CO₂ with a probability of at least 66%.

⁹ Rogelj 2019.

¹⁰ Lenton 2008.

¹¹ Weitzman 2014.

¹² Huppmann 2018.

1.2. Extended Socio-economic Pathways beyond *A Clean Planet for all*

Following the baseline Emissions Scenarios (2000) and the Representative Concentration Pathways that underlay the Intergovernmental Panel on Climate Change’s previous Assessment Reports, the Sixth Assessment Report will be based on new baseline scenarios describing alternative socio-economic developments, called the *Shared Socio-economic Pathways (SSPs)*¹³. When coupled with mitigation or adaptation policies – the *Shared climate Policy Assumptions (SPAs)* – these pathways represent five families of potential trajectories for the decades to come. The SSPs (widely) differ in terms of six broad categories of variables: demographics, human development, economy and lifestyle, policies and institutions, technology, and environment and natural resources. Global energy consumption ranges from 400 to 1 200 EJ in 2100; annual CO₂ emissions could be as low as 25 Gt CO₂ to a baseline with more than 120 Gt by 2100, i.e. before any specific additional climate policy is assumed to be implemented.

These baseline scenarios act as canvas against which various mitigation or adaptation SPAs can be explored. To what extent do the underlying trends make it easier or harder to mitigate (or adapt to) climate change? Crucially, the associated costs and benefits of such climate action strongly depends not only on the policy assumptions themselves or the climate objective – 2°C, say – but also on the underlying narrative, i.e. policy choices and consumer or producer behaviour.

To be consistent with the SSP narrative to which they are adopted, the Shared climate Policy Assumptions will correspondingly differ in the degree of international collaboration, the delay for concerted action, the risk of implementation failures or the coverage of land-use emissions but can encompass any range of individual mitigation policies or instruments. The high energy demand in SSP5 has its counterpart in the focus on conventional but highly engineered infrastructure. The ineffective institutions and barriers to trade, and the slow progress in human development create high challenges to mitigation and adaptation in SSP3, etcetera. Bio-energy infrastructure is state-of-the-art in SSP1, whereas in SSP4 biomass is burnt traditionally due to income inequality and failure to access energy across the globe.

Table 1: Selected assumptions of elements of SSPs

	SSP1	SSP2	SSP3	SSP4	SSP5
Narrative	Sustainability – Taking the Green Road	Middle of the Road	Regional Rivalry – A Rocky Road	Inequality – A Road Divided	Fossil-fuelled Development – Taking the Highway
Population growth	Relatively low	Medium	Low	Low	Relatively low
Migration	Medium	Medium	High	Medium	High
Urbanisation	High, well managed	Medium, as it was	Low, poorly managed	Medium, mixed	High, better management

¹³ Riahi 2017. We note that the paper is part of a special issue dedicated to a detailed presentation of the Shared Socio-economic Pathways. The SSPs are somewhat similar to some of the earlier IPCC scenarios. In particular, SSP1 and SRES B1, SSP2 and SRES B2, SSP3 and SRES A2, and SSP5 and SRES A1F1 share quite some characteristics.

Education	High	Medium	Low	Medium, unequal	High
Health investments	High	Medium	Low	Medium	High
Equity	High	Medium	Low	Medium	High
Growth per capita	Medium	Medium, uneven	Slow	Medium	High
Inequality	Reduced	Uneven	High, across countries	High, within countries	Strongly reduced
International trade	Moderate	Moderate	Strongly constrained	Moderate	High, regional specialisation
Globalisation	Connected markets, regional production	Semi-open globalized economy	De-globalising, regional security	Globally connected elites	Strongly globalised
Consumption & Diet	Low growth in material consumption, low-meat diet	Material-intensive, medium-meat	Material-intensive consumption	Elites: high, Rest: low	Status consumption, meat-rich diet
International cooperation	Effective	Relatively weak	Weak, uneven	Effective for globally connected	Effective in pursuit of development goals, not environmental goals
Environmental policy	Improved management, tighter regulation	Concern for local pollutants, moderate success	Low priority for environmental issues	Focus on local environment, little attention to global issues	Focus on local environment, little concern with global problems
Policy orientation	Toward sustainable development	Weak focus on sustainability	Oriented toward security	Toward the benefit of the elite	Toward development, free markets
Institutions	Effective	Uneven, modest effectiveness	Weak global, national govts. dominate	Effective for elite, not for rest of society	Increasingly effective
Technology development	Rapid	Medium, uneven	Slow	Rapid in high-tech, slow in others	Rapid
Energy tech change	Away from fossil fuels	Continued reliance on fossil fuels, unconventional	Slow, directed toward domestic sources	Diversified investments	No fossil fuel constraints
Carbon intensity	Low	Medium	High in regions with large fossil fuel reserves	Low/medium	High

Environment	Improving	Continued degradation	Serious degradation	Highly-managed for elite	Highly-engineered, success with local issues
Agriculture	Improved productivity, best practices	Medium pace of tech change	Low tech development, restricted trade	High productivity high-scale farming, low for others	Highly-managed, resource-intensive

Source: Riahi 2017.

To some extent, the baseline built on the Reference Scenario 2016 in *A Clean Planet for all*¹⁴ can be considered the (single) counterpart of the global SSPs¹⁵, reflecting the 2030 energy (efficiency) and climate policies and targets, the reformed EU emissions trading system as well as the proposed legislation to improve the CO₂ efficiency of cars and trucks, national greenhouse gas emission reduction targets and legislation to maintain the Union’s carbon sink. This baseline scenario is projected to reduce greenhouse gas emissions by ca. -45% by 2030 and -60% by 2050.

The related SPAs come in the form of the eight mitigation “pathways” in *A Clean Planet for all*. The scenarios incorporate “a portfolio of mitigation options” where different technologies are deployed in varying combinations and with varying intensity: electrification and renewable energy production, the use of alternative energy vectors such as synthetic gases or liquids and e-fuels, energy efficiency of buildings and industrial processes, lifestyle changes in a circular economy, enhancing the sink of land use including agriculture and forestry, and (bio-energy or direct-from-air) carbon capture and storage.

The European Commission ought to extend its portfolio scenarios in *A Clean Planet for all* to building and disseminating Extended Socio-Economic Pathways for Europe, taking into account the specifics of the European Union’s institutions, land use but also, say, the attitude towards inequality and international cooperation. Whereas the in-depth analysis of *A Clean Planet for all* duly considers how the Union’s citizens might react to different technology choices such as an increase in renovation rates or the use of hydrogen in transport, the focus is on the extent to which emissions targets are achievable rather than on comprehensive storytelling as a travel guide along the various potential paths from now to 2050. In particular, the SSP framework suggests accommodating multiple pathways that differ in ideological views on most of the variables included. The crucial advantage is that political choices with respect to socio-economic issues can be identified and assessed separately from technological or environmental considerations.

Importantly, how decisions are modelled gives rise to differences in the shape of the preferred mitigation or adaptation pathways. Assuming economic agents have perfect foresight of what is possible in the future, investment plans will incorporate the knowledge of specific technologies’ future prices and the staggered cost of reducing emissions later on. More often than not, this leads to early abatement due to the anticipation of significantly higher ‘carbon’ prices in the longer term. Models in which decision-makers are myopic tend to result in higher required carbon prices in the short term which increase more slowly.

¹⁴ European Commission 2018b. The 2016 Reference scenario is the ancestor of the family of energy modelling EUCO scenarios, the most recent of which is the 2019 EUCO3232.5 scenario that reflects the revised Clean energy for all Europeans package.

¹⁵ Interestingly, the scenario analysis does incorporate two alternatives, depending on whether climate action will occur globally in a collaborative way, or remain fragmented.

The Green Deal's multiple-objective programme will in general not have a single solution that is optimal in terms of economic efficiency, social equity and ecological sustainability. In this case, where a public good – climate mitigation – is concerned, economic theory holds that efficiency and equity (including sustainability) are not separable¹⁶. There may be an entire set of candidate 2050 European Unions in which none of the individual objectives can be improved upon without taking a step back from some of the other objectives.

Any solution will thus be a so-called *second-best* solution, where the first-best solution of simultaneously checking all of the boxes may be unavailable. From the seminal paper¹⁷: “it is *not* true that a situation in which more, but not all, of the optimum conditions are fulfilled is necessarily, or is even likely to be, superior to a situation in which fewer are fulfilled.” The optimal second-best solution therefore does not push each of the objectives individually as close as possible to its first-best solution.

The overriding concern underlying the theory of second best is that policy choices and their impact must be designed and assessed on a system-wide basis. Piecemeal politics, optimising economic activities or sectors on a separate basis and abstracting from their links to other parts of the system, risks to end up with suboptimal outcomes. Whereas policies devised in, say, the energy sector or the transport sector by itself may appear to come as close as possible to their first-best (economic or environmental) optimum, these policies will in general be suboptimal when combined with the rest of the system, a fortiori when the combined social-economic-environmental objectives are considered.

1.3. Incorporating the Sustainable Development Goals

The SSPs can be extended to account not only for considerations that are specific to the European Union as well as to incorporate more objectives, in particular the achievement of the Sustainable Development Goals. The general idea is to link the socio-economic evolutions, in connection with the climate change and the modelled mitigation and adaptation measures, with indicators – “vital signs”¹⁸ – that reflect the SDGs: access and prices of energy¹⁹, the impact of sea level rise²⁰, income distributional consequences, food security and availability, mobility, ecosystem services²¹. The identification and monitoring of the SDGs cannot be done on an activity-per-activity basis; they represent systemic properties if you will that interact on multiple levels. Low energy demand for example is beneficial to food security as well, relieving pressure on agricultural land to produce biofuels, or biodiversity and pollution. But increased efficiency and lower energy prices may give rise to the rebound effect, stimulating consumption to negate the advances made – with feedbacks to again other SDGs.

In the table below we present a selection of indicators as approved by the Inter-Agency and Expert Group on Sustainable Development Goal Indicators that may be relevant to assess within the Extended Socio-economic Pathways for the European Green Deal.

¹⁶ Chichilnisky 1994.

¹⁷ Lipsey 1956. See also Meade 1955.

¹⁸ Ripple 2020.

¹⁹ McCollum 2018.

²⁰ Nauels 2017.

²¹ Griscom 2017.

Table 2: Selected Sustainable Development Goal Indicators

Goals	Indicators
I. End poverty	1.5.1 Number of deaths, missing persons and persons affected by disaster per 100 000 people 1.5.3 Number of countries with national and local disaster risk reduction strategies
II. End hunger	2.3.1 Volume of production per labour unit by classes of farming/pastoral/forestry enterprise size 2.4.1 Proportion of agricultural area under productive and sustainable agriculture
III. Ensure health	3.6.1 Death rate due to road traffic injuries 3.9.1 Mortality rate attributed to household and ambient air pollution 3.9.3 Mortality rate attributed to unintentional poisoning
IV. Ensure education	4.7.1 Extent to which (i) global citizenship education and (ii) education for sustainable development, including gender equality and human rights, are mainstreamed at all levels in: (a) national education policies, (b) curricula, (c) teacher education and (d) student assessment
V. Achieve gender equality	5.5.1 Proportion of seats held by women in national parliaments and local governments 5.5.2 Proportion of women in managerial positions
VI. Ensure safe water	6.1.1 Proportion of population using safely managed drinking water services 6.3.1 Proportion of wastewater safely treated 6.6.1 Change in the extent of water-related ecosystems over time
VII. Ensure access to affordable, reliable, sustainable and modern energy for all	7.1.2 Proportion of population with primary reliance on clean fuels and technology 7.2.1 Renewable energy share in the total final energy consumption 7.3.1 Energy intensity measured in terms of primary energy and GDP 7.a.1 Mobilized amount of USD per year starting in 2020 accountable towards the \$100 billion commitment 7.b.1 Investments in energy efficiency as a percentage of GDP and the amount of foreign direct investment in financial transfer for infrastructure and technology to sustainable development services
VIII. Promote sustainable growth and decent work	8.1.1 Annual growth rate of real GDP per capita 8.4.1 Material footprint, material footprint per capita, and material footprint per GDP
IX. Build resilient infrastructure and foster innovation	9.1.2 Passenger and freight volumes, by mode of transport 9.4.1 CO ₂ emission per unit of value added 9.5.1 Research and development expenditure as a proportion of GDP
X. Reduce inequality	10.1.1 Growth rates of household expenditure or income per capita among the bottom 40% of the population and the total population 10.7.2 Number of countries that have implemented well-managed migration policies
XI. Make cities and settlements sustainable	11.2.1 Proportion of population that has convenient access to public transport, by sex, age and persons with disabilities 11.3.1 Ratio of land consumption rate to population growth rate 11.5.2 Direct disaster economic loss in relation to global GDP, including disaster damage to critical infrastructure and disruption of basic services 11.6.1 Proportion of urban solid waste regularly collected and with adequate final discharge out of total urban solid waste generated, by cities 11.6.2 Annual mean levels of fine particulate matter (e.g. PM _{2.5} and PM ₁₀) in cities (population weighted) 11.a.1 Proportion of population living in cities that implement urban and regional development plans integrating population projections and resource needs, by size of city
XII. Ensure sustainable consumption and production	12.1.1 Number of countries with sustainable consumption and production (SCP) national action plans or SCP mainstreamed as a priority or a target into national policies 12.3.1 Global food loss index 12.4.2 Hazardous waste generated per capita and proportion of hazardous waste treated, by type of treatment 12.5.1 National recycling rate, tons of material recycled 12.7.1 Number of countries implementing sustainable public procurement policies and action plans 12.a.1 Amount of support to developing countries on research and development for sustainable consumption and production and environmentally sound technologies 12.c.1 Amount of fossil-fuel subsidies per unit of GDP (production and consumption) and as a proportion of total national expenditure on fossil fuels

XIII. Combat climate change	13.3.2 Number of countries that have communicated the strengthening of institutional, systemic and individual capacity-building to implement adaptation, mitigation and technology transfer, and development actions
XIV. Conserve oceans and seas	14.1.1 Index of coastal eutrophication and floating plastic debris density 14.2.1 Proportion of national exclusive economic zones managed using ecosystem-based approaches 14.3.1 Average marine acidity (pH) measured at agreed suite of representative sampling stations 14.4.1 Proportion of fish stocks within biologically sustainable levels 14.a.1 Proportion of total research budget allocated to research in the field of marine technology
XV. Protect terrestrial ecosystems and biodiversity	15.1.1 Forest area as a proportion of total land area 15.1.2 Proportion of important sites for terrestrial and freshwater biodiversity that are covered by protected areas, by ecosystem type 15.3.1 Proportion of land that is degraded over total land area 15.9.1 Progress towards national targets established in accordance with Aichi Biodiversity Target 2 of the Strategic Plan for Biodiversity 2011-2020
XVI. Promote inclusive institutions	16.7.2 Proportion of population who believe decision-making is inclusive and responsive, by sex, age, disability and population group
XVII. Strengthen the Global Partnership	17.7.1 Total amount of approved funding for developing countries to promote the development, transfer, dissemination and diffusion of environmentally sound technologies 17.10.1 Worldwide weighted tariff-average 17.14.1 Number of countries with mechanisms in place to enhance policy coherence of sustainable development 17.18.1 Proportion of sustainable development indicators produced at the national level with full disaggregation when relevant to the target, in accordance with the Fundamental Principles of Official Statistics

Source: Inter-Agency and Expert Group on Sustainable Development Goal Indicators 2016.

The IPCC's *Special Report on Global Warming of 1.5°C* lists some of the positive “synergies” and negative “trade-offs” between the impact of climate change mitigation options on energy demand or supply and land use, and SDGs²². The stringent pathways to limit temperature rise well below 2°C risk endangering in particular SDGs 1 (poverty), 2 (hunger), 6 (water), and 7 (energy access). The stronger dependence on biomass in some mitigation strategies may have negative effects on biodiversity as well.

Finally, when going beyond mitigation towards adaptation, long-term comprehensive scenarios are even more important as these, by definition, interact with the texture of the economic system and society as a whole. An evaluation of the European Commission's EU Adaptation Strategy estimates²³ that the risk of (coastal and river) flooding may cost up to 1 trillion EUR per year under SSP5 in an adverse climate change scenario while at the same time water shortages may severely threaten (agriculture in) the Mediterranean countries.

We would add to the list of SDG-indicators therefore the work of the Common International Classification of Ecosystem Services (CICES) developed from the work on environmental accounting undertaken by the European Environment Agency (EEA).

1.3.1. The activity-based EU Taxonomy versus system-wide SDGs

Whereas *A Clean Planet for all* is “meant to set the direction of travel of EU climate and energy policy,” it does not develop a comprehensive pathway that incorporates the more wide-ranging objectives of the Sustainable Development Goals. Of course, many of these goals are incorporated in adjacent

²² IPCC 2018, especially Figure SPM-4.

²³ Ciscar 2018.

European legislation such as the European Pillar of Social Rights. But they do not explicitly feature to the extent comparable with the SSPs.

Neither are social or more generally sustainable development criteria present in the current Taxonomy proposal, with one exception. The Technical Expert Group on Sustainable Finance (TEG) has preferred to focus first on an enumeration of environmental objectives and only require the environmentally sustainable economic activities to comply with minimum social safeguards, i.e. the “eight fundamental conventions identified in the International Labour Organisation’s declaration on Fundamental Rights and Principles at Work”²⁴. The TEG states that “[t]he impact of the Taxonomy on social issues is hard to assess but seems rather limited, given that it is a soft law tool designed to help investors more easily identify green assets” but that “[s]hould the Taxonomy be extended to social objectives in future, relevant expertise would be needed”. In fact, in that same context the Taxonomy report makes abundantly clear that the interactions between climate exposure, technological and financial resources, and socio-economic characteristics should inform policy-making and the design of mitigation and adaptation actions.

The EU taxonomy defines the eligible activities as those substantially contributing to one or more of the six environmental objectives and has indicated that any activity that significantly harms any of those objectives can be considered a negative economic activity. (As indicated, eligible activities must further comply with minimum social safeguards and the technical screening criteria.) The environmental objectives are the following:

- Climate change mitigation, i.e. phasing out or stabilising greenhouse gas atmospheric concentrations through renewable energy systems or materials, energy efficiency, clean mobility, carbon capture;
- Climate change adaptation, i.e. reducing or preventing an increase or shifting of the current or expected negative physical effects of climate change on an underlying economic activity and the natural or built environment in which it takes place;
- Sustainable use and protection of water and marine resources;
- Transition to a circular economy, waste prevention and recycling;
- Pollution prevention and control; and
- Protection of healthy ecosystems.

Being best-in-class is considered good enough. A carbon-intensive production process such as the manufacturing of steel or cement, if done at the level of performance achieved by best performing plants, is considered to make a substantial contribution to climate change mitigation.

The taxonomy commenced “with a full life cycle scope in mind”²⁵ but ultimately ended up with a list of individual activities, in the large because not every supply chain could be tracked (such as the transport sector), stocks or flows of natural resources are not recorded when not monetised, and/or similarly for potentially harmful activities which have been avoided. Because it does not matter where and by whom greenhouse gas emissions are reduced, the mitigation objective can be assessed on the level of an individual activity, the Taxonomy argues. That is no longer the case for adaptation, which inherently concerns a context-specific response to the detrimental effects of climate change, and resilience is to be assessed on a principles’ basis, i.e. whether the economic activity (i) measurably reduces all material

²⁴ EU Technical Expert Group on Sustainable Finance 2019.

²⁵ EU Technical Expert Group on Sustainable Finance 2019.

physical climate risks to the extent possible and on a best effort basis, (ii) addresses systemic barriers to adaptation, and (iii) does not adversely affect adaptation efforts by others.

Be that as it may, too narrow a focus on individual activities may lead to a fragmented view on the value chain or wider system in which these isolated environmentally sustainable activities take place. Investors – and supervisors – may distinguish direct emissions from indirect emissions, or debate to what extent unsustainable activities upstream or downstream are indispensable to the well-functioning of an overall green value chain – think: the manufacturing of electric vehicles or the fact that steel is an essential component to, say, wind turbines.

The Taxonomy anticipates on the discussion with its additional categories of “greening of” and “adaptation of” versus “greening by” and “adaptation by” activities, depending on whether the environmental performance or exposure to all material physical climate risks of the activity in itself or other activities is improved. Even if the activity whose environmental performance is considered does not necessarily qualify as environmentally sustainable, the contributing activity may qualify as a “greening by” activity both by the owner or operator of the enabled activity as well as the entity performing the enabling activity. Of course, activities that are already “green” can still be eligible for investments to further their deployment.

The Taxonomy added the “do no significant harm” criterion, albeit only relative to the other environmental objectives and not, say, social or other SDG-criteria. It remains difficult to see how the activity-based approach of the taxonomy will be able in subsequent steps to do justice to the system-wide nature of the sustainable development goals without embedding the discussion in a more comprehensive roadmap as with the Extended Shared Socio-economic Pathways. Adaptation in particular is largely about understanding and actively reinforcing negative feedbacks such as natural carbon sinks, building resilience through modularity and redundancy, encouraging learning effects, or promoting shared governance rather than narrowing the discussion down to constructing a particular levee.

1.4. The social cost of carbon

1.4.1. The Law of One Price

The dynamics within the (E)SSPs is governed by the urgency of climate action. Climate change suggests two approaches to indicate the passage of time, time which may not flow “equally without regard to anything external”²⁶ but will depend on measured changes in the biogeochemical environment, advances in technology, political choices leading to pivoting from one trajectory to another within a shared pathway – or to another SSP altogether.

The first approach consists of setting a target such as global near-surface air temperature rise relative to preindustrial levels with a pre-set probability, and deducing the total amount of emissions beyond which the target becomes unachievable. Estimates vary but centre around 500 GtCO₂ (50% below 1.5°C) to 1 500 GtCO₂ (50% below 2°C)²⁷. This remaining carbon budget can then be allocated over time and will determine at each point in time, say, the technology mix, the final energy demand or the required measures to preserve natural carbon sinks along the pathway.

The second, theoretically, equivalent approach defines the social (marginal) cost of carbon as the net present value of all future costs minus benefits of emitting one additional ton of greenhouse gas today.

²⁶ We refer to Isaac Newton’s famous characterisation of “absolute, true and mathematical time” in his Scholium.

²⁷ IPCC 2018.

The recommended approach²⁸ to calculate social cost of carbon starts with our socio-economic pathways, including the baseline emissions trajectories in the absence of climate change, which is then linked up with the climate model. The third step consists of converting the climate's changing characteristics into (localised) damages to the (socio-)economic system²⁹. Finally, the future damages are summarised into the social cost of carbon present value.

Box 1: Discounting future generations' welfare

A highly contentious input in the calculation of social cost of carbon is the discount rate: how does welfare in the future compare to welfare today? Is it ethical to "discount" at all the well-being of future generations?

Following Ramsey (1927), the discount rate is built up out of two terms: the rate of pure time preference, and a risk premium. The rate of pure time preference ρ measures impatience: assuming that consumption levels today and tomorrow are the same, how much is consumption today preferred to tomorrow? The higher ρ , the less one cares about the future and the damages occurring therein. As a result, the social cost of carbon will fall. Note that the time preference forces us to express our opinion on short-term effects versus longer-term effects. For reference, the Stern review used $\rho = 0.1\%$, an extremely low rate. A typical value is 1%.

The other term is more difficult to interpret, as a number of considerations interact in its estimation. The term multiplies a measure for the growth of well-being in money terms (consumption or GDP per capita growth) with a coefficient η , called the elasticity of the marginal utility of consumption. η essentially translates material progress in happiness.

In doing so, it also measures how much happier a poor person is with an extra euro compared to a rich person. That makes η an indicator of one's aversion to inequity. If country-specific climate damages are expressed purely in monetary terms and summed to arrive at a global estimate, abstraction is made from the fact that poorer nations may suffer more from the same damage in absolute money terms than their richer neighbours. Weighing damages by relative per capita income for example will take this into account. η serves as a weighing parameter then, expressing the global impact not in terms of monetary terms but in terms of utility – welfare. (Compare with the Just Transition Fund allocation key.) If one is convinced that climate change disproportionately impacts the poor, the social cost of carbon must go up.

By comparing money holdings when poor relative to when one is rich, η is a measure of risk aversion as well. We pay an "insurance premium" proportional to η to get rid of the uncertainty of outcomes. The higher our aversion to risk, the lower the social cost of carbon must be [...] but only up to a point. Our aversion to catastrophic outcomes requires the social cost of carbon to rise as η increases further.

The Stern review used $\eta = 1$, within the range the literature cites.

Source: Anthoff 2009, Ramsey 1927.

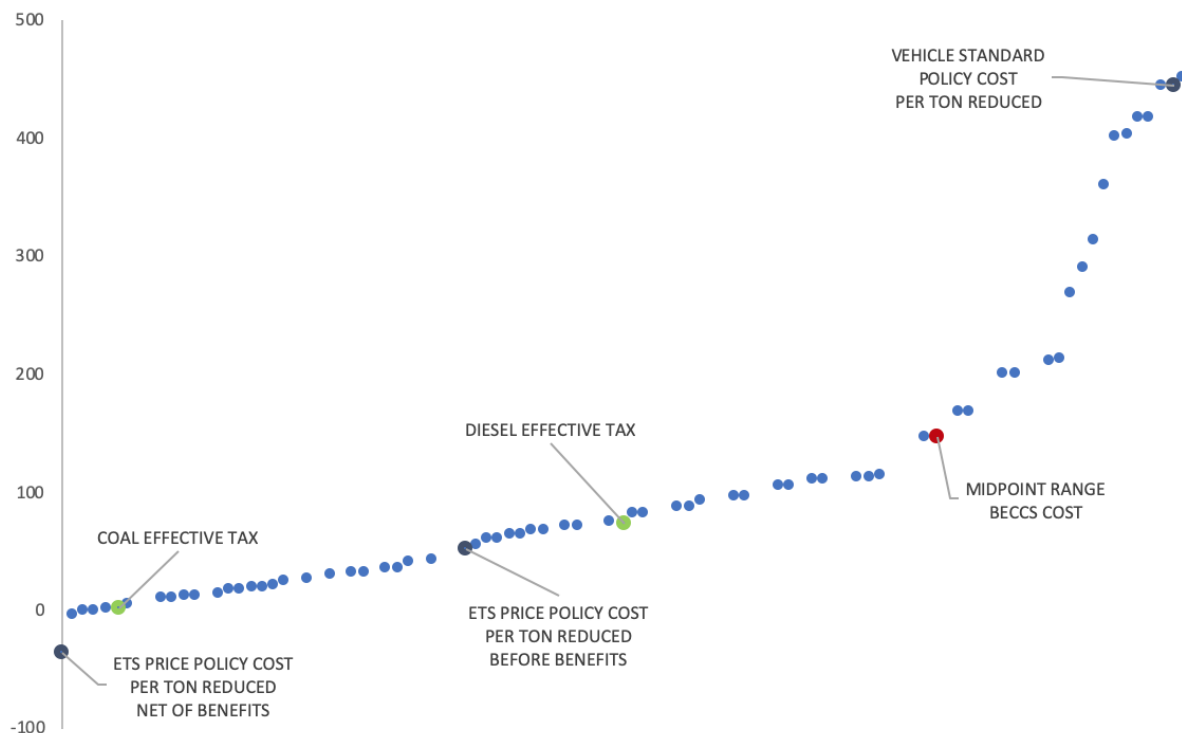
²⁸ US National Academies of Science 2017.

²⁹ Such as Burke 2015. Note that the damage functions herein are derived from empirical, macroeconomic damage and do not fully capture adaptation costs, cross-border effects from trade or migration, "non-market damages" such as loss of biodiversity, and other very-long-term effects (such as sea level rise and, of course, catastrophic events).

Not unlike the so-called Levelized Cost of Electricity in power generation, the social cost of carbon – the carbon price – represents the threshold value against which to assess the cost-effectiveness of climate action. Any action contemplated at any moment that costs less than the carbon price at that time adds value from a purely monetary point of view; any action with an explicit or implicit cost above the current carbon price does not, or at least not in a direct way. Typically, regulation ‘costs’ much more than current carbon prices would suggest is optimal, but proponents argue that regulation has its place in a comprehensive climate policy because such measures may be more palatable politically for example.

Pursuing the analogy with Levelized Cost of Electricity, various climate actions can be integrated in a single graph with social cost of carbon on the common vertical axis. The horizontal axis could then measure the cumulative emissions reduction potential of the policy-cum-technology choices, where each action is ranked from lowest social cost of carbon to highest as their emissions reduction potential is accumulated along the horizontal axis.

Figure 1: Illustration of the social cost of carbon as time indicator in the ESSPs



Source: Carbon effective tax rates (OECD 2019), policy cost per ton reduced (for various policy refinements analysed in Parry 2020, in particular the *ETS Price* policy considered there), CCS technology cost estimates (Bui 2018). The graph is for illustrative purposes only, suggesting possible uses of social cost of carbon trajectories. No emissions reduction potential was imputed in the illustration (see text).

The social cost of carbon acts as a benchmark for (i) cost-effectiveness of technology alternatives, (ii) policy costs net of benefits of climate action, or (iii) carbon taxes. Under the influence of the factors we mentioned earlier, the social cost of carbon will vary through time while continuing to play its three-part role. It is generally assumed then that the social cost of carbon ought to increase from current estimates of, say, 25 EUR per tCO₂ to typically 250 EUR/tCO₂ or more in 2050, reflecting the fact that the quick wins in climate change are harvested earlier on. In the event of a catastrophic outcome of climate

change, the social cost of carbon would escalate to thousands of EUR/tCO₂ – in the limit going off to infinity.

A number of analyses suggest themselves. First, a specified target budget of emissions reduction on the horizontal axis corresponds with an estimate of the social marginal cost of carbon and an idea of the optimal-cost abatement mix at that point in time along the roadmap, taking into account each of the policy options to the left of the point representing the remaining carbon budget. To the extent that the social cost of carbon reflects actual capital expenditures, it can inform estimates of the “green investment gap”, i.e. the cost of the Green Deal (cf. infra).

Second, varying the cost and benefit components taken into account in the calculation of the social cost of carbon differentiates the cost-effectiveness comparison. For example, excluding benefits focuses on the gross costs of mitigation, excluding social cost and benefits reduces the analysis to a strict greenhouse effect assessment. As the horizon of the analysis is extended to a longer term, more technology options may become available.

Third, varying explicit carbon taxes or assessing the evolution of the emissions trading allowance price through time (cf. infra), will in general shift the order in which abatement options occur in the graph. From a theoretical point of view, carbon taxes can be considered efficient when they fully reflect the social cost of carbon and emitters internalise those costs by paying for carbon use at a level corresponding to the present value of the marginal damage due to their emission. The polluter pays.

There is a trivial corollary to the polluter-pays principle, one that gives rise to arguably the most contentious aspect of mitigation and adaptation measures in general, and the Green Deal in particular. This point will continue to require vast efforts to communicate properly to all stakeholders, not least the general public. Because greenhouse gases cause the same marginal effect, regardless of who, how or where the emission takes place, each and every ton of CO₂-equivalent ought to be priced equally. The corollary is at least equally contentious in its inverse formulation: it does not matter to global warming by whom, how or where abatement takes place either. By imposing the same price across the globe, it is expected that all actions to abate emissions that cost less than that price will be implemented, at the minimum global cost.

The principle is reflected for example in the quota for renewable energy production in the European Union: these apply to each member state but the EU has included the possibility that one member state provides for production in another member state where production conditions may be more beneficial.

This ‘law of one price’ must not simply be dismissed as the theoretical result it is. The law can inform value judgments on how to distribute the gains and losses of climate change as well as the proper design of financing and regulatory instruments in the Green Deal. To be precise, the ‘theorem’ states that if money transfers are possible both within a country or region as well as across borders in a way that would not affect the incentives of consumers, investors, producers and regulators (and in the absence of other market failures), it is possible to separate the issue of where reductions in emissions takes place from who should pay for these abatement efforts. The achievement of the climate objective *stricto sensu* can therefore be considered separately from the social (read: distributional) concerns. From a purely ecological perspective, a globally uniform carbon price implies that it would be optimal to pick the low-hanging fruit and seize the least-cost opportunities to reduce emissions first, regardless of location or the nature of the emission source. If these efforts result in an unequal distribution of costs and investments, an international transfer mechanism could correct for the distribution. Such a mechanism may entail the transfer of fiscal revenue or could for example be achieved through the appropriate distribution of certificates in a world-wide emissions trading system.

In the second-best reality in which we live, most of the conditions required to separate efficiency and equity are probably no longer fulfilled and carbon prices may differ across countries³⁰. Equity and other considerations will enter again such as the fact that short-term climate change measures tend to be incident most on the same people that may – (but only) in the long-term – most benefit from them. Given that low-income countries have a buffer of more and cheaper abatement potential and a high opportunity cost of consumption, they may choose to overweigh social and economic development in the short-term, provided they do not lock in technology and infrastructure that would significantly alter that potential. Just transition within Europe could be complicated by the fact that lower-income countries prefer to spend resources on adaptation whereas higher-income countries would benefit most from mitigation efforts, for example.

1.4.2. Do country-specific carbon prices exist?

From a first-best perspective then, there is only one carbon price. It is a matter of indifference to global warming where a particular ton of greenhouse gases was or will be emitted, through which process or by whom. Of course, historic emissions overwhelmingly took place in developed countries whereas future emissions and future energy demand may come from developing countries. To the extent damages and benefits (avoided damages) are local as well a social cost of carbon can be calculated country by country, in line with Article 2(2) of the Paris Agreement referring to the “common but differentiated responsibilities” enshrined in the *United Nations Framework Convention on Climate Change*.

Hypothetically, such a calculation could also be performed with historic dates as reference point. Including historic emissions and damages since, say, preindustrial levels, could arguably provide a basis for discussion of how to split the bill globally.

Starting today, north-western Europe has a *negative* social cost of carbon then, whereas high emitters such as India, the United States or China have very high social costs of carbon. The results are stark: “If countries were to price their own carbon emissions at their own country-level social cost of carbon, approximately only 5% of the global climate externality would be internalized [...] Fully internalizing the CO₂ externality (i.e., pricing carbon at global social cost of carbon) would allow meeting the Paris Agreement goal and beyond”³¹.

1.5. Credible commitment and consistency

The key advantage of dynamic roadmaps with explicit decision rules is that they “free” policy makers to some extent from their degrees of freedom – and allow them to credibly commit to the optimal policies that aim to simultaneously achieve the ecological sustainability, social fairness and economic efficiency objectives of the Green Deal. Making use of shared pathways to design and explain the European Union’s path provides a response to the drawbacks of the inadequate pledge-and-review approach to climate change³². Where the country-by-country pledge-and-review process discards the law of one price and leads to inefficient abatement efforts without a comprehensive overall strategy, its main deficiency is that it lacks credible commitment mechanisms. Rather, it represents a waiting game in which holding out to commit is a superior bargaining strategy.

³⁰ Chichilnisky 1994.

³¹ Ricke 2018/9.

³² Gollier and Tirole 2015.

Picture a country evaluating its long-term power generation mix³³. Society is well aware that it is not desirable to use coal-fired plants – the fall-out of environmental damages such as air pollution would simply be too costly in terms of premature mortality and ultimately unemployment support. Suppose however that government fails to deter new coal-fired plants to be built. Should the government then after all provide for healthcare and create new economic opportunities for the affected region? When society deems the answer is yes, a time consistency problem has arisen. If the government could have committed to not providing healthcare and support, people would rationally have decided against coal-fired power generation – which was the social objective. If, on the other hand, the government cannot make its threat credible, coal-fired plants will be difficult to avoid: people will trust they will be provided for, and a socially less desirable outcome obtains.

Kydland and Prescott's Nobel prize-winning insight is that in fact most policy is riddled with similar time consistency problems. Even if government and citizens share the same objectives and policymakers know the timing and magnitude of the effects of their actions, the mere ability for government to (re-)optimise its policy at a later date in view of changes in circumstances is enough to bring about less than optimal results. The reason is that our own decisions incorporate our expectations of how government will act in the future. As a result, government policy that insists on maintaining a degree of discretion, rather than strictly adhering to a roadmap, is always subject to credibility issues. Policymaking is not a game against nature but a game among rational agents, current and future citizens and current and future policymakers.

Kydland and Prescott's analysis follows in the wake of the so-called Lucas critique³⁴ that building macroeconomic policy on historical aggregated data will not work without explicitly modelling how consumers, taxpayers, producers, investors, ... actually make their decisions. Crucially, policymakers must be aware that in this process these agents will rationally consider how they expect policymakers to act as well. In other words, the economic models are influenced by policy itself, so any policy that naively takes these models as given, is likely to go astray.

Making explicit not only the biogeochemical processes that drive climate change but linking these up with the behavioural changes in the socio-economic system provides for an appropriate policy framework that is sufficiently dynamic to accommodate future evolutions and sufficiently rigorous to constrain – or at least make transparent – the impact of policy choices.

The European Climate Law will need to provide for a framework that allows policymakers to credibly commit to the 2030 and 2050 targets, steering clear in particular from a naïve country-by-country pledge-and-review process. Union-wide climate neutrality in 2050 implies that free-riding remains a possibility for decades to come. Non-cooperative game theory and the study of traditional common pool management systems led Elinor Ostrom³⁵ to formulate a set of design principles for such a climate governance system in which the mutual gains from cooperation are enhanced. A response to free-riding is to make sure that the allocation of mitigation and adaptation efforts – between member states, between sectors, over time – be congruent with the potential to do so, taking into account the other social or economic objectives. A shared narrative can provide for consistency among these common but differentiated responsibilities. Good governance is based on continuous and transparent mutual monitoring of efforts, and graduated sanctioning in a manner accountable to the members. These members must further be able to modify the collective rules along the road in mutual consent and have access to conflict resolution mechanisms.

³³ The seminal Kydland and Prescott 1977 provides a similar example considering settlement in an area vulnerable to flooding risk.

³⁴ Lucas 1976.

³⁵ Ostrom 1990.

2. THE GREEN DEAL GROWTH DRIVERS

KEY FINDINGS

There are four essential economic growth opportunities in the Green Deal transformation:

- the electrification of power generation, consisting of a network infrastructure that can accommodate both variable-rate supply as well as demand flexibility; and the substitution of fossil-fuel power generation with more sustainable energy sources and carriers;
- the electrification or 'coupling' of the (energy-efficient) construction, industry and transport sectors, and potentially the development of carbon capture, storage and usage;
- the push for energy efficiency, in particular in residential heating, and the move towards a circular economy and less carbon-intensive consumption patterns; and
- the preservation and strengthening of the natural carbon sinks.

Digitalisation is a key enabler in each of these transformations, redesigning processes, information exchange and interaction among machines and/or humans in general.

The Green Deal and Energy Union legislation can foster the markets for the new energy sources and energy vectors such as hydrogen. Demand-side flexibility and energy efficiency can be incentivised by exposing end-users in a controlled manner to the price risk of the wholesale energy markets. The most conspicuous gap in European energy policy is arguably the lack of effective carbon pricing in the heating (oil) sector, with its important distributional aspects. The construction sector in fact represents the largest stock of potentially stranded assets in the guise of most existing and energy-inefficient homes.

The social dimension of these transformations in behaviour must not be underestimated. Policymakers must make sure that resistance to change does not impede the Green Deal transformation by timely raising awareness.

The big push forward, radically transforming the landscape, is difficult to derive from a pure pricing policy. The Green Deal innovation framework, through InvestEU and the Innovation Fund as well as co-investments by the European Investment Bank, will need to prioritise high-risk activities in order to benefit as much as possible from resolving uncertainty in the least possible time.

Finally, measures to promote safeguarding and strengthening of natural sinks must reinforce these vital negative feedbacks in the climate system. That does not preclude leveraging on these ecosystem services.

2.1. Four agents of change

Perhaps unsurprisingly, most pathways that have been explored in the literature to arrive at a climate-neutral world in a cost-effective way share the following essential building blocks³⁶:

- the production of electricity as energy vector by means of renewable energy, with the added conversion of excess electric power in novel vectors such as hydrogen, synthetic gases or liquids ('power-to-X' or 'e-fuels');
- the concomitant electrification or 'coupling'³⁷ of the (energy-efficient) construction, industry and transport sectors, including the hard-to-abate segments involving specific industrial processes, long-haul shipping or aviation, in a later stage complemented with zero-net carbon strategies involving carbon capture;
- the push for energy efficiency, in particular in residential heating, and the move towards a circular economy and less carbon-intensive consumption patterns; and
- preserving and strengthening the natural carbon sinks through sustainable land-use change, forest and ocean management.

Digitalisation is a key enabler in each of these transformations, redesigning processes, information exchange and interaction among machines and/or humans in general.

The electrification of power generation consists of two interrelated investment opportunities: a network infrastructure that can accommodate both variable-rate supply as well as demand flexibility; and the substitution of fossil-fuel power generation with more sustainable energy sources and carriers. This cross-disciplinary challenge highlights again that the strict activity-based approach of the EU Taxonomy may not be perfectly adapted to the technology roadmap of the Green Deal.

Energy markets and infrastructure will need to absorb massive generation capacity from renewables at times and locations that largely depend on the weather. Excess supply must be converted into useful energy without dislocating wholesale electricity markets. Innovation is focused on 'power-to-X' conversion of excess power into alternative energy carriers, in particular hydrogen and other synthetic gases. The new network architecture must allow for the injection of these energy vectors at appropriate times in, preferably existing, transmission networks. The challenge to balance supply and demand on electrical power grids is the main driver for innovation and investment in storage technology as well.

The Green Deal and Energy Union legislation, including but not limited to a revised Energy Taxation Directive and Alternative Fuels Infrastructure Directive, can foster the market for new energy carriers through making related projects eligible for government support, by introducing feed-in tariffs, auctioning contracts-for-difference, promoting blended injections or explicitly reserving the use of excess capacity for hydrogen electrolysis and similar production facilities.

Existing regulation of (quasi-)monopolistic power generation will need to make room for renewables. Paradoxically, the framework for utilities may well revert to a 'pre-deregulation' regime in which power generators are paid (just) to keep capacity ready. To avoid new fossil-fuel capacity being built in markets with such capacity mechanisms, investment in renewables must be sustained. Well-known incentives include auctioning long-term contracts for renewable power, obligating suppliers by means

³⁶ See for example High-Level Commission on Carbon Prices 2017, referring to scenarios from the Deep Decarbonization Project, the United Nations, the International Energy Agency or the Energy Transitions Commission, the 2018 report of the High-Level Panel of the European Decarbonisation Pathways Initiative, or Ripple 2020.

³⁷ BloombergNEF 2020 presents a detailed pathway for sector coupling.

of renewable portfolio standards or emission thresholds, or creating a level-playing field for renewables to apply for capacity mechanisms.

Policymakers³⁸ will need to incentivise the grid flexibility on the demand side as well, exposing end-users in a controlled manner to the price risk of the wholesale energy markets. Instruments include promoting the uptake of more finely structured time-of-use, variable-peak or location-specific electricity tariffs, taking advantage of solar peak generation while discouraging net peak demand, dedicated tariffs for the (public and private) recharging of electric vehicles, dynamic power purchase agreements with industrial users, or the increased decoupling of network charges from electricity consumption for behind-the-meter assets. Demand-side flexibility can further be enhanced by promoting end-user storage and 'smart' appliances. The social dimension of these transformations in behaviour must not be underestimated: lower-income households for instance may need additional support to be able to replace less efficient appliances.

The resistance to transformation must be addressed in a timely and efficient manner. Citizen disputes of permitting of grid replacement and extension, including in the 'last mile', can potentially be overcome by compensating the communities affected. Demonstrator projects showing the added value of the electrification of coupled sectors can benefit from support from Horizon Europe and the ETS Innovation Fund in particular to raise awareness.

Related to the electrification of power generation is the electrification and coupling of the construction, industrial and transport sectors. To alleviate undue pressure on the grid infrastructure, these sectors must be incentivised to maximally reduce emissions. The most conspicuous gap in European energy policy is arguably the lack of effective carbon pricing in the heating (oil) sector, with its important distributional aspects. More generally, the revision of the Energy Taxation Directive, expected for June 2021, ought to significantly increase the minimum (fossil-fuel) rates up to the point where they become binding. Preferential fiscal treatment of renewables and power-to-X applications can further direct technical change and investments.

In addition to lowering emissions in the aforementioned sectors, a more efficient (effective) use of energy and natural resources, in particular materials, is called for. We note that energy efficiency, a cornerstone of the transition to climate-neutrality, must be carefully managed through time. It can induce a fall in supply-side investments and consequently growth, and at the same time to excessive consumption of carbon-intensive goods and services caused by rebound effects.

Each sector comes with specific challenges. The manufacturing of steel or cement hinges on lowering carbon intensity and the avoidance of pollutants. Radical innovations in steel derive from the ULCOS programme such as the HIsarna-process or the direct hydrogen reduction of iron ore. Similar programmes are under way in Korea, Japan and the US. At present, it is hard to see however how decarbonising these industrial sectors could work without Carbon Capture and Storage technology conditional on the final cost per unit of decarbonised product remaining competitive in international markets.

Electrification in the transport sector hinges on the power-to-weight ratio. Rail and road transport can benefit from efficiency improvements as a result of digit(al)isation in engine and transmission technology, electric powertrains with high-performance batteries, or smart infrastructure, and the same may apply to short sea shipping and inland water transport. Aviation and long-distance shipping however will probably require hybridisation and continue to rely on biofuels or carbon-free e-fuels. It is expected that intercontinental flights will ultimately fall under the Carbon Offsetting and Reduction

³⁸ For example, by strengthening and enforcing European Parliament Directive (EU) 2019/944.

Scheme for International Aviation (CORSIA) developed by the International Civil Aviation Organization with the purpose of stabilising CO₂ emissions at 2020 levels through a progressively evolving cap-and-trade system. The ICAO has recently published the framework for its pilot phase until 2023, including its principles of sustainability, stating that “CORSIA eligible fuel shall achieve net greenhouse gas emissions reductions of at least 10% compared to the baseline life cycle emissions values for aviation fuel on a life cycle basis”, and “should not be made from biomass obtained from land with high carbon stock”³⁹. Similar steps forward have been made with respect to long-haul shipping with the International Maritime Organization pledging to halve greenhouse gas emissions by 2050.

And the construction sector represents the largest stock of potentially stranded assets in the guise of most existing and energy-inefficient homes. Doubling the rate of retrofitting of public and residential buildings to (at least) the 2.4% p.a. objective is indispensable, for example by prioritising retrofitting in homes where direct energy technologies can be implemented, while bringing the most inefficient residential buildings closer to the decarbonisation frontier. The challenge is not exclusively technological; we mention only the design of proper demand-side incentives between renters and owners as a regulatory hurdle.

Finally, measures to promote safeguarding and strengthening of natural sinks must reinforce these vital negative feedbacks in the climate system. That does not preclude leveraging on these ecosystem services. The European Union possesses (or possessed) the largest Exclusive Economic Zone in which it could harvest energy from the oceans, whether from wave energy, tidal effects, or energy conversion of thermal or salinity gradients. The Ocean Energy Forum⁴⁰ believes that “under favourable regulatory and economic conditions”, 100 GW of ocean energy could be harnessed to produce about 350 TWh of electricity, some 10% of the European Union’s expected power demand by 2050.

The agricultural roadmap will similarly feature precision farming on the one hand, and the valorisation of nature-based and ecosystem services (including carbon sequestration) on the other hand. The rearing of livestock in particular, abstracting from fundamental changes in lifestyle, will always produce (non-CO₂) greenhouse gas so process engineering and ultimately negative emissions technology will be called for.

2.1.1. Carbon Capture and Storage – the case of negative-emissions technology

Radical innovation does not stop with these four key drivers. Contentious issues include geo-engineering such as enhanced weathering, the culture of biomass for use as biofuels, and the extent to which pathways ought to rely on negative-emissions technologies, exemplified by BECCS, i.e. Bio Energy with Carbon dioxide Capture and Storage.

Note that the roadmap for Carbon Capture and Storage (CCS) cannot be considered independently from that of the fossil-fuel fired power generation (and to a more limited extent the flue gas from hard-to-abate sectors such as steel and cement manufacturing) which it is expected to absorb. As long as CCS is not expected to become a viable technology option, climate action elsewhere poses a threat to the rent embedded in fossil-fuel reserves which its owners will not be able to recoup without negative emissions technology. They should consequently be expected to react. If fossil-fuel plants become stranded early on, CCS may actually come too late – at least for that part of its mitigating role. We will come back to this issue when we discuss the green paradox.

³⁹ International Civil Aviation Organization 2019.

⁴⁰ Ocean Energy Forum 2016.

On the other hand, as negative emissions technology advances, abatement efforts and the scale-back of fossil-fuel use in the near term may appear less urgent. It is a matter of debate whether decarbonisation of the power generation sector for example excludes the use of CCS where policy targets explicitly refer to proportions of renewable energy sources. Political reluctance to endorse CCS probably reflects the lack of public acceptance and it remains to be seen how this perception could be turned if and when stringent climate targets or delayed climate action would require serious consideration of large-scale negative-emissions technology, including the currently virtually non-existent CO₂ transport and storage infrastructure in the European Union.

2.2. Industrial policy as *active portfolio management*

A common denominator among each of these drivers of transformation is the considerable uncertainty at almost every Technology Readiness Level, from basic research to commercial operations. Although carbon taxes and/or cap-and-trade systems are the preferred – because cost-effective – economic instruments to mitigate global warming, these pricing measures remain (by definition if you will) *marginal* measures. The big push forward, radically transforming the landscape, is difficult to derive from such policy. A big push typically follows from relaxing or even dissolving a previously binding constraint – countries getting stuck in classical comparative advantage activities, industries suffering from the lock-in of obsolete technologies – rather than from marginal gains in efficiency. In that sense, industrial policy is a joint private-public effort to discover and resolve these binding constraints⁴¹.

Rather than coercing the unwilling, industrial policy attempts to create coalitions of the willing⁴². What propels these coalitions forward is the belief that internalising the costs of climate change on the one hand and capturing the benefits of technological progress on the other hand may actually go hand in hand. The prototypical critique of industrial policy is that governments cannot pick winners – and do not let go losers. The appetite for private risk sharing is therefore a prime indicator of viability of a particular initiative⁴³.

The benchmark is the counterfactual: what would have happened if government had not intervened? How does an initiative or firm that received support fare in comparison with those that (just) did not? An important indicator is supply-side dynamics? Is R&D expertise increasing, in terms of patent activity or thought leadership? Does manufacturing activity expand in variety? Does export performance improve? Structural transformation is not first and foremost about inventing new goods or services but rather about how to use the available skills to generate a persistently profitable model that captures the benefits of inventions and is difficult to emulate by outsiders. The positive technological externality is therefore not limited to fundamental research and product R&D; it encompasses the discovery of the proper market proposition and cost structure, the ability to resolve coordination failures, establishing previously missing markets (in insurance or credit for example), and the appropriate regulation.

The EU is home to 6 of the 25 largest renewable energy businesses, particularly strong in wind power, and employs almost 1 in 7 people in the business worldwide. Although the Union was at the forefront of developing and deploying renewable energy and electricity, the continent cannot keep up with manufacturing moguls as the United States, China and currently India. With most of the investments in new installed capacity and storage taking place outside the EU, this evolution will not easily be reversed. Europe's R&D spending stagnates at just over 2% of GDP in 2017. Europe is marginally surpassed by China (2.1) and lags significantly behind the United States (2.8) or Japan (3.2)⁴⁴. The Union

⁴¹ Rodrik 2014.

⁴² Meckling 2015, 2017.

⁴³ Laffont and Tirole 1993.

⁴⁴ Eurostat 2020.

is a long way away from its target to reach 3% by 2020 – Germany’s 2017 level – despite a 40% rise from a decade ago.

Reluctant to hit and miss individual potential winners, public authorities resort to formulating mission-oriented research and innovation policies that tend to lack focus, or portfolio approaches. What is often misunderstood, is that these portfolios of options require *active* management as well. The theory of investment under uncertainty, and real options in particular, has shown that the crucial driver must be a fast and efficient resolution of uncertainty as long as “switching costs” between competing technologies are not prohibitive – before effectively deciding where to invest in full deployment.

A marginally positive net present investment value is not sufficient in an uncertain environment. The expected return on investment must not only cover the cost of capital but also the opportunity cost of being no longer able to wait to invest. Any decision to invest (or research) in a specific activity entails a loss of flexibility, a loss that must ultimately be compensated as well. As a result, uncertainty gives rise to a zone of inertia in decision-making space in which the optimal strategy is to stick with the previous choice. Only once the higher barrier is broken, is switching optimal as sufficient uncertainty – proportional to the extent of the inertial zone – has been resolved⁴⁵.

Importantly, whereas traditional investment analysis holds that uncertainty or volatility make investments more expensive, the real options approach aims to leverage on the very same uncertainty by exploiting the asymmetric nature of options: if things work out, we go all in, if they don’t, we cut our limited losses from exploring uncertainty. Note that both traditional analysis as well as the real options literature advocates to build portfolios of parallel projects, the reason to do so is arguably the opposite. Traditional investors aim to diversify the risk, whereas real options investors on purpose seek out projects with the highest risk in order to benefit as much as possible from resolving uncertainty in the least possible time.

In such a strategy, not the individual project but the overall portfolio performance matters. Competition within the portfolio tends to accelerate lowering of prices, upholds quality and efficiency, increases variety and innovation, and goes against regulatory capture. In the presence of combined economic, ecological and social objectives, the marginal portfolio project must in fact be unprofitable when viewed from a purely economic perspectives, in particular when the externalities are strong.⁴⁶

The Green Deal innovation framework, through InvestEU and the Innovation Fund’s grants and guarantees, as well as co-investments by the European Investment Bank, will need to prioritise high-risk activities without access to regular financing, in particular early-stage research in radical innovation. The knowledge spill-over that drives the transformation towards a sustainable economy essentially hinges on the cumulative nature of innovation. Relaxing the most binding constraint here mostly comes down to kickstarting the process by subsidising basic or fundamental research and early learning effects. All too often public resources are spent on installing existing technologies or on “grey” innovation to enhance efficiency. We highlight the mission of the Innovation Fund, financed by ETS allowances auctions, and explicitly established to support demonstrator projects by “sharing the risk with project promoters to help with the demonstration of first-of-a-kind highly innovative projects,” as well as “cross-cutting projects”. Public procurement, easily more than 15% of the EU’s GDP, is a case in point to help at-scale roll-outs.

Funding and competition policy will need to take into account the fact that most innovation required for may have a cross-sector nature (infrastructure, digitalisation, redesigning industrial processes) and

⁴⁵ Dixit 1994, Trigeorgis 1996.

⁴⁶ National Research Council 2001.

lifecycles traversing and linking many sectors. The experience Europe has gained recently with the European Fund for Strategic Investments provides guidance and best practices for the guarantee scheme under InvestEU in particular. Importantly, the European Court of Auditors pointed out⁴⁷ that (at least) one third of the projects were not additional, i.e. they could and would have been implemented even in the absence of investment guarantees by the European Union, although not on such favourable terms. In addition, the mobilisation or multiplier effect is easily overstated by including all eligible investment in a project, regardless of whether other sources of (public) funding may already have been in place.

More generally, the interplay between InvestEU, Horizon Europe, the Innovation Fund, the enhanced European Innovation Council, cohesion policy including the ETS Modernisation Fund and now the Just Transition Mechanism, will need to be carefully managed to encourage (strict) complementarity between EU financial instruments and EU budgetary guarantees, and mitigate the risk of regulatory (instrument) competition or arbitrage. The Auditors stated that “[t]he lack of comparable performance and monitoring indicators for all EU financial instruments diminishes transparency and the ability to assess results.” In the same vein, the “Wise Persons”⁴⁸ have voiced similar concerns when it comes to the plethora of development financial instruments available. The “overlaps, gaps and inefficiencies” in the financial development architecture between notably the European Investment Bank and the European Bank for Reconstruction and Development call for stronger coordination and the establishment of a single entity, a “European Climate and Sustainable Development Bank”, either by transferring the extra-EU activities of the EIB to the EBRD, creating a subsidiary within the EIB, or create an entirely new structure.

Box 2: A Model of Directed Technical Change

To provide some intuition for the dynamics of an industrial policy programme such as the Green Deal, we take our cue from the celebrated model for directed technical change by Acemoglu and collaborators. The climate deteriorates when dirty technology (or input) is produced at a given pollution rate but it has the potential to regenerate, proportional with the quality of its “state of nature” at a specified feedback rate. Importantly, innovations that improve the pollution or regeneration rate are pure public goods. As a result, little or no research would be directed towards such innovation by private parties without government intervention. Under *laissez-faire*, the economy grows unboundedly but society edges towards climate catastrophe. An important question therefore is how to direct technological change to stave off such an outcome. Should clean technologies that both increase economic welfare – consumption – while reducing environmental degradation be subsidized permanently? If this reallocation of resources lowers productivity growth, temporarily or permanently, to what extent is long-run growth and welfare reduced?

Innovation is modelled as a cumulative process: success implies that the specific technology – dirty or clean – is upgraded, i.e. innovation builds on the current level. Advances in one sector make future advances in that sector more profitable or more effective, steering innovation towards the sector that enjoys the highest productivity already.

Intuitively, if both sectors are highly substitutable, it requires immediate intervention to discourage continuing on the dirty path. However, optimal environmental regulation, or even

⁴⁷ European Court of Auditors 2019.

⁴⁸ High-Level Group of Wise Persons on the European financial architecture for development 2019.

simple suboptimal policies just using carbon taxes or profit taxes/research subsidies, would be sufficient to *redirect* technical change and avoid an environmental disaster as the production of dirty inputs goes to zero. In most cases, optimal environmental regulation involves modest carbon taxes because research subsidies are able to redirect innovation to clean technologies before there is more extensive environmental damage. Moreover, these policies need to be in place for only a *temporary* period, because once clean technologies are sufficiently advanced, research would be directed towards these technologies without further government intervention.

If substitutability exists but is less than above, permanent policy intervention is required because the price effect – relatively speaking, the dirty input's price increases, encouraging production of dirty inputs – starts to outweigh the market size effect. Without directed technical change, policy has no effect on the allocation of research efforts then and continuing, even increasing intervention is called for. If both sectors are complementary, the only way to stave off disaster in the theoretical model is to stop long-term growth.

If substitutability is sufficiently high, but the depletion of an exhaustible dirty input implies a continuously rising input price, that in itself may be sufficient to direct efforts towards the clean sector, even without government intervention.

Aghion et al. (2016) studied the particular case of the car manufacturing industry. The authors constructed new firm-level panel data on auto industry innovation distinguishing between "dirty" (internal combustion engine) and "clean" (e.g. electric and hybrid) patents across 80 countries over several decades. They show that firms tend to innovate relatively more in clean technologies when they face higher tax-inclusive fuel price – a proxy for a carbon tax. The measured effect is almost proportional, i.e. a 10% increase in fuel prices is associated with some 10% more clean technology patents. Furthermore, the path dependence in the Acemoglu model in the type of innovation is confirmed, both from aggregate (country-specific) spillovers and from the firm's own innovation history, both in the clean and dirty sector. The model suggests that the increase in carbon taxes needed to allow clean to gain parity and subsequently overtake dirty technologies is quite large, in the order of 40%. This illustrates that path dependency is a double-edged sword as pointed out by Acemoglu et al. (2012). In the absence of effective policies, it creates a kind of lock-in for dirty innovation. But if effective policies are introduced like a carbon tax or R&D subsidy, path dependency can help reinforce the growth of clean innovation as the economy accumulates clean knowledge more rapidly. Hence, if we switch off the two path-dependency channels, innovation trends become less responsive to tax policy.

Grey innovation (in energy efficiency) lies somewhat in the middle between clean and dirty innovation. Interestingly, in contrast to the proxy for carbon taxes (fuel prices) neither R&D subsidies or emissions regulations appear to be statistically significant policy variables when it comes to dirty versus clean technology. An important reason may be that most subsidies now relate to energy efficiency, i.e. grey technology.

Source: Aghion 2016, Acemoglu 2012.

3. THE GREEN INVESTMENT GAP CAN BE BRIDGED

KEY FINDINGS

The “green investment gap” implied by the Green Deal is in the order of 250-300 billion EUR per year in addition to a baseline investment need of 1-1.5 trillion EUR. These investments are considerable but not insurmountable, considering the outlays they might potentially replace, and the benefits of the Green Deal transformation.

More than half of the EU-28’s gross available energy comes from imported sources, representing some 331 billion EUR of fossil fuel imports in 2018. With fossil fuel subsidies amounting to at least 55 billion EUR in the European Union – and up to 264 billion EUR when the cost of climate change and its co-externalities such as traffic congestion are included - a reallocation towards Green Deal initiatives represents an additional considerable push.

The idea that the reallocation of investment would constitute a supply shock that significantly reduces either the level or the growth rate of GDP is not corroborated by the analysis. Importantly, introducing carbon pricing almost invariably has a positive contribution to GDP when the fiscal revenue is recycled to alleviate more distortionary taxes elsewhere (notably increasing labour participation).

New investments in clean energy are about 360 billion USD annually now, of which about 75 billion USD occurred in Europe in 2019, in particular in solar and on- and off-shore wind technology. Green bond issuance in 2019 was at a global record of more than 250 billion USD, more than 50% larger than in 2018, primarily driven by the European market which accounted for 45% of total issuance.

If the absolute size of the green investment gap does not pose an impossible task, and demand is arguably insatiable, the success of the European Green Deal Investment Plan further hinges on the ability to match supply and demand, i.e. allocating the appropriate supply-side portions to the different investor risk classes at the appropriate time along the roadmap. These portions will typically not coincide with individual projects.

Technical support and assistance can assist in carving up projects into risk classes (segmentation), bundling different but related portions into investable packages (securitisation) and time-matching issuance to the Green Deal roadmap (synchronisation). The European Commission will need to carefully design the incentives for individual Member States to adhere in the long-term to the Green Deal’s roadmap, including but not limited to the monitoring and guiding instruments of the European Semester, the Stability and Growth Pact, and monetary-financial-prudential policy.

3.1. The average annual additional investments in perspective

The European Green Deal Investment Plan wants to mobilise at least 1 trillion EUR over the next decade, half of which comes from the EU budget itself⁴⁹, triggering 114 billion of national co-financing, in addition to at least 100 billion EUR in the Just Transition Mechanism. Not part of the EU budget, the auctioning of allowances under the Emissions Trading System will provide ca. 25 billion to finance the Innovation and Modernisation funds. The remainder consists of 279 billion expected to be mobilised by crowding in private investors in higher-risk projects as well through the InvestEU guarantee scheme.

The European Investment Bank in particular is expected to mobilise 250 billion to the Investment Plan under EU mandate. This amount will contribute to the EIB’s own pledge to support 1 trillion EUR in “green” investments over the next decade.

These numbers beg the question how much the transition towards a climate-neutral socially fair Europe would cost.

The European Commission’s *A Clean Planet for all* built on earlier assessments such as those accompanying the revision of the Energy Efficiency Directive to arrive at an estimate of 176 to 290 billion EUR average additional annual investment compared to a baseline investment of 1.1-1.5 trillion EUR⁵⁰. The gap was updated for the 2030 targets (using the EUCO3232.5 scenario) in 2019 during the Commission’s assessment of the draft national energy and climate plans of Member States, to around 260 billion EUR. That would make the “green investment gap”, the incremental investments relative to the baseline scenario, taking into account the much steeper 2050 targets rather than the 2030 targets, to be close to or exceeding 300 billion EUR a year, net of benefits.

The Commission’s estimates and those from other recent sources such as the IPCC Special Report on Global Warming of 1.5°C, are largely comparable in terms of energy infrastructure investment as a percentage of GDP. For comparison, the International Energy Agency together with the International Renewable Energy Agency estimated the cumulative investment gap in the power generation, transport, construction and industrial sectors at 29 trillion USD to 2050 relative to a baseline of 116 trillion⁵¹, in order to keep the temperature rise below 2°C with a 66% probability. They added that “[r]educing the impact on human health and mitigating climate change would save between two- and six-times more than the costs of decarbonisation.”

Table 3: Green investment gap. Average annual additional investment by EUCO scenario

	Baseline 2031-50	EE	CIRC	ELEC	H2	P2X	COMBO	1.5 TECH	1.5 LIFE	Baseline 2021-30	32-32.5
Power grid	71	9	20	39	19	24	28	31	19	59	13
Power plants*	41	11	21	37	52	96	69	102	70	54	21
Boilers	1	-0	1	1	-0	-1	-1	-1	-1	2	2

⁴⁹ Across multiple programmes, including the European Agricultural Fund for Rural Development, the European Agricultural Guarantee Fund, European Regional Development Fund and Life funds, the Cohesion Fund, and Horizon Europe.

⁵⁰ European Commission 2018b, 2019d, 2020a. Capros 2018.

⁵¹ IEA & IRENA 2017. The IRENA estimates were refined in IRENA 2018 to 120 and 27 trillion USD.

Industry	11	25	2	3	2	3	15	17	11	18	4
Residential	199	36	12	15	-1	-1	19	27	28	199	125
Tertiary	54	10	7	3	4	6	13	22	14	64	71
Transport	813	44	24	68	94	30	68	91	34	685	21
Total	1190	135	86	166	171	157	212	290	176	1081	257

Source: European Commission 2018b, 2019c. *Baseline* displays average annual investments over 2031-2050 (in billion EUR₂₀₁₃) and 2021-2030 respectively in *A Clean Planet for all* reference scenario (adapted from Table 10 in European Commission 2018b). *EE - 1.5LIFE* columns adapted from Table 11 in European Commission 2018b refer to the average annual additional investments over 2031-2050 (in billion EUR₂₀₁₃) for the respective *A Clean Planet for all* scenarios relative to *Baseline*. 32-32.5 refers to the average annual additional investments over 2021-2030 derived from the EUCO3232.5 scenario (European Commission 2019c). * including "new carriers" or "new fuels".

It is important to remark that among the *A Clean Planet for all* pathways considerable differences in investment needs arise. Power generation and network infrastructure require significantly less outlays in scenarios where energy efficiency is promoted (EE and 32-32.5) but these latter scenarios imply much higher investments in residential construction and in industry relative to other scenarios. Investment in energy efficiency and in clean energy production to some extent act as substitutes. Similarly, the road to (hydrogen) fuel cells versus electrification can make for a vastly different investment landscape in the transport sector. Without sufficient uptake, technologies are unlikely to become viable but too much uptake may compete with the supply of other technologies or even the supply of food.

The Green Deal roadmap can therefore not be indifferent between the different "portfolios of mitigation options" in a second-best world where investment capital will not be limitless and where visibility with respect to behavioural changes in consumption and lifestyle choices is limited at best.

We note in closing that the rate of investment is generally projected to steadily rise in the next decades before levelling off from its peak in 2040 and beyond.

These investments are considerable but not insurmountable, considering that gross fixed capital formation is in the order of 20% of GDP across member states. Whether these additional investments will displace private consumption in turn depends on how other investment or consumption items will change as a result of the Green Deal. We highlight two of these items.

More than half of the EU-28's gross available energy comes from imported sources⁵², representing some 331 billion EUR of fossil fuel imports in 2018. Russia is the Union's main supplier, as well for hard coal, natural gas as oil. The dependency rate has steadily edged up from 44% in 1990 to 55% now; in fact, each individual Member State is a net importer now. Freeing up those resources and reallocating them towards green energy will contribute trillions of euros over the coming decades to bridging the green investment gap.

Fossil fuel subsidies, from protectionist tariffs over capacity payments to public investments in infrastructure had their *raison d'être* in the coupling of energy with growth. Without access to cheap energy, growth was supposed to stall. The ongoing decoupling, together with the growing share of

⁵² Eurostat 2019.

renewables in the energy mix, could render this argument void in the foreseeable future. Fossil fuel subsidies create unfair competition, increase the risk of locking in stranding assets, undermine the carbon price signalling, and may well be regressive.

The European Commission’s returning call over at least a decade for phasing out fossil fuel subsidies has so far not met with success. The reform of fossil fuel consumption and production subsidies is included under SDG 12 on Sustainable Consumption and Production, together with a method for tracking progress on this goal⁵³. With fossil fuel subsidies amounting to at least 55 billion EUR in the European Union – and up to 264 billion EUR when the cost of climate change and its co-externalities such as traffic congestion are included⁵⁴ – a reallocation towards Green Deal initiatives represents an additional considerable push.

Pricing coal and fuel prices at full (or efficient) cost would lower global CO₂ emissions by a quarter and premature mortality as a result of air pollution by almost half, according to the International Monetary Fund. Similar findings apply to the European Union. Note that the avoided healthcare cost is estimated to be in the same range as the green investment gap, implying that not taking these co-benefits into account vastly overestimates the net cost of climate mitigation.

Table 4: Air pollution cost and benefit estimates for 2050 in the 1.5LIFE decarbonisation pathway of *A Clean Planet for all*

	2015	Change by 2050 in 1.5LIFE
Premature deaths ozone and PM2.5 [1000 cases per year]	317	-146
Health impact PM2.5 [millions of life years lost]	5.3	-2.5
Monetary damage health PM [billion EUR ₂₀₁₃ per year]	368-884	-173 - -414
Air pollution control cost [billion EUR ₂₀₁₃ per year]	80	-45
Total	448 - 964	-218 - -459

Source: European Commission 2018b, Table 21.

Estimates of macroeconomic costs as a result of efficiently pricing carbon vary only to a limited extent. The idea that the reallocation of investment would constitute a supply shock that significantly reduces either the level or the growth rate of GDP is not corroborated by the analysis. Any hypothesised reduction in GDP is either quite small – at or below 1% – or non-existent at all. The different model outcomes depend among others on whether climate action such as the Green Deal kicks off in a European economy operating below full capacity, or in an economy at equilibrium. The additional

⁵³ UNEP 2019.

⁵⁴ Alberici 2014, Trinomics 2019, European Commission 2019b, Coady 2019, UNEP 2019. The United Nations proposed to define fossil fuel subsidies according to four categories: (1) direct transfer of funds – payments made by governments to individual recipients; (2) induced transfers – i.e. regulated energy prices; (3) tax expenditure, other revenue foregone, and underpricing of goods and services – for example, tax reductions, allowances, rebates or credits; and (4) risk transfers – direct involvement of a government in the fossil fuel industry, by taking on risks on behalf of parts of the industry. We mention the IMF’s approach including the costs of climate action and co-externalities as well to arrive at a global estimate of some 5 trillion USD, a quarter of which is due to global warming and an alarming half to undercharging for domestic air pollution. Note, finally, that renewable energy is subsidised too.

investments stir the economy into a growth spurt in the first case whereas in the equilibrium case reallocation of production factors at first negatively impacts productivity.

Importantly, introducing carbon pricing almost invariably has a positive contribution to GDP when the fiscal revenue is recycled to alleviate more distortionary taxes elsewhere (notably increasing labour participation in the “formal” economy) and, a fortiori, when environmental benefits are taken into account as we saw⁵⁵.

The investment gap can be put in perspective as well relative to the total market capitalisation of equity shares and outstanding amount of bonds issued by European companies in the most affected sectors. Together fossil-fuel companies and utilities (and agriculture) on the supply side, energy-intensive industry and the transportation sector, construction on the demand side have close to three trillion and half a trillion respectively⁵⁶ outstanding in order of magnitude, with most of the exposure through the energy-intensive industry.

New investments in clean energy are about 360 billion USD annually now, of which about 75 billion USD occurred in Europe in 2019, in particular in solar and on- and off-shore wind technology. 60% of renewable energy assets is financed on the balance sheet of the promotor company, with most of the remaining 40% making use of project finance in which some 60-80% comes from debt financing and the remainder from project equity. Renewable power generation now accounts for two thirds of the net addition to global capacity⁵⁷. At the same time, 117 billion USD (104 billion EUR) of Green Bonds were issued in the European Union, aligned with the principles of the EU Taxonomy. Energy allocations were reduced to about one third of issuance, with buildings and transport taking up the market share in Europe.

Green bond issuance in 2019 was at a global record of more than 250 billion USD, more than 50% larger than in 2018⁵⁸, primarily driven by the European market which accounted for 45% of total issuance, and a doubling of issuance by non-financial corporates. We note in particular the first ever dedicated *climate resilience bond*, issued by the EBRD, and the first *SDG-linked bond*, launched by Italian energy producer Enel. The company is required to measure its performance against several environmental and social KPIs and conditional on falling short of these targets must pay a coupon premium of up to 25 basis points to bondholders. Sustainability bonds tripled from 21 billion in 2018 to 65 billion in 2019, 20 billion was issued in social bonds.

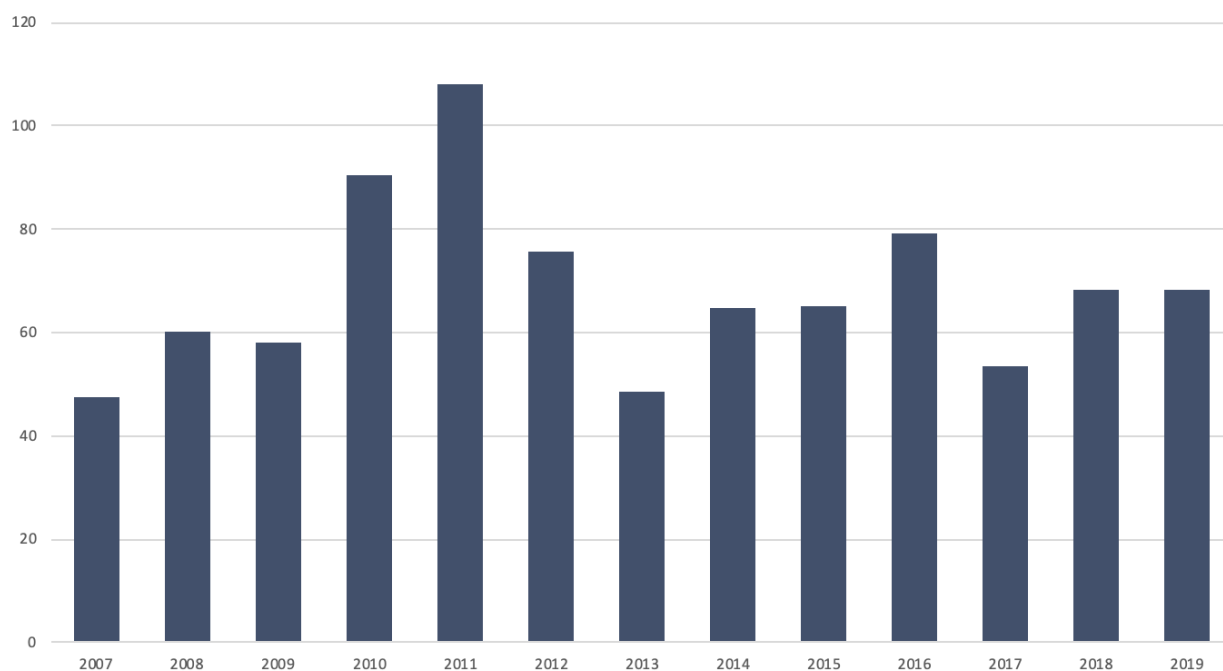
⁵⁵ Metcalf 2020.

⁵⁶ Battiston 2017.

⁵⁷ Frankfurt School 2019.

⁵⁸ Climate Bonds Initiative 2020.

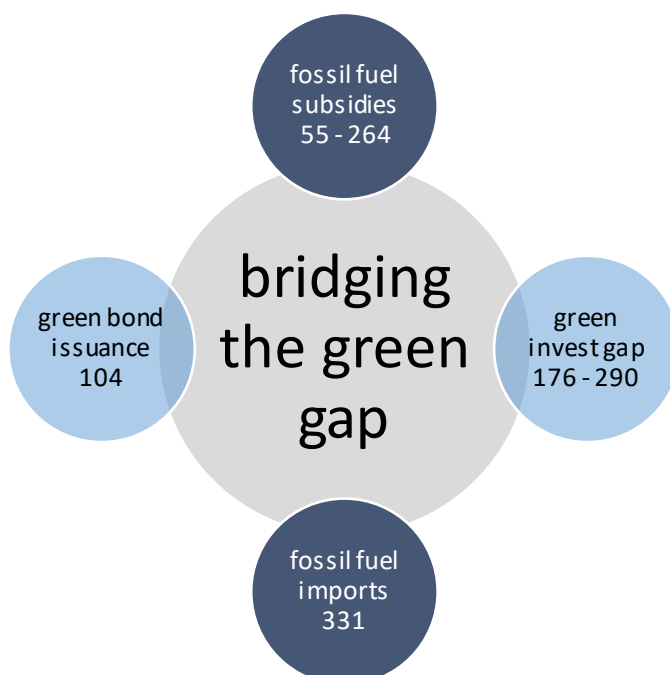
Figure 2: New investment in clean energy in Europe



Source: BloombergNEF 2020. USD amounts converted to EUR by EoY rates (in EUR billion).

Between these numbers, the green investment gap implied by the European Commission’s scenarios appears not unreasonable to bridge.

Figure 3: Bridging the green investment gap



Source: European Commission 2018b (green investment gap), European Commission 2019a and Coady 2019 (fossil fuel subsidies, in EUR₂₀₁₅), Climate Bonds Initiative 2020 (2019 green bond issuance, not including sustainable and social bonds), Eurostat 2019 (2018 fossil fuel imports, in EUR₂₀₁₇). Estimates in billion EUR per year.

3.2. Matching supply and demand of the green investment gap

3.2.1. Segmentation

If the absolute size of the green investment gap does not pose an impossible task, and demand is arguably insatiable⁵⁹, the success of the European Green Deal Investment Plan further hinges on the ability to match supply and demand. The green investment gap shows that there can be no shortage of eligible investment projects in compliance with the EU's proposed taxonomy⁶⁰. On the demand side, investors have indicated a willingness and the capacity to absorb trillions of those same projects.

The Investment Plan provides for technical support to Member States and promoters to channel the eligible investment projects to the capital markets. Eligible projects can at first sight differ widely, both in terms of nature (precision agriculture versus e-fuels), scale (trans border transmission infrastructure versus home electric vehicle recharging installations) or ownership (state-owned utilities versus residential home-owners). What is decisive from an investor perspective however is risk class, the relative predictability of cash flows and/or capital appreciation.

Matching demand and supply essentially boils down to allocating the appropriate supply-side portions to the different investor risk classes at the appropriate time along the roadmap. These portions will typically not coincide with individual projects. Technical support and assistance can assist in carving up projects into risk classes (segmentation), bundling different but related portions into investable packages (securitisation) and time-matching issuance to the Green Deal roadmap (synchronisation).

Consider the example of a Carbon Capture and Storage project⁶¹. A number of key risks withhold private investors from investing, including the CO₂ storage performance risks and the financial securities related to a CO₂ storage permit. Carving these risks out of the project and transferring them to the public sector would create investable assets that appeal to particular technology investor risk classes.

Take as a second illustration the so-called *yieldcos* in the renewable energy space. Developers of solar farms for example can sell the rights to the cash flows from selling the electricity generated on these farms or the operating assets themselves once the riskier steps in the process have been covered. The buyers are dedicated investment vehicles that pay out (almost all of) their earnings in the form of dividends to investors. The predictability of the cash flows derives from the steady margin difference between the income from long-term service contracts or electricity sales and the (debt) financing costs. Furthermore, the pay-out to investors may benefit from favourable fiscal treatment.

The predictability of cash flows in renewable energy projects until recently derived from generous feed-in tariffs or similar government contracts. With subsidies being cut back, project promoters have had to look for other stable sources of guaranteed income in an attempt to steer clear of the volatility of wholesale electricity markets. Utilities and increasingly energy-intensive corporate users such as Facebook sign up for long-term power purchase agreements – in part to comply with their sustainability goals. The alternative is competing in auctions for capacity, a segment that grew exponentially in volume but at significantly lower electricity prices as we saw some years ago.

⁵⁹ The United Nations Principles for Responsible Investment Montréal Pledge for example already counts 500 signatories representing more than 40 trillion USD in assets. The Institutional Investors Group on Climate Change has about half the number of members but control 30 trillion in assets.

⁶⁰ The European Commission has stated it "will prepare the climate taxonomy by the end of 2020 and will prepare the taxonomy for all other environmental objectives by end 2021."

⁶¹ Oxburgh 2016, Bui 2018.

The promotor typically continues to own a sizeable stake as well in the yieldco to further align the incentive to optimally manage the asset. She would typically leverage the cash flow dividends into the development and construction of new solar farms that can after de-risking again be sold or transferred – “dropped down” – to refresh the yieldco’s installed base. The challenge is to find the transfer price that is fair to the promotor and that leaves sufficient value on the table for the investor – as indicated by its “investment-grade” credit rating.

By isolating the steady flow of operating earnings from the much riskier R&D or construction activities associated with renewable energy, a yieldco caters to different market segments in the investor world. When yieldcos were brought to the equity markets through initial public offerings however, equity investors became disillusioned as yields were too fixed-income like, and capital appreciation occurred very slowly – in line with the long-term service contracts – if at all. Recently we saw yieldco shares, sometimes together with their development arm, being sold to institutional investors such as pension funds that use the fixed-income cash flows to “immunise” their pension liabilities over a very long-term.

Incidentally, these yieldcos provide utilities with an additional source of power generation if and when their own generation falls short, without having to build and operate (and have approved) new power plants themselves. It becomes increasingly advantageous for incumbent utilities in terms of per-unit energy production cost to substitute these electricity sources for their own gas- or coal-fired plants. One can envisage a scenario in which these stranded or likely-to-strand assets will be isolated in a “bad bank” type of investment vehicle that isolates the “going concern” assets of the utility or owner from these assets, and that can be transferred to specialised distressed assets investors.

Finally, *cat(astrophe) bonds* and other insurance-linked securities such as the new *resilience bonds*, developed in the mid-nineties to transfer hurricane reinsurance risk, can combine the effect of securitisation and insurance. Cat bonds for example compensate the issuer, typically an insurance company, for losses in the event of a predefined catastrophic event. Cat bonds and similar securities allow for risk transfer to capital markets for more than 40 billion USD outstanding currently⁶².

3.2.2. Securitisation

There is a second matching challenge to overcome: another class of Green Deal investment, notably in energy efficiency and distributed renewables power generation, will take place in individual residential buildings or in SMEs.

Table 5: Global Trends in Renewable Energy Investments

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Global capacity	311	354	414	481	564	658	749	854	982	1122	1282	1449
Capacity added	30	43	60	67	83	94	91	105	128	140	160	167
New Investment	148	177	168	239	287	252	233	288	318	294	325	288
Total Financial Investment	129	149	125	169	203	173	183	242	277	252	270	238

⁶² Artemis Deal Directory 2020.

Small distributed capacity	14	22	35	61	75	70	40	37	33	33	43	37
Government R&D	3	3	5	5	5	5	5	5	4	5	5	6
Corporate R&D	2	3	3	4	4	4	4	4	4	4	7	8
New Investment Europe	65	79	77	112	130	90	57	69	61	71	45	62

Source: UN Environment, Frankfurt School-UNEP Centre, BloombergNEF 2019, Figure 21. Capacity in GW, investments in billion USD₂₀₁₈. Total Financial Investment includes (predominantly) Asset Finance, Venture Capital and Public Markets.

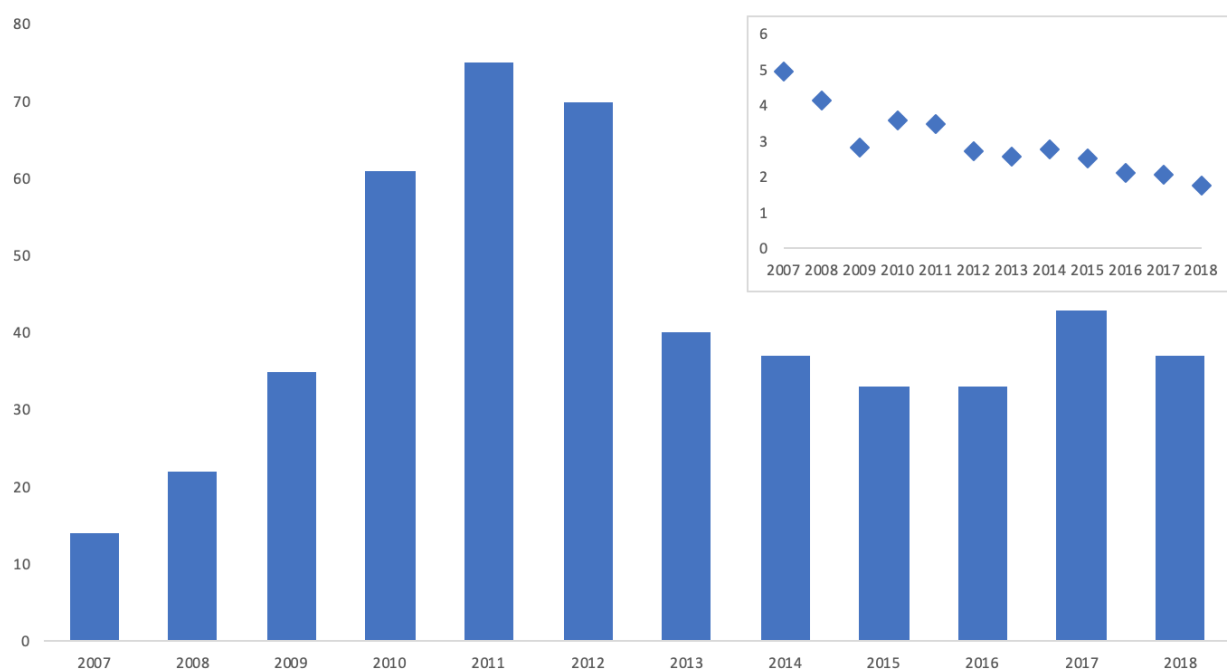
Global investments in small distributed capacity have subsided after the boom of a decade ago, in large part because of decreasing technology costs and possibly the scaling back of generous feed-in tariffs. (The inset graph shows the evolution in USD/W of newly added renewable energy capacity in general, where the same trend applies.) But the key growth drivers of electrifying renewable power generation and enhancing energy efficiency are expected to lead to a pick-up in installed small-scale capacity.

In addition to segmenting high-risk from lower-risk aspects of investments in green technology, vehicles such as yieldcos and other securitised assets in general offer a way to bundle distributed investments. Community-led investment-scale initiatives can relax potential credit constraints on the demand-side. Carefully combining substitute and complementary technologies into a single package lowers volatility, up to the point of providing cash flows with baseload-like characteristics. Insurance contracts determined by heating & cooling degree-days can be aggregated over locations where different weather patterns reign in hedging strategies, etcetera.

Energy efficiency investments are peculiar from a structured investment point of view because they do not result in a cash-generating asset but rather in the avoidance of future outlays, typically in the form of lower energy bills. There is consequently no collateral asset nor an explicit cash flow that can be ring-fenced to repay financing costs. In addition, energy efficiency improvements are somewhat self-defeating: if energy prices fall because efficiency reduces demand, the avoided costs decrease. Solutions explored include a third party that pays for the investment in distributed power generation and returns are shared between the capital provider and the energy consumer. The third party may be the local utility or a public authority. The challenge is how to adapt the revenue sharing to the price dynamics of energy content and equipment – as was learnt in the generous feed-in tariff programmes in Europe. Other solutions are auctioning contracts-for-difference or subsidising energy users for adopting less carbon-intensive processes, which allow for more dynamic and technology-neutral incentives.

The Green Deal Investment Plan's support and assistance capabilities could be used to streamline regulatory and credit rating approval processes and standardise securitised assets to the extent possible, to expand and deepen more liquid markets.

Figure 4: Global investments in small distributed renewable energy capacity



Source: UN Environment, Frankfurt School-UNEP Centre, BloombergNEF 2019. Investments in small distributed capacity in billion USD₂₀₁₈. Inset figure represents cost [USD/W] of newly added renewable energy capacity in general.

The advantages of securitisation are conceptually clear: expansion and diversification of the investor base, lowering financing and energy costs and stimulating credit provision, improving capital utilisation and allocation for financial institutions and institutional investors. The downside is tied up with the financial system's inherent pro-cyclicality or even "excess elasticity"⁶³: its inability to prevent the build-up of excessive debt, driving booms and busts, largely as a result of misguided incentives and asymmetric information. Designing better incentives mechanisms will include:

- Rewarding the originators and structuring parties of the underlying funding transactions based on subsequent transactions' performance rather than origination commissions and complex fee structures;
- Regulating the credit rating process, for example by aligning rating fees with investors rather than promoters, and through effective supervision by publicly accountable authorities;
- Safeguarding financial macro-stability by discouraging investors' excessive search for yield, with implications for suitability assessments, risk weighting and capital charges, or eligible collateral rules.

These lessons learnt in the subprime and euro credit crises provide for the best practice framework for new types of securitisation. In particular, prudential supervisors, multilateral financing and development institutions and central banks have their role cut out to avoid the cascades of misallocation and contagion, the break-down of interbank markets and the emergence of shadow banking, or the macro-economic risks of financial instability we witnessed a decade ago.

⁶³ Borio 2002, Borio 2011.

Regulation in place since the financial crisis to some extent discourages financial institutions to engage in or invest in securitised assets. In fact, regulatory obstacles and political uncertainty, such as the risk of “retrospective” regulation, carry a considerable risk premium. They will need to be removed to unlock green investments and match supply and demand.

Institutions such as the InvestEU programme or the European Investment Bank signal the European Union’s willingness to create regulatory stability through the issuance of guarantees. *Covered bonds* in particular benefit from the claim investors have over the collateral “cover pool” as well as a general recourse to the issuer, typically a bank. Public guarantees enhance this dual recourse structure in return for investments through the covered bonds in projects that have a multiplier effect on public policy. Covered bonds have already been used for centuries to finance real estate and infrastructure; they can easily be adapted to finance climate action as well. Furthermore, their highly-regulated nature offers perspectives to mitigate or transfer risk in the more uncertain phases of sustainable activities during development and construction.

3.2.3. Synchronisation

The Green Deal is perhaps most advantageously framed as a transformation, a reallocation of the European Union’s economy – and society at large – rather than a (net) growth investment. The impact on, say, GDP growth may well be underwhelming or exaggerated, depending on whether one expects a significant positive respectively negative impact.

The implication is that such a reallocation, in particular in its transitory phases, demands an active guidance or at least an active monitoring of where we are on the roadmap, pivoting or accelerating where needed. In short, from an investment theoretical point of view, the Green Deal represents a vast portfolio of real options. The Green Deal’s reallocation roadmap comes with switching costs that will determine the location and the timing of specific actions during the transition. It is this complex of switching cost that must be managed, in particular by means of the European Union’s cohesion policy.

As a result, the European Commission will need to carefully design the incentives for individual Member States to adhere in the long-term to the Green Deal’s roadmap, including but not limited to the monitoring and guiding instruments of the European Semester, the Stability and Growth Pact, and monetary-financial-prudential policy.

The current Commission has made clear⁶⁴ it will “refocus” its European Semester country recommendations with a view to achieving the sustainable development goals. The European Green Deal represents the Commission’s new sustainable growth strategy, with its four interlocked dimensions: the transition to a nature-friendly and climate-neutral Europe by 2050, productivity enabled by digital technologies, financial stability in a completed Economic and Monetary Union, and social fairness ensured by a just and inclusive transition. Although the recently released country reports⁶⁵ show progress towards most of the SDGs, member states differ widely in terms of the preconditions or constraints for sustainable investment: demographics and skills mismatches, public debt and private investment, the level of digitalisation or the state of infrastructure. The Semester cycles could be used therefore not simply to check the box of SDG indicator lists or tally the progress towards 2030 or 2050 climate goals, but to provide path-dependent and country-specific guidance to member states along the shared socio-economic pathways incorporated in the Green Deal.

⁶⁴ European Commission 2019e.

⁶⁵ European Commission 2020b.

The Stability and Growth Pact's structural reform clause and the investment clause in particular could allow for a temporary deviation from the medium-term budgetary objective or the adjustment path towards it. The waiver comes with well-defined conditions, specifically that these structural reforms must have a verifiable positive impact on the long-term sustainability of public finances. The risk is that by and large most public spending lends itself to be interpreted as fostering sustainability on the time-scale of the Green Deal, negating the exceptional and/or temporary nature envisaged in the Pact. Embedding individual member states' investment plans in the extended Shared Socio-economic Pathway of the Green Deal, with the support of the Commission's Structural Reform Support, may mitigate the risk of selectively invoking the relevant clauses.

A European Central Bank actively promoting green investments in its prudential and (re)financing role can further guide member states along the chosen pathway.

A key variable is timing. Scientific understanding of climate change is advancing but cannot be considered complete, in particular when tipping points, critical phase transitions to a qualitatively different state of the world are concerned. The portfolio of technology options is diverse and continues to expand, and uncertainty at most Technology Readiness Levels is large. One of the main drivers of the transformation, behavioural changes among consumers, is notoriously difficult to predict. Finally, the need for policy and regulation well beyond the "horizon" of political decision-makers creates additional risks of credible commitment and time-consistency. Each of these sources of uncertainty interacts with every other source – but within the time constraints posed by climate change itself, we are compelled to act. To the extent possible, action must be coordinated to avoid individual actors acting rationally to the detriment of society as a whole. Such implies in particular that policymakers, regulators and supervisors will need to coordinate investment plans, sometimes beyond what self-interested individual agents would be inclined to do. In sum, again, the Green Deal is in need of a detailed and dynamic roadmap to which innovation, investment and incentives should be synchronised.

4. NO TAXATION WITHOUT RECYCLING

KEY FINDINGS

The design of taxes and other government interventions requires careful analysis of the trade-off between achieving the objective of the measure – typically a behavioural change – and the extent of distortion. Taxing (fossil-fuelled) electricity or heating typically impacts lower-income households more than others for example. Any such tax scheme is best complemented with well-designed targeted transfers to these lower-income households that maintains the incentive for more sustainable electricity production or heating but mitigates the increase in inequality as a result of the environmental taxation.

Policymakers must be aware of these trade-offs, in particular by not restricting the design of roadmaps to task forces or expert groups concerned with a single objective without taking into account the interdependency with other objectives.

The advantage of properly designed environmental taxes is their double dividend: they not only mitigate the negative externality but, in the process, raise considerable revenues. Packaging carbon taxes together with proper ‘revenue recycling’ makes such taxes much more acceptable. Reducing labour costs or income taxes is a favoured form of recycling, as well as compensations to counter any regressive impact of carbon taxation. Note however that the balance between on the one hand the distortions that environmental taxes generate in the economy and on the other hand the benefits of recycling fiscal revenues will undoubtedly change through time.

We add again that other externalities, in particular the positive effects of knowledge spill-overs or the negative effect of coordination failures to build the required (transport, electricity, information) network infrastructure, and other objectives such as the SDGs, may in any case require complementary policies in addition to carbon pricing. These policies too, constrain households and firms, putting an *implicit* price on carbon. The OECD’s ongoing research on effective carbon rates in its member countries indicates that these carbon prices vary widely, from close to zero to hundreds of euros per ton CO₂-equivalent. Vehicle emission rate standards in particular are considered extremely expensive and regressive, especially when they do not take the power-to-weight ratio into account.

The transition towards a carbon-neutral economy is not without impact on employment, although the impact should not be overstated, with a reallocation of only 1.3% of the Union’s workforce. The revenues from carbon pricing can however be recycled to remove these labour market rigidities. Providing dislocated workers with the ability to rebuild human capital is especially important.

The programme of the Just Transition Mechanism now resembles a Green Deal in miniature version, with the added geographical targeting. One would have expected the Mechanism to focus on exclusively social or labour market measures and leave wider measures such as economic reorientation to a more comprehensive framework integrating the Green Deal and cohesion policy.

4.1. A second-best Green Deal

Taxes and other government interventions wilfully or necessarily distort decision-making by households, firms and other governments. The design of such distortions in a second-best world requires careful analysis of the trade-off between achieving the objective of the measure – typically a behavioural change – and the extent of distortion. More often than not, targeted intervention with multiple instruments is to be preferred over single measures that work reasonably well in their primary market but generate excessive distortion in related contexts. Taxing (fossil-fuelled) electricity or heating typically impacts lower-income households more than others for example. Any such tax scheme is best complemented with well-designed targeted transfers to these lower-income households that maintains the incentive for more sustainable electricity production or heating but mitigates the increase in inequality as a result of the environmental taxation⁶⁶.

On the other hand, when a particular market distortion cannot be removed, it may be efficient, paradoxically, to introduce another distortion, perhaps in a related market, that can mitigate the original distortion. Polluting inputs or activities may be difficult to monitor and therefore tax directly. A tax on the output of these activities can raise the price for the end user, potentially reducing production. When combined with a subsidy for a cleaner alternative, incentives to reduce pollution or promote recycling are further enhanced. A well-known example is the deposit-refund system for various forms of packaging⁶⁷.

Finally, it may be better to let two market distortions exist side by side, rather than to focus on fixing one – with the consequence that we are further away from the overall objective. The prototypical case here is where a vital good can only be produced through a process that causes environmental damage and is at the same time controlled by a monopolist. Depending on the situation, it may not be optimal to break the monopoly because competition may lead to higher production and consequently more damage to the environment. Alternatively, society may be required to accept a particular level of environmental damage⁶⁸.

Policymakers must be aware of these trade-offs, in particular by not restricting the design of roadmaps to task forces or expert groups concerned with a single objective without taking into account the interdependency with other objectives.

The Green Deal and climate action in general will be called on to respond to the arguably gratuitous critique that it is an expensive way of ‘curing by killing’: in a well-intentioned effort to create a “safe operating space for humanity”⁶⁹, the patient – our current way of living – is terminated. Often, such critique derives from the unwarranted belief that the economic and ecological objectives are necessarily irreconcilable, and from a general aversion to government intervention. Proponents of the Green Deal will need to make clear that at its core lies the double externality of global warming (negative) and an economic re-engineering based on knowledge spill-overs (positive) and that exploiting the latter may go a long way towards mitigating the former.

It is in the nature of externalities that the market cannot resolve these issues by itself. The challenge, both from a policy implementation as well as communication perspective, is that a careful design of market distortions – carbon taxes and innovation subsidies, cross-border tariffs and emissions trading systems – may well have counterintuitive results that require equally careful explanation to the parties

⁶⁶ Zachmann 2018. We refer to the analysis of Box 2 as well for another example where a portfolio of policy instruments is more effective than a single instrument such as a carbon tax.

⁶⁷ Fullerton 2005, Sandmo 1976.

⁶⁸ Buchanan 1969 and the vast literature deriving therefrom.

⁶⁹ Rockström 2009.

involved and the public in general. We already remarked that welfare losses and gains of electricity taxes tend to not be distributed uniformly in the population. We will see more examples later on. Theoretically for instance, it makes no difference to emissions whether we travel by train or by airplane within the European Union. The ability to exchange allowances within the cap set by the EU-Emissions Trading System created a waterbed effect where a reduction of emissions in one place frees up allowances to emit elsewhere, a phenomenon that the recent ETS reforms attempt to correct. Protecting infant industries with tax exemptions or feed-in tariffs deliberately distorts the economy in the short run for the purpose of positive dynamic effects in the long run.

Even more pressing is the perception that the ecological motive will increasingly polarise the world, and European member societies in particular, into winners and losers. A very important result⁷⁰ for our purposes is the effect of second-best theory on commodity taxation, in particular the taxation of carbon-intensive goods and services. The Diamond/Mirrlees result states that it continues to be desirable to strive for production efficiency, i.e. the ability of society to produce as many of each good as possible without sacrificing the production of another good. In other words, production must take place at the lowest possible cost – in this case, of course, including the social cost of carbon.

Pushing the economy towards the production possibilities frontier may lead to unemployment and bankruptcy for those workers and firms who have no place on the efficient frontier. The Diamond/Mirrlees result requires that the affected people need not lose out indefinitely and could be redeployed in other jobs at the same after-tax wage. Any drive for efficiency should therefore be accompanied by measures such as outplacement or retraining or other forms of redistribution and compensation. The cost of doing so need still be inferior to letting inefficiencies linger on just to cater to particular interest groups. In other words: the inefficiency introduced by the taxation – its ‘deadweight loss’ – must (and can) be countered by the benefits of redistributing its fiscal revenue to where it is most effective.

4.2. Carbon taxes

The overexploitation of common resources such as clean air could be remedied by privatising these resources. But fencing in meadows is relatively easy compared to segmenting the world’s atmosphere. The other classical solution goes by the name of Pigouvian taxes: partially nationalising the resource by levying taxes on its use or appropriation. There is also an equivalent⁷¹ solution to the problem based on quota instead, budgeting and auctioning usage rights. It is a matter of debate whether it is easier to control prices (taxes) or volumes (emissions and their effect on the planet’s ecosystem). The idea is that taxes or quota lead to guiding (changing) behaviour as would a price signal bring about in an efficient market or through private bargaining⁷².

The optimal design of taxing the production or consumption of goods considered harmful, requires a precise understanding of the behavioural change the fiscal authority wants to achieve, and of the factors that determine supply and demand for these goods, their complements and substitutes. Who actually pays for the tax, is not necessarily the one nominally designated by the government to pay.

- When demand is perfectly elastic – for example, a ‘world’ price is given, irrespective of the quantity demanded – producers bear the entire tax burden; when the supply curve is horizontal, the situation is reversed;

⁷⁰ Diamond and Mirrlees 1971.

⁷¹ Pigou 1920, Weitzman 1974, Dasgupta and Heal 1979.

⁷² Coase 1960.

- When firms benefit from market power, producers can (but need not) shift more than the tax to consumers. Producers of goods and services in particular for which low-carbon substitutes are easily available, will bear the carbon tax; when no low-carbon alternatives are available, the carbon price is typically passed through to end-consumers. Climate action will impact prices of agricultural produce differently, for example, and it will depend on dietary changes how carbon pricing will turn out. Vegetable production would be much less affected than rearing livestock; and
- When the climate mitigation quality of an energy source is reflected in a characteristic that is untaxed by a specific energy tax, taxation may lead to decarbonisation. Electricity taxes only focused on price on the other hand may provide little or no incentive to switch to cleaner power sources and substitution with cheaper more carbon-intensive alternatives remains a risk.

As discussed, from a policy perspective the social cost of carbon represents the threshold against which (marginal) abatement costs ought to be evaluated. One consequence is that within activities or sectors where the abatement cost differs significantly from the social cost of carbon, its incentivising effect is minimal. Professions such as fishermen or farmers may on the one hand be particularly vulnerable to climate change yet on the other hand be constrained, in particular because the option to substitute diesel fuel or fertiliser for sustainable alternatives is not easily available.

Countries too differ in terms of reduction potential, the availability of renewable energy sources and, of course, socio-economic make-up. This may provide countries, such as member states within the European Union, with some (political or second-best) degrees of freedom to either have lower carbon prices in those sectors or have recourse to other complementary carbon regulation. The typical example is heating, on which low-income households spend relatively more than high-income households do, in contrast with putting a higher carbon price on, say, aviation⁷³. Energy-related expenses in Europe have already gone up significantly as a share of income since 2000 and that share of income (ca. 7.5%) is not expected to rise significantly and will decrease beyond 2030. However, income group and regional differences are considerable⁷⁴: the lowest income decile pays 10% whereas higher-income deciles less than 6%; northern and western European households spent about 4-8% whereas central and eastern Europeans spent 10 to 15% on energy (ex transport) in 2015. Harmonising carbon pricing across member states would tend to benefit those countries with more stringent targets more than (typically lower-income countries) with less stringent targets. Internationally⁷⁵, the burden falls more on average-income consumers in poor countries than on poor consumers in average-income countries.

As a general rule, the carbon price will be required to rise but countries may elect to increase the pace or the level of prices if they want to incentivise emissions reductions or effort sharing faster. A priority candidate for such an increasing lower bound would be to set higher (binding) minimum taxation rates for fuels, through a revision of the 2003 Energy Taxation Directive (2003/96/EC).

There is also an ethical consideration: to what extent are polluters allowed to buy off the 'right to pollute'? In contrast with the cap-and-trade systems we will discuss in the next section, environmental taxes do not guarantee an upper limit to usage – and consequently harm. The appetite for abatement largely depends on producers' willingness to pay then. Of course, if caps are less than ambitious, the upper limit will not be binding either in emissions trading systems.

⁷³ Fajgelbaum and Khandelwal 2016. They estimated expenditure shares for countries of different income levels and assumed that the expenditure differences hold for individuals of different income level.

⁷⁴ European Commission 2019a.

⁷⁵ Sager 2019.

The advantage of properly designed environmental taxes is their double dividend: they not only mitigate the negative externality but, in the process, raise considerable revenues. If all energy-related CO₂ emissions were effectively taxed at 30 EUR per ton, on average an additional 1% of GDP in fiscal revenues could result⁷⁶. Note however that the balance between on the one hand the distortions that environmental taxes generate in the economy and on the other hand the benefits of recycling fiscal revenues will undoubtedly change through time. At the current abatement levels, the positives appear to dominate. But as the carbon tax base is eroded and notwithstanding rising efficient carbon prices, the distortionary effect may get the upper hand, reinforcing the need for a consistent policy roadmap.

Packaging carbon taxes together with proper ‘revenue recycling’ makes such taxes much more acceptable⁷⁷. Reducing labour costs or income taxes is a favoured form of recycling, as well as compensations to counter any regressive impact of carbon taxation. The problem then is not to create perverse incentives again that would go against the environmental objective: reducing VAT on electricity for example might lead to higher consumption. Or the government can opt to tax the use of carbon in a progressive manner – proportional to airmiles, say – and then return the revenue uniformly to all taxpayers. If, more generally, a fee for carbon-intensive goods and services is combined with rebates for lower-carbon items – a combination known as “feebates” – to the *same* household or firm, the latter may be efficiently incentivised to engage in the transition towards a more sustainable economy.

We add again that other externalities, in particular the positive effects of knowledge spill-overs or the negative effect of coordination failures to build the required (transport, electricity, information) network infrastructure, and other objectives such as the SDGs, may in any case require complementary policies in addition to carbon pricing. It will depend on the overall strategy implemented in the roadmap to decide which instrument is most appropriate at a particular instant in time. Governments sometimes intentionally choose to earmark carbon tax revenue for the promotion of investment in research and development of low-carbon technologies. Fiscal revenue however is fungible so there is no need to do so if removing other distortions is a more efficient option. On the contrary, earmarking may invite interest groups to try and capture such revenue.

4.3. Cap-and-trade emissions systems

The “cap” in emissions trading systems refers to the maximally remaining budget of greenhouse gases that can be emitted before a particular temperature or atmospheric concentration threshold is reached. The “trade” component refers to the possibility that within that budget parties are free to exchange permits to emit – at a price. Within the limits imposed by the cap, optimal emission paths can be determined depending on the precise objective function. In essence, we mimic the search for an optimal extraction path of an exhaustible resource such as an oil field. From Hotelling’s rule⁷⁸, the systems price should increase at the rate of interest at which the proceeds from extraction could have been reinvested.

By consistently lowering the upper limit with time, the cap imposes an increasingly stricter constraint on the emissions themselves and the exchange of permits, thereby increasing the price. Given the uncertainty in scientific understanding, economic and social impact, political feasibility and a fortiori our combined emissions path, the cap could theoretically be made to decrease faster – or slower – but

⁷⁶ OECD 2019 in an average over 44 countries.

⁷⁷ Fay 2015.

⁷⁸ Hotelling 1931.

it remains to be seen how government(s) could credibly commit to uphold such a long-term policy. Enshrining climate objectives in law as foreseen in the Green Deal can help to foster confidence.

Emissions trading systems come with often quite complex rules and functions that may or may not enhance the original idea. Permits may be allowed to be banked or borrowed. Auctions of permits may set a floor price. Stabilisation funds may call for excess permits to be cancelled, or additional permits to be offered, etcetera.

In February 2018, European lawmakers formally approved the EU ETS phase 4 (2021–2030) reforms. The reforms include increasing the linear annual cap reduction from 1.74% to 2.2%, increasing the impact of the Market Stability Reserve on the surplus by withholding more allowances from the market and cancelling a portion of allowances in the Reserve, and revising rules related to free allocation of allowances. Free allocation will be more aligned with recent activity levels, the benchmark levels will be updated every five years to take technological progress into account, and the free allowances for sectors not deemed at risk of carbon leakage will be phased out. The fear is that the Market Stability Reserve has arguably injected (more) uncertainty into the system. Individual member states' unilateral policy can now affect cumulative emissions in Europe, the amount of which has become difficult to predict as a result of "automatic" corrective actions.

An important handle to improve the European Union Emissions Trading System's working is the introduction of minimal threshold prices that ratchet up through time, potentially combined with protection against prices falling below that threshold. The World Bank has its Climate Auction Programs, built on the Pilot Auction Facility for Methane and Climate Change Mitigation. The programs reflect a "pay-for-performance" scheme, in which price guarantees for future climate results, think: greenhouse gas emissions reductions, are auctioned. These price guarantees provide holders with a put option, i.e. the right, but not the obligation, to sell future climate results to the World Bank at a predetermined price. The competitive auction essentially reveals the minimum price required by the private sector to make the pre-defined green investments. If carbon prices would fall, the project owner (the bondholders providing the capital) are protected; if carbon prices remain above the minimum price, the private party keeps the upside. The auction winner must pay the option premium for the price guarantee upfront, incentivizing her to deliver the agreed upon climate results. Furthermore, funds are only disbursed once the climate results have been independently verified. Similar proposals have been proffered with respect to the EU ETS⁷⁹. The European Investment Bank could have the mandate to sell similar put options – "price guarantees" – to protect allowance holders against low future carbon prices.

What is often misunderstood or even considered unacceptable is that the exchange of permits at a certain point in time makes the system indifferent as to who actually emits. The law of one price, combined with the cap, implies that the substitution of one source of emissions for any other covered in the system leaves total emission intact. What is more: reducing emissions at one source will simply create the opportunity for another source to take up and replace that emission, leaving the original abatement effort without any net effect on total emission. Similarly, replacing the production of energy or electricity in a renewable manner does not in itself lower emissions in a cap-and-trade framework. The unused emission permit can be used in the same or other member state to buy emission rights using fossil-fuel technologies. Only the gradual lowering of the cap ensures that total emission will decrease over time.

⁷⁹ Cf. e.g. Claeys 2019.

The complexity of the dynamics of emissions trading systems is further compounded by the so-called green paradox⁸⁰. The paradox maintains that the announcement of a policy that aims to increasingly reduce the use of fossil-fuel resources actually induces their owners to accelerate the extraction of these resources and sell them to whomever is willing to pay, in the process accelerating global warming. We will discuss the issue in the context of international trade in a later chapter. Suffice to say here that one needs to assess the behavioural reactions to climate change not only from the demand side – constraining the consumption of fossil fuels – but also from the supply side. How will owners of fossil-fuel reserves react to the unfolding dynamics along the Green Deal roadmap?

4.4. Implicit, notional or shadow carbon pricing

Both explicit pricing options are usually combined with complementary policies, in particular regulation and other measures to discourage the burning of fossil fuels such as construction standards or reforestation. These policies too constrain households and firms, putting an *implicit* price on carbon. To be able to identify the least-cost way to reduce emissions, these measures need to be converted and made explicit. The OECD's ongoing research⁸¹ on effective carbon rates in its member countries indicates that these carbon prices vary widely, from close to zero to hundreds of euros per ton CO₂-equivalent!

Vehicle emission rate standards in particular are considered extremely expensive and regressive, especially when they do not take the power-to-weight ratio into account. Fleet standards furthermore incentivise producers to price less efficient cars relatively higher in order to reduce more the (absolutely) higher price of more efficient cars, with a different effect on lower- versus higher-income households. Vehicle emission rate standards may be replaced with revenue-neutral feebates, perhaps combined with properly designed fuel taxes that additionally raise the cost of driving an additional kilometre. Stimulating higher renewable content in the fuel mix for example by means of the Fuel Quality Directive and Renewable Energy Use Directive will affect car manufacturers as well.

Mandating energy efficiency can misfire as well when it does not differentiate between saving, say, solar energy during periods of high insolation – with no effect on emissions – versus saving heating oil from better building insulation. Demanding that every actor adheres to the same regulatory measure, say roof isolation, irrespective of location and other specific characteristics is a misguided drive for equitability. As we discussed earlier, both from an efficiency and equity perspective, the optimal policy is to combine cost-effective abatement with compensatory transfers.

Fossil-fuel use can also be managed by using notional carbon prices in, notably, financial instruments used for hedging – or speculating – such as loan guarantees or interest rate agreements. Financial regulators and central banks investigate how to calculate risk-weighted capital costs of assets in terms of the carbon content or value they represent. Multilateral development banks such as the World Bank, or the European Bank for Reconstruction and Development have followed the European Investment Bank's lead in applying shadow prices for carbon as a "non-financial value-added" in their investment and credit analyses. By imputing a notional social value of carbon to the emissions pathways in a project, a more comprehensive assessment of the cash flow generating capacity and other outcomes can be made. The practice has been adopted by governments in assessing public services and firms for internal pricing purposes. The mechanism established under Article 6 of the 2015 Paris Agreement provides for a similar approach.

⁸⁰ Sinn 2008.

⁸¹ OECD 2018.

4.5. The impact on employment and the Just Transition Mechanism

The benefits of climate policy accrue to those who would otherwise have to bear the excess of the social cost over private costs. These benefits are not uniformly distributed across the (global) population. Improvements in air quality are perceived as a luxury product, more valued by high-income households. Not only is the income distribution affected by climate change, the distribution of wealth is too. Adaptation measures may lead to higher real estate valuations in the otherwise affected (coastal) regions. Whereas low-income households may not have accumulated much tangible wealth to feel that impact, their most important capital is their human capital, the accumulated earning potential of their set of skills. Investments in human capital are arguably the most specific type of investment, or in other words: the risk of degradation of human capital is not easily diversifiable. As a result, providing dislocated workers with the ability to rebuild human capital is especially important.

More generally, the supply-side costs of climate (change) action depends on the nature and proportion of the inputs producers use. The more specific these resources are, such as dedicated machinery or labour with particular skills, the more the owners of these inputs will be hit. If clean technology would be more capital-intensive than labour-intensive for example, the demand for capital represented by the green investment gap may cause returns to capital to rise relative to labour wages. If at the same time, the skills set required may be verging towards more highly-skilled jobs, the result is lower relative wages for lower-skilled jobs, potentially hitting low-income families disproportionately.

The transition towards a carbon-neutral economy is not without impact on employment, although the impact should not be overstated. Even without taking into account climate action, labour markets in the baseline scenario are already structurally changing under the influence of climate policies already in place and other socio-economic drivers such as demographics. Estimates of the impact of climate change mitigation range from an additional 500 000 to more than 2 000 000 jobs created on a net basis in 2050 relative to the baseline⁸². More importantly, the analysis shows that the structural, regulatory or fiscal interventions in Europe's rigid labour market are the crucial driver of the estimates, rather than the decarbonisation in itself with a reallocation of only 1.3% of the Union's workforce. The revenues from carbon pricing can however be recycled to remove these rigidities and facilitate the relocation of labour from the fossil-fuel sectors to sustainable development. That ought to be the objective of the Just Transition Mechanism.

The European Commission⁸³ has dedicated some 10% of its 1 trillion European Green Deal Investment Plan, to its Just Transition Mechanism. The Mechanism incorporates

- The Just Transition Fund, with 7.5 billion euros of "fresh EU funds", allocated among member states and conditional on member states filing a "territorial just transition plan [...] providing an outline of the transition process until 2030" and matching each euro with resources from their share in the European Regional Development Fund, the European Social Fund Plus and national co-financing according to cohesion rules;
- A just transition scheme under InvestEU, seeking to attract private investments (up to 45 billion) in sustainable energy and connectivity that benefit affected regions, aimed at reflecting the same national allocation key; and
- The announcement of a public sector loan facility with the European Investment Bank backed by the EU budget to mobilise 25-30 billion of investments in local sustainable energy projects.

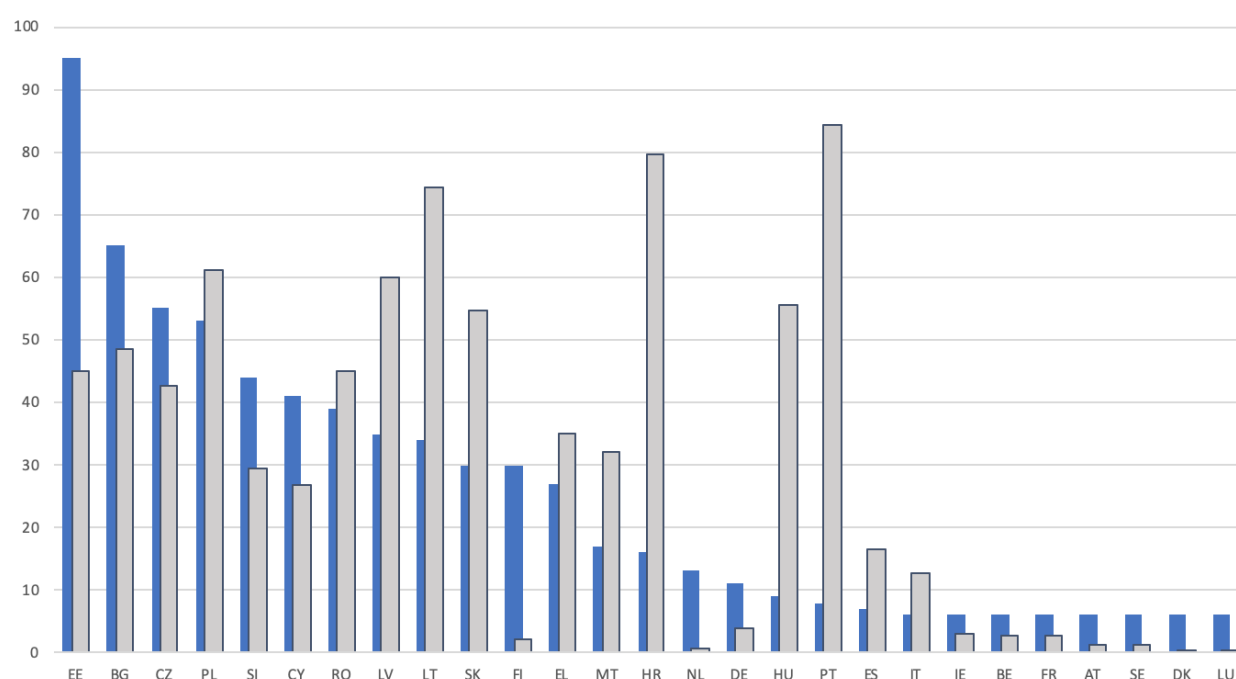
⁸² European Commission 2018b. IRENA 2018.

⁸³ European Commission 2020a.

The Commission has chosen to narrow the Just Transition’s “single specific objective of enabling regions and people to address the social, economic and environmental impacts of the transition towards a climate-neutral economy” to supporting the economic diversification and the reskilling and active inclusion of workers in regions (NUTS level 3 or parts thereof) that have significant legacy employment in mining and extraction – think: North Eastern Scotland or Silesia – or energy-intensive industries.

The Fund’s proposed allocation mechanism aims to reflect the size of the challenge and member states’ capacity to finance the appropriate accommodating investments. The allocation key derives from an average of CO₂-equivalent industrial emissions in regions with above-average carbon intensity (industrial greenhouse gas emissions relative to gross value added), and of employment in industry in those regions. The resulting share is capped or adjusted negatively or positively by 1.5 times the difference by which a Member State’s GNI per capita (measured in purchasing power parities) for the period 2015-2017 exceeds or falls below the average GNI per capita of the EU-27 Member States.

Figure 5: The Just Transition Fund allocation relative to the Share of Cohesion Policy



Source: European Commission 2020a, Eurostat 2020. Just Transition Fund allocation key (in blue) expressed as EUR per capita. Share of Cohesion Policy (in grey) expressed as share [%] per Member State of public investment (2015-2017).

Whether the “scale of the transition challenge” can be crudely proxied by the current industrial emissions (on NUTS level 2) is up for debate, as well as whether the “social challenges” are proportional to legacy industrial employment⁸⁴, without referring to, say, the nature and extent of the barriers to reskilling and relocation of these workers or the specific ability to redesign the chemical or automotive manufacturing processes. It is therefore unclear how the Just Transition Fund’s overall size has been determined. In fact, the specific “social, economic and environmental challenges” do feature in the

⁸⁴ Note furthermore that the allocation must minimally amount to 6 EUR per capita for each member state, i.e. irrespective of occupational status, income, etcetera.

territorial just transition plans – *after* the money has been allocated, that is. Incentives are skewed to the past and the slow rather than the fast and the future.

If the socio-economic repercussions of phasing out coal is at stake, it has already been proposed⁸⁵ to simply make better use of the already existing European Globalisation Adjustment Fund to ease the pain of the labour market transition in the affected regions. Relevant policy instruments for a just transition may include retraining and outplacement of labour (especially when the skills transition is abrupt), wage subsidies to other industries to absorb displaced workers, planned capacity reduction, or relaxing credit constraints. Estimates⁸⁶ of coal-related job losses expected until 2030 are 160 000 jobs out of the 216 000 – most of which would be at risk irrespective of any climate mitigation or “just” transition action. Poland employs some 115 500 people in coal mining and related business, 0.71% of its total employment⁸⁷. The European Globalisation Adjustment Fund provides up to 60% for two-year projects in outplacement of dislocated workers as a consequence of globalisation, the global financial and economic crisis, or for young people not in employment, education or training (NEETs). Climate change is a ready candidate then for broadening the fund’s scope once more.

The Just Transition Fund grants are “exclusively” aimed to support:

- productive investments in SMEs and the creation of new firms leading to economic diversification and reconversion;
- investments in research and innovation and fostering the transfer of advanced technologies other than nuclear or fossil fuel technologies, including affordable clean energy, greenhouse gas emission reduction, energy efficiency and renewable energy, and in digitalisation and digital connectivity (but not in additional broadband networks);
- investments in regeneration and decontamination of sites, land restoration and repurposing projects;
- investments in enhancing the circular economy, including through waste prevention, reduction, resource efficiency, reuse, repair and recycling; and
- upskilling and reskilling of workers, job-search assistance and active inclusion of jobseekers.

The programme reflects the Commission’s intention to comprehensively transform the affected regions’ economies, creating a perspective for the dislocated occupational groups. The proposal appears to segment a – modest – fraction of the overall 200-300 billion annual green investment gap by means of geographical targeting. Such a fragmented approach is prone, again, to second-best like risks of misallocation of funds and resources. (For one, using public funds to repurpose brownfields sends out the wrong signal.) A comprehensive approach to the European Sustainable Investment Plan, i.e. a priori taking into account objectives of different nature (economical, environmental and social), in combination with Europe’s overall cohesion policy may well have singled out these regions for preferential investments within a coherent framework. The overlap of the Just Transition Mechanism with EU budget and with the ETS-financed Modernisation fund will have to be managed therein.

Finally, as suggested earlier, the Green Deal’s risks for employment need not be overstated. Similarly, the alleged “skills challenge” relative to the (considerable) skills supply constraints already present in

⁸⁵ Tagliapietra 2017.

⁸⁶ Alves Dias 2018.

⁸⁷ Incidentally, Tagliapietra 2017 uses a 10 000 EUR estimate for financial support per worker: that would imply 1 155 000 000 EUR for Poland if its entire coal mining labour force would be dislocated.

the baseline scenario, is modest at best⁸⁸. Recycling revenue from, say, the auctioning of emissions allowances or carbon taxes into social policies provide a more efficient response to improve welfare. One would have expected the Just Transition Mechanism to tackle these issues and provide for interregional or intrapopulation income transfers to soften adverse distributional effects of climate change mitigation and/or adaptation during the transition. Ultimately, the consensus among analysts and researchers is all but unanimous that the distortionary, perhaps in part regressive nature of environmental policy in the form of carbon taxes, emissions trading or command-and-control regulation, is largely mitigated or even reversed by the progressive nature of the benefits of climate policy⁸⁹. Countries with a high social cost of carbon are also the countries that stand to gain most from mitigation and adaptation.

⁸⁸ Cambridge Econometrics 2018.

⁸⁹ For a recent inter-country analysis within the European Union, we refer to Parry 2020.

5. EXPORTING DECARBONISATION

KEY FINDINGS

The risk that production relocates as a result of differential climate change-related taxes or subsidies is referred to as ‘carbon leakage.’ With carbon prices expected to ratchet up – or caps being lowered – in the coming decades, this risk may intensify but is arguably quite low today.

Any country or region that unilaterally imposes stricter measures in the form of carbon pricing or regulation, exposes not only its economy but its ecological environment as well. If a region reduces its demand for fossil fuels, international oil and gas and coal prices will tend to decrease, incentivising less virtuous regions to use more of these inputs. A green paradox arises: the expected downward trend in fossil fuel prices incites fossil-fuel companies to increase their production today – to mitigate the risk of these oil and gas or coal reserves ending up as stranded assets.

A truly global, comprehensive system of emissions trading would effectively combine the consuming countries into a single global buyer and coerce the fossil fuel reserve owners to follow a sustainable extraction path. The mutual gains from trade on which the WTO is based may provide a solid foundation for this repeated game. Repeated games typically involve strategies where one cooperates as long as everybody else cooperates.

The sanction for non-cooperation most discussed is a Border Carbon Adjustment – with rebates to Member State exporters. Although the idea of creating a level-playing field by ‘counting carbon’ is attractive, its impact on multiple interrelated domains merit careful assessment. From an economic point of view, imputing emissions only makes sense when the entire value chain has been considered, including implicit carbon pricing in regulation. Secondly, the WTO essentially requires that imported products are not treated worse than domestic products are.

From a political point of view, a European BCA might be considered as extraterritorial overreach, implying extensive negotiations and, at worst, retaliatory measures from other trading blocs. One should perhaps not underestimate the power of the “Brussels Effect” then. The aim of nudging the rest of the world towards decarbonisation is probably best effected already through the Single Market’s elevated environmental standards.

There is a particular use of a BCA that may warrant further attention. Temporary import tariffs in general are a preferred instrument of defence to protect infant industries. The key to success then is, as we already discussed in the context of industrial strategy in general, the ability to resolve as much uncertainty as possible – i.e. ‘learning’ – in the least possible time.

5.1. Carbon leakage, the green paradox and border carbon adjustments

Trade is no longer exclusively determined by comparative advantage, where static differences among countries in technology or human capital decide whether a country exports machines and imports food produce or vice versa forever. Increasingly, trade takes place between similar countries and often within industries – whereby a country both exports and imports clothes for instance. Specialisation is key. Producers try and cater to the ever-increasing appetite for variety among consumers. The more successful they become in exploiting a particular niche, the more producers will be able to capture the

benefits of economies of scale⁹⁰. The consequence is that core regions where production is concentrated will enjoy the profits of increasing returns, attracting even more production, enlarging product variety and lowering costs, increasing wages, increasing knowledge spill-overs, etcetera. In sum, “new” trade, as we saw in innovation, is a cumulative process.

The cumulative nature of trade patterns is a double-edged sword. If innovation or any other demand or supply shock tilts the scales to the other side, the cumulative process runs away from you. The question therefore is to what extent climate change and climate action such as taxing carbon could push, say, production costs beyond a threshold that would trigger a cumulative process in the other direction, disrupting the economic geography. The risk that production relocates as a result of differential climate change-related taxes or subsidies is referred to as ‘carbon leakage.’ With carbon prices expected to ratchet up – or caps being lowered – in the coming decades, this risk may intensify from the arguably quite low levels of leakage today. A country would then not only lose in terms of employment and export potential, society’s perception of climate adaptation and mitigation policies may quickly deteriorate as well.

Furthermore, any country or region that would unilaterally impose stricter measures in the form of carbon pricing or regulation, exposes not only its economy but its ecological environment as well. The economic gains from trade migrate elsewhere whereas ecologically nothing has changed by the displacement of harmful production. If a region reduces its demand for fossil fuels, or augments the domestic prices through taxation for example, international oil and gas and coal prices will tend to decrease, incentivising less virtuous regions to use more of these inputs. A green paradox⁹¹ arises: the expected downward trend in fossil fuel prices as a result of credible commitments such as Europe’s to use more renewable energy sources incites fossil-fuel companies to increase their production today – to mitigate the risk of these oil and gas or coal reserves ending up as stranded assets. The ‘sinner countries’ benefit from burning not only the fossil fuels that the virtuous countries do not but also the ever faster extracted fossil fuels as a result of the lower price expectations. In other words, reducing the demand for fossil fuels on the one hand lowers the appetite for suppliers to extract more (as prices are low) yet on the other hand induces these suppliers to extract more (as future prices are expected to be even lower). Which of these two effects prevails, determines whether reducing demand effectively mitigates the greenhouse effect.

A truly global, comprehensive system of emissions trading would effectively combine the consuming countries into a single global buyer and coerce the fossil fuel reserve owners to follow a sustainable extraction path. Ostrom’s design principles⁹² we discussed earlier provide a basis for more policy coordination on the international scene as well to create a level-playing field and incentivise the world’s countries and regions to commit to such a global governance system.

Getting as many countries as possible to participate in an emissions system is, of course, crucial to its success. Because countries or regions are quite different in terms of their energy use, social fabric and environmental context, a naïve price negotiation is a non-starter. The outcome of a global non-cooperative game would only lead to emissions being priced to a fraction of the first-best price⁹³. Reputation results from a shared past and shared future, in a repeated game.

The mutual gains from trade on which the WTO is based may provide a solid foundation for this repeated game. The World Trade Organisation would represent a natural habitat for such a governance

⁹⁰ Krugman 1979, 1980, 1991.

⁹¹ Sinn 2008.

⁹² Ostrom 1990.

⁹³ Nordhaus 2015.

system⁹⁴, a largely self-regulating body of countries, albeit with a relatively high threshold for changing the rules. Repeated games typically involve strategies where one cooperates as long as everybody else cooperates. That does not preclude the system from investing in monitoring and sanctioning, carried out either by the members themselves or by someone who is accountable to the members. Non-compliance would resemble dumping then, in a sense. Countries suffering a shortfall of certificates could be treated as increasing their sovereign debt⁹⁵.

A Europe-like subsidiarity principle could create the potential for layers that accommodate the different nature of issues to be resolved by the various members in the governance system and allow for participation to enhance accountability. Such subsidiarity need not be defined exclusively based on nations; but could extend to cities as well.

In practice, the system may require some compensatory mechanism to get countries on board. Between member states with large and growing economies, member states where emissions reductions are expensive and potentially member states that might gain from global warming, incentives to commit to a trading system vary widely. High-polluters would then transfer permits or funds to below-average emitters⁹⁶. In cap-and-trade systems, such transfers typically take the form of free emissions permits⁹⁷ in so-called grandfathering clauses. The practice is widely considered regressive, benefiting emitter firms at the expense of (lower-income) households. Without appropriate control and monitoring, opportunities for underreporting fossil fuel use abound.

The sanction most discussed is a Border Carbon Adjustment – with rebates to Member State exporters – or punitive border taxes in general⁹⁸. Although the idea of creating a level-playing field by ‘counting carbon’ is attractive, the Commission’s forthcoming Impact Assessment of an adjustment mechanism will need to integrate the different and not easily separable nor commensurable dimensions of carbon leakage. From an environmental perspective, carbon leakage centres on the increase of emissions outside of the EU relative to the decrease in emissions within the EU. Its economic aspects include employment as well as competitiveness. A socially fair adjustment mechanism furthermore must steer clear from imposing disproportional burdens of a tax on lower-income or otherwise vulnerable groups.

Issues that could be addressed include:

- How do the various implementation options – ranging from consumption taxes over import duties to non-tariff barriers, and the manner in which carbon content is assessed in each of these options in particular – trade off efficiency, equity and/or ease of implementation?
- Does one need to impute emissions along the entire value chain of a good or service, including implicit carbon pricing in regulation, to establish a level-playing field?

⁹⁴ It is perhaps interesting that the 1994 Marrakesh formulation of the World Trade Organization establishment starts with the same wording as the 1947 GATT text “Recognizing that their relations in the field of trade and economic endeavour should be conducted with a view to raising standards of living [...] except that the phrase “developing the full use of the resources of the world” made way for “allowing for the optimal use of the world’s resources in accordance with the objective of sustainable development, seeking both to protect and preserve the environment and to enhance the means for doing so in a manner consistent with their respective needs and concerns at different levels of economic development [...]”.

⁹⁵ Tirole 2016.

⁹⁶ Cramton 2015, Weitzman 2015.

⁹⁷ Ellerman 2000, 2003.

⁹⁸ Nordhaus 2015.

- How should one measure the BCA's effectiveness in discouraging delocalization and/or the substitution of domestic production with non-EU production in the tradable sectors and their value chains⁹⁹?
- How does any adjustment mechanism interact with other measures to mitigate carbon leakage such as the allowance-against-benchmark policy in the EU-ETS or the "export" of EU standards?
- How regressive is a border carbon adjustment in the sense of disproportionately impacting goods and services consumed relatively more by lower-income or otherwise vulnerable segments of the population – such as energy or food?
- Does the WTO requirement that imported products are not treated worse than domestic products are, mean that any BCA cannot be higher than the carbon tax effectively paid on comparable products in the European Union? Does the EU-ETS price constitute a tax? And how would the implicit carbon prices of Europe's environmental standards be considered in this respect? The effectiveness of the adjustment mechanism to contain carbon leakage will furthermore depend on keeping the tariff in synch with carbon pricing and evolving best-practice benchmarks: does such imply repeated negotiation rounds within the WTO?
- To what extent does any possible rebound effect of EU's Green Deal, leading "sinner" countries to use more fossil fuels because of a fall in prices, affect the border adjustment mechanism? More generally, how would the adjustment mechanism lead to a differential treatment of third countries, a priori favouring those less reliant on fossil fuels and actively urging other countries to decarbonize – with all of the political and distributional considerations involved?
- Is there a political risk that a unilateral European Border Carbon Adjustment might be considered as extraterritorial overreach, implying extensive negotiations with and, at worst, retaliatory measures from other trading blocs?

In fact, border taxes are best considered a second-best approximation to the first-best solution of a global carbon tax combined with transfer mechanisms to fairly distribute its burden. As in any second-best situation, a proper evaluation will require a comprehensive approach, considering the impact on multiple interrelated domains. Such impact assessment is further complicated by the fact that the implied behavioural changes – producers delocalizing or switching to other inputs, consumers being variously sensitive to price incentives, other trading blocs retaliating – are all but impossible to predict or model *ex ante*.

One should perhaps not underestimate the power of the "Brussels Effect"¹⁰⁰ then. The aim of nudging the rest of the world towards decarbonisation is probably best effected already through the Single Market's elevated environmental standards.

5.2. Domestic-before-trade policies

Trade and taxation theory holds that the best option is almost always to directly target a domestic distortion rather than manipulate cross-border flows – unless the country or region is so large that its (domestic) policies can steer international prices and decisions. Again in this second-best context¹⁰¹,

⁹⁹ A particularly complex consequence of import tariffs is trade deviation through the value chain. The recent US tariffs on steel and aluminium did lower steel imports per se but at the expense of an increase in imports of steel nails or aluminium wire, and thus at the expense again of domestic production. Extending the protectionist measures to these other links in the value chain exposes policy to additional regulatory capture. The example highlights the difficulty in defining the covered sectors of any adjustment mechanism.

¹⁰⁰ Bradford, forthcoming.

¹⁰¹ We remark that the term "second-best" was actually coined in the context of trade policies affecting welfare (Meade 1955).

long-standing principles may be quite counterintuitive and require some explanation. Removing a tariff on some import for example – creating a customs union – may actually lower global economic efficiency¹⁰². When a member country of the customs union now diverts trade to another member country whereas an external country would still have been the cheaper source, even taking into account the tariff, the economy is worse off.

The domestic impact of a Border Carbon Adjustment ought to be assessed then in comparison with directly taxing consumption of carbon-intensive goods and services at the same rate. Consumer surplus will be lower by a comparable amount: the BCA tariff and the tax raise consumer prices to the same level. But domestic producers of the targeted goods are unaffected if their price remains the same. Fiscal revenue is larger than government would collect from the tariff to the extent that consumption is greater than imports. The net economic efficiency loss then is equal to the reduction of consumer surplus minus the gain in tax revenue, so the loss in the tax case is smaller than in the tariff case. In other words, the cost in efficiency of gaining the same environmental benefit is lower when a consumption tax is levied rather than when a tariff is imposed. The tariff in fact causes a loss to both consumer and producer surplus whereas the tax only implies a consumption efficiency loss.

Note that the tariff itself may well have improved domestic welfare but the gain is more modest than with a consumption tax. Note too that the public may disapprove of the consumption tax because domestic production of carbon-intensive goods is *not* reduced despite the net effect being an overall welfare gain. The additional fiscal revenue could be used then to compensate consumers in the form of rebates. If for instance the government would return the tax revenue uniformly across all households, it would effectively redistribute consumer surplus from heavy users of carbon-intensive goods and services to below-average consumers.

There is a particular use of a BCA that may warrant further attention. Temporary import tariffs in general are a preferred instrument of defense to protect infant industries. Firms in the early stage of their development may lack the economies of scale or the knowhow to produce let alone compete with (foreign) incumbents at prevailing world prices. Although reviled as protectionist and inefficient, infant industry protection was considered a mainstay of 20th century industrial policy in Asia (as part of the 'export-led strategies' of the Tigers) and Latin America (in the guise of the distinctly less successful 'import substitution'), and the United States or Germany in the 19th century.

The controversy around infant industry protection to a large extent derives from its dynamics, in particular the ability to generate knowledge spill-overs sufficiently fast. If the infant industry can compete at the original 'free trade' price in a later period, the tariff can again be removed. The tariff policy will have generated net welfare gains when the new producer surplus and potential spill-overs to other domestic industries in later periods outweigh the deadweight loss during the period in which the import tariff was effective. The key to success then is, as we already discussed in the context of industrial strategy in general, the ability to resolve as much uncertainty as possible – i.e. 'learning' – in the least possible time.

Policymakers need to monitor this trade-off and terminate policy if results are not satisfactory. That efficiency gains – learning effects and spill-overs – may require time to develop complicates the evaluation. On the other hand, letting protection linger too long blunts the incentive for domestic producers to improve and incur investments in innovation and training while they are sheltered from international competition. In a sense then, infant industry protection is self-defeating in the absence of strict and knowledgeable supervision. But how can a government ascertain which domestic industries

¹⁰² Viner 1950.

are the perfect candidates for spill-overs? Or whether learning effects are effectively taking place in these industries? And how much protection is appropriate for what period of time? We recommend considering these questions as well in the Commission's forthcoming Impact Assessment of its planned adjustment mechanism.

Of course, this trade policy is again second-best to a direct subsidy targeted at generating early learning effects and spill-overs. By raising domestic producer prices by the amount of the subsidy, government – actually, taxpayers – will allow domestic production to occur, albeit at a smaller aggregate loss to society compared with a tariff. "In the second-best setting of green growth, what ultimately matters is whether the global supply of green technologies expands (good) or contracts (bad). From a global standpoint, it would be far better if national competitiveness concerns were to lead to a subsidy war than a tariff war. The former expands the global supply of clean technologies while the latter restricts it"¹⁰³.

¹⁰³ Rodrik 2014.

6. FINANCIAL STABILITY IN A NON-EQUILIBRIUM WORLD

KEY FINDINGS

“Mitigation risk — stranded assets — is the price of success in the fight against global warming. Physical risk is the price of failure.” The paradox is that policymakers rely to large extent on the financial markets to reallocate resources to a low-carbon future, whereas from an accounting (and often regulatory) perspective, these financial actors have no incentive to do so in view of the risk of impairing their balance sheet.

Although oil & gas reserves have received most attention, in fact the largest asset class at the risk – in fact, certainty – of stranding are residential buildings. Stranded assets currently make up a considerable part of the solvability of specific firms – and nations – without which these entities paradoxically may lack the resources to transition to a low-carbon business model.

Again, it is the timing of the roadmaps that is decisive: too long a delay in climate action increases the risk of an abrupt shock to the financial system. To a large extent, every measure proposed by the European Commission and its Expert Groups essentially comes down to promoting “long-termism”. When carbon prices rise too fast, the socio-economic system may become dislocated and the central banks may in extremis be asked to “save” stranded assets to mitigate the shock to the system. When they do not rise fast enough, climate change may lead to damages exceeding regions’ resilience in which a central bank will again be called upon as a “lender of last resort”.

The debate will flare up again whether in particular central banks have an active role to play in these complex systems, through fiscal-cum-monetary-cum-prudential policy, or that they need to stand back as a watchful observer and regulator. At the very least, the drive to promote sustainable investment suggests an active system-wide reallocation towards “green” investments that will need to be carefully monitored - by those same central banks.

6.1. Stranded assets – the price of success

“Mitigation risk — stranded assets — is the price of success in the fight against global warming. Physical risk is the price of failure”¹⁰⁴. And with failure comes the search for someone to pay for these liabilities, an additional “broad channel through which climate change can affect financial stability”¹⁰⁵.

The long-term nature of climate change also shows up on the balance sheet of asset owners and their insurers. “Discovered resources” recorded on an oil & gas company’s balance sheet may at some point no longer reflect cash flow generation potential, becoming stranded assets. About one third of oil reserves, one half of gas reserves and at least 80% of known coal reserves cannot be burnt and need to be kept in the ground¹⁰⁶. European banks’ direct exposure to the fossil fuel sector is quite limited¹⁰⁷ so there is no outspoken direct risk to financial stability from stranding fossil reserves. But we learnt from

¹⁰⁴ Buiter 2019.

¹⁰⁵ Carney 2015.

¹⁰⁶ Bos 2019. McGlade 2015.

¹⁰⁷ Battiston 2017. Long-term investors such as pension funds are relatively more at risk.

the financial crisis that intra-financial-sector exposures might wreak havoc when individual institutions are heavily impacted and ripple effects reverberate through the sector.

What Mr. Carney's quote makes clear, is the incentive design issue with fossil reserves: policymakers such as the European Commission rely to large extent on the financial markets to reallocate resources to a low-carbon future, whereas from an accounting (and often regulatory) perspective, these financial actors have no incentive to do so in view of the risk of impairing their balance sheet. As long as governments continue to dole out massive subsidies to fossil-fuel sectors and are only reluctant (or unable) to propose a credible consistent long-term roadmap, it is difficult to see why the financial markets would align themselves to the political vision.

Again, it is the timing of the roadmaps that is decisive: too long a delay in climate action increases the risk of an abrupt shock to the (financial) system. Financial stability hinges on the transparency of assets (and liabilities) on the balance sheet of households, firms, governments and the financial institutions themselves. In order for their balance sheets to fairly reflect the current value of their assets, corporations have to engage in regular impairment tests to see whether the carrying value of the assets is aligned with their value in use (or sales value). If not, assets must be written down.

Fiscal authorities have experimented in the past¹⁰⁸ with accelerated depreciation, a measure that allows investors, especially corporations, to depreciate assets such as fossil fuel technology and reserves threatened with obsolescence at a fast pace, in the process giving rise to deferred taxes. If, say, a coal-fired plant is retired before the term of its useful life – and depreciation period – accelerated depreciation is to some extent forced upon the asset owner.

Ultimately, accelerated depreciation aims to fiscally influence the trade-off between the (elasticity of) higher expected rate of return versus a lower cost of capital. Because the bottom-line result, and consequently whether in fact new investments in green(er) technology are incentivised by allowing accelerated depreciation of brown or grey technology, depends on corporate profit or income tax rates, consistency in fiscal policy is decisive. The critical phase is when depreciation deductions fall, and taxable income rises. When marginal rates are simultaneously expected to rise, firms, especially smaller firms, will feel reluctant to adopt accelerated depreciation. Inflation may, in addition, interfere with the scheme.

Finally, the nature of most of these firms complicates matters. Because utilities are rigorously regulated, the added expense of accelerated depreciation in the case of an unrecovered investment must be compensated for somewhere, e.g. from consumers in paying higher rates. American utility Xcel recently saw its Colorado Energy Plan almost rejected by its regulator, unwilling to increase rates to account for the accelerated depreciation of retiring coal-fired plants 10 years ahead of schedule. The regulator was unconvinced that the renewable energy generators that substituted for the coal plants would not generate sufficient savings to compensate for the accelerated depreciation expense. Alternatively, the reduced taxes paid as a result of accelerated depreciation could be considered as an increase in earnings, which must be translated in lower rates, in effect transferring the fiscal benefits to the current customers.

The central question is whether the investment transitioning from fossil-fuel to green technology would have occurred irrespective of whether the fiscal authorities would allow accelerated depreciation. That question cannot be homogeneously answered across all candidates: how to qualify maintenance expenditures and repairs versus "new" investments, why would long-term investments by large (balance sheet) companies be favoured versus short-term investments by SMEs, or incumbent

¹⁰⁸ Koowattanatianchai 2019.

firms relative to young firms that may not have significant accumulated income, can renters and owners of buildings share the benefits, etcetera. Importantly, if funds are allocated to investments that would qualify for accelerated depreciation at the expense of investments that would actually make more sense economically, incentives are badly designed.

The roadmap for emissions reduction – or the lack thereof – will further determine whether negative emissions technologies are called for, with decisive impact on stranding oil and gas reserves. Oil and gas companies could potentially reinvent themselves if technologies to capture and store carbon extend their useful life.

Note that stranded assets give rise to a final paradox as well. These assets currently make up a considerable part of the solvability of firms – and nations – without which these entities paradoxically may lack the resources to transition to a low-carbon business model. As oil and gas reserves – and their corresponding extraction costs – are highly concentrated across the globe, it will depend on these individual countries' political and socio-economic preferences, the abatement options available at reasonable costs, to identify which resources will actually strand. Stranding coal in view of the recent additions in Asia might disrupt global value chains.

Although oil & gas reserves have received most attention, in fact the largest asset class at the risk – in fact, certainty – of stranding are residential buildings¹⁰⁹. The overwhelming majority of homes in 2050's Europe already exist today and all but a few percent will conform to the 2050 expected standards of energy efficiency and energy generation, absent monumental efforts – more than a doubling – in renovation rates, switching to renewable heating, and the use of smart infrastructure and appliances. Assets may be stranded due to many reasons¹¹⁰: the depletion of the natural resources on which they depend, obsolescence of technology, unviable prices, regulatory change or mass resistance. In addition to these assets losing their value, their owners may be liable for decommissioning them, restoring the environment to its previous state, paying punitive damages or compensating victims.

Governments could step in to compensate stakeholders, such as Germany's nuclear energy companies or the displaced workers in the Just Transition Mechanism, or the *Reducing Emissions from Deforestation and Forest Degradation* mechanism where developing countries claim compensation for the opportunity costs of stranding their forest resources. Here too, the credible commitment to compensate, or the credible threat certainly not to, comes into play.

For these reasons, scenario-analysis based on detailed socio-economic baselines, coupled with climate change and sustainable development modules and detailed sustainable action roadmaps is the appropriate policy tool. The ESSPs that were proposed in earlier chapters would provide the appropriate framework to do so.

6.2. The dynamics of “long-termism” for macroprudential supervision

The European Commission's Action Plan to finance sustainable and inclusive growth¹¹¹ aims to mobilise and reorient capital flows towards the longer-term investments required to “manage financial risks stemming from climate change, resource depletion, environmental degradation and social issues.” The Commission sees its main mission in convincing investors that taking these longer-term risks into account “makes economic sense and does not necessarily lead to lower returns for investors.” To a large

¹⁰⁹ IRENA 2018.

¹¹⁰ Bos 2019.

¹¹¹ European Commission 2018a.

extent, every measure proposed by the European Commission and its Expert Groups essentially come down to promoting “long-termism”, as exemplified in the Regulation of November 2019¹¹²:

- Disclosure requirements must make the exposure of securities issuers to these risks “fully transparent”¹¹³;
- Sustainable investment benchmarks, standards, labels and credit ratings are to foster performance measurement relative to the long-term risks; and
- The integration of SDG-objectives and indicators in prudential regulation such as Solvency II, IORP II, UCITS, AIFMD, MiFID II or IDD must make sure that investors can convey their preference for “environmentally sustainable” investments to their advisors and assess their portfolio’s carbon footprint.

Closer scrutiny of the Action Plan and the follow-on work suggests a dichotomy between arguably easily quantified financial (and to some extent physicochemical) variables and the much more elusive social and other ecological issues tied up with climate action. The High-Level Expert Group on Sustainable Finance¹¹⁴ calls to end “the misuse of natural capital” although the EU Taxonomy – another initiative of the Expert Group – nowhere refers to the environmental accounting undertaken by the European Environment Agency and implied in the Common International Classification of Ecosystem Services. The High-Level Expert Group further adds that “EU legislation does not yet have a clear and standardised definition of social factors and social risks.”

What is missing, is a long-term risk assessment, not only with respect to the social issues (“Attention should be paid to how forward-looking social risk analyses could be developed, particularly in relation to the trend of growing inequalities”, dicit the High-Level Group) but also the co-externalities of unsustainable natural resources use in addition to greenhouse gas emissions, notably the preservation and strengthening of ecosystem services such as access to water, sustainable land use, air quality and biodiversity.

We believe that the mismatch between readily quantifiable and more system-wide properties is that in particular the inclusion of natural capital in the equation introduces a fundamental asymmetry between inherently reversible, fungible, individualised money transactions and sometimes irreversible, unique, systemic changes in natural capital. Any accounting for natural capital or ecosystem services that ignores this asymmetry is missing the point. There is a context- and path-dependent aspect to natural capital (and socially inclusive aspects) that is absent from a purely transactional view: “[f]or instance, the depletion of natural capital in a warming world cannot be compensated by higher income”¹¹⁵.

But even within a financial context, climate change presents a number of challenges to macroprudential supervision and monetary policy that relates to the dynamics within those Extended Shared Socio-economic Pathways. The crux is that in contrast with “traditional” risk management, climate risk management and the corresponding macroprudential regulation and supervision cannot simply build on existing historical data. Instead of probability distributions, multiple possible worlds must be considered. These very long-term forward-looking scenarios are highly non-linear, in extremis punctured with high-impact low-probability events at critical but undetermined tipping points. Climate risks are intertwined with the socio-economic behavioural changes and political choices that

¹¹² European Parliament 2019b.

¹¹³ Network for Greening the Financial System 2019, Task Force on Climate-related Financial Disclosures 2019.

¹¹⁴ High-Level Expert Group on Sustainable Finance 2018.

¹¹⁵ Bolton 2020.

feed back to biogeochemical processes, the outcomes of which again elicit socio-economic responses, giving rise to a non-equilibrium approach with path dependency – where what took place in previous time steps continues to impact future outcomes.

When carbon prices rise too fast, the socio-economic system may become dislocated and the central banks may in extremis be asked to “save” stranded assets to mitigate the shock to the system. When they do not rise fast enough, climate change may lead to damages exceeding regions’ resilience in which a central bank will again be called upon as a “lender of last resort”. A low-carbon future entails more transition risk, a “Hothouse World” will carry (much) more physical risk.

As with other complex coordination problems, individual “rational” decisions may not turn out to be socially optimal in this context, requiring a truly “macro”prudential supervision to safeguard against systemic risks. 70% of climate-related losses are not insured¹¹⁶ for example, threatening the solvency of households and corporations, in addition to the rise in insured losses with insurers and reinsurers.

The debate will flare up again whether in particular central banks have an active role to play in these complex systems, through fiscal-cum-monetary-cum-prudential policy, or that they need to stand back as a watchful observer and regulator. We point to the Technical Expert Group’s recommendation that the European System of Central Banks and the members of the Network for Greening the Financial System “express a preference for EU Green Bonds when purchasing green bonds” – a macro-allocation advice the effects will need to be carefully monitored – by those same central banks. If green bonds effectively replace the safe assets that proved elusive in the credit crisis as eligible collateral, must central banks then engage in “green” Quantitative Easing? If governments would pursue (deficit) public investment programmes to stimulate climate-neutrality, what would then be the extent and nature of “support” of fiscal policy by monetary policy – if only by setting accommodative interest rates?

¹¹⁶ IAIS 2018.

7. CONCLUSIONS AND FINAL REMARKS

In this paper we have explored some of the Green Deal's growth, financial and regulatory challenges. This closing chapter wants to briefly list some of the key take-aways:

- The Green Deal would benefit from a comprehensive narrative – an extended Shared Socio-economic Pathway in the parlance of the current climate research literature – that goes beyond the technological scenarios from *A Clean Planet for all*;

These pathways represent families of similar trajectories, leaving sufficient degrees of freedom for individual actors to carve a path in the shared general direction. They allow for the discussion of political-ideological choices next to socio-economic, environmental and technological evolutions. They provide the framework to assess 'system-wide' indicators, in particular those related to the Sustainable Development Goals that cannot be evaluated on an activity-per-activity basis such as that of the proposed Taxonomy. Most importantly, they offer a shared narrative in which individual climate actions can be situated in time, where trade-offs between the various social, environmental and economic objectives can be transparently made, and through which awareness and public support can be raised.

- The four key growth drivers of the Green Deal are to a large extent interrelated and must be actively managed accordingly;

The electrification of power generation, with its intertwined need for flexible grid infrastructure and the replacement of fossil fuels with renewable energy sources; the electrification and coupling of the construction, industrial and transport sectors, incentivised to maximally reduce emissions; a more efficient (effective) use of energy and natural resources, in particular materials; and measures to promote safeguarding and strengthening of natural sinks cannot be considered as separate tasks. They will require active management that steers clear of trying to 'pick the winners' but focuses on relaxing the constraints that may hinder social, environmental and economic progress. The language of financial options is an apt description of best practice industrial policy: maximal resolution of uncertainty in the minimum possible time is the key driver propelling the transformation along its pathway(s).

- The "green investment gap" can be bridged, taking into account the displacement of fossil fuel subsidies, and the net benefits (to health care for example) of a more sustainable environment;

The annual additional investment need of 250-300 billion EUR is comparable to the amount of fossil fuel subsidies in the European Union *and* to the net benefits of a more sustainable environment, in particular the health care savings as a result of decreased pollution of air, land and water.

- To finance the Green Deal, the key challenge is matching supply with demand. This largely is a question of appropriately 'slicing and dicing' the risks inherent in the Green Deal investments;

If the absolute size of the green investment gap is surmountable and demand is high, it is the appropriate supply of eligible investment vehicles that must be the objective of the European Sustainable Investment Plan. The various risks in environmentally sustainable activities – from development over building to operating renewable energy facilities for example – suggest that investors' appetite could be catered to by carving out homogeneous risk classes out of individual investment projects, aggregating these by means of careful securitisation and synchronising their timing to the Green Deal roadmap.

- Environmental taxation must be accompanied with 'revenue recycling' to enhance acceptability;

European regulation and legislation, including Member States' fiscal stance towards environmental taxation, could be reformed where necessary to ensure that taxpayers understand how and where carbon tax revenue is 'recycled' into measures that mitigate or eliminate distortions – i.e. other taxes – elsewhere: lowering labour taxation, correcting for unintended distributional effects, targeting lower-income households or regions. Combining taxation with regulation and recycling has been shown to enhance fiscal acceptability and help achieve the coupled objectives of social fairness, environmental sustainability and economic efficiency.

- The 'Brussels Effect', the Union de facto exporting its elevated environmental standards, should not be underestimated. The explicit alternative, a Border Carbon Adjustment, merits a careful impact assessment from an environmental, economic, social and political point of view;

Absent a global governance system – a world-wide emissions trading scheme – two not unrelated international risks arise: the possibility that manufacturers and service providers will relocate to less stringent regions (known as carbon leakage) and the possibility that fossil-fuel companies will accelerate extraction to avoid stranded assets (known as the green paradox). The attractiveness of the Single Market de facto exports the European Union's world-leading standards. The impact of explicitly imposing a Border Carbon Adjustment in order to create a level-playing field must be carefully assessed, considering its effects in multiple interrelated domains. Economically, the question is one of implementation and may be overcome. The political challenges – the accusation of extraterritorial overreach, and the possible threat of retaliation by other trading blocs – must be evaluated relative to the potential risk of carbon leakage.

- The timing of climate change introduces a specific risk to macro- and financial stability. Too slow climate action gives rise to physical risk; too fast may lead to stranded assets. Central banks in particular will need to make clear to what extent they are actively involved – for example promoting "green" bonds – or rather act as a passive watchful observer and regulator.

The pace of the pathways finally will largely determine the risks to macro-economic and financial stability. Too fast a transition to a climate-neutral Europe may shock the financial system with stranded assets, too slow risks damages to exceed regions' resilience – again calling on central banks as a "lender of last resort." Promoting transparency through climate-related disclosures and in particular natural capital accounting comes with a non-trivial complication that tends to be underestimated. There exists a fundamental asymmetry between inherently reversible, fungible, individualised money transactions and the often irreversible, unique, systemic changes in "natural" capital. Simply stated, one cannot simply add or exchange natural and financial capital. That makes evaluating the trade-off between the two essentially incommensurable 'worlds' a delicate exercise. On the other hand, keeping separate tabs on the economy or the financial system versus the social and natural environment – as in the naive approach to ESG investing or sustainable development – decouples the links between the economic, environmental and social objectives of the Green Deal. The comprehensive pathways proposed earlier attempt to capture these links and trade-offs in a consistent dynamic framework.

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The aim of this study is to critically assess the proposed Green Deal's growth, financing and regulatory challenges. The study discusses the need for extended Shared Socio-economic Pathways. It examines the key growth drivers of the Green Deal and the green investment gap, the optimal mix of taxation and command-and-control measures, trade and competition policy and the implications for macroprudential supervision.

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