NET ZERO 2050

Industrial Transformation 2050

Towards an Industrial strategy for a Climate Neutral Europe

INSTITUTE FOR EUROPEAN STUDIES

In collaboration with

ECOS

E3G

IDDRI

DIW BERLIN

About Industrial Transformation 2050

This report has been commissioned by the European Climate Foundation. It is part of the Industrial Transformation 2050 project and the Net-Zero 2050 series, an initiative of the European Climate Foundation with contributions from a consortium of experts and organisations.

The mission of Industrial Transformation 2050 is to co-develop, together with basic manufacturing and manufacturing industry and other stakeholders, pathways and policy options to enable a net-zero heavy industry in Europe by 2050, in line with the objectives of the Paris Agreement, while strengthening industrial competitiveness and the EU's overall economic development and performance.

The objective of Net-Zero 2050 is to start building a vision and evidence base for the transition to net zero emission societies in Europe and beyond, by mid-century at the latest. Reports in the series seek to enhance understanding of the implications and opportunities of moving to climate neutrality across the power, industry, buildings, transport, agriculture and forestry sectors; to shed light on some of the near-term choices and actions needed to reach this goal, and to provide a basis for discussion and engagement with stakeholders and policymakers.

Publication Details

Authors:
Tomas Wyns, IES-VUB
Gauri Khandekar, IES-VUB
Matilda Axelson, IES-VUB
Oliver Sartor, IDDRI
Karsten Neuhoff, DiW

Please quote this report as:
Wyns et. al., (2019), *Industrial Transformation 2050 – Towards an Industrial Strategy for a Climate Neutral Europe*, IES. Available at ies.be

The authors extend their sincere gratitude to all the experts and stakeholders who have participated in the process of creating this report and have shared their expert input with us. The views expressed in this publication are those of the authors alone.

About the IES

The Institute for European Studies (IES) at the Vrije Universiteit Brussel (VUB) is an academic Jean Monnet Centre of Excellence and a policy think tank that focuses on the European Union in an international setting. The Institute advances academic education and research in various disciplines, and provides services to policy-makers, scholars, stakeholders and the general public.

Table of Contents

1. EXECUTIVE SUMMARY 6

2. INTRODUCTION 17

3. CHALLENGES ON THE PATHWAYS TO A CLIMATE NEUTRAL INDUSTRY 19

3.1. INTRODUCTION 19
3.2. INNOVATION GAPS FROM BASIC R&D TO DEPLOYMENT OF NEW TECHNOLOGIES 20
3.3. AN INSUFFICIENT CIRCULAR AND MATERIALS EFFICIENT ECONOMY 21
3.4. BARRIERS TO MARKET ENTRY FOR LOW-CO_2 SOLUTIONS 23
3.5. LACK OF STREAMLINING BETWEEN THE ENERGY AND INDUSTRIAL TRANSITION TO CLIMATE NEUTRALITY AND INFRASTRUCTURE NEEDS FOR THE TRANSITION 23
3.6. POSSIBLE BOTTLENECKS IN SCALING UP OF INVESTMENTS AND THE RISK OF HIGH-CARBON LOCK-IN 24
3.7. THE COMPLEXITY OF INTEGRATING DIFFERENT TYPES OF POLICY INSTRUMENTS, POLICY AREAS AND COMPETENCES INTO A COHESIVE (INDUSTRIAL) STRATEGY 25

4. INNOVATION FOR A CLIMATE NEUTRAL INDUSTRY 27

4.1. INTRODUCTION 27
4.2. OUTSTANDING R&D CHALLENGES 27
4.3. MAKE KEY TECHNOLOGIES READY FOR DEPLOYMENT BY 2030 29
4.4. ENHANCED INNOVATION GOVERNANCE FOR INDUSTRIAL TRANSITION 30

5. AN ENHANCED CIRCULAR ECONOMY PACKAGE FOR BASIC MATERIALS 33

5.1. INTRODUCTION 33
5.2. POLICY OPTIONS FOR ENHANCING THE QUALITY OF RECYCLED MATERIALS TO PRESERVE MATERIAL VALUE 33
5.3. POLICY OPTIONS FOR IMPROVING MATERIAL EFFICIENCY IN MANUFACTURING AND CONSTRUCTION 36
5.4. POLICY OPTIONS FOR RAISING COLLECTION AND RECYCLING RATES OF OLD SCRAP 38

6. CREATING COMPETITIVE LEAD-MARKETS FOR LOW-CO_2 SOLUTIONS 44

6.1. INTRODUCTION 44
6.2. MAKING LOW-CO_2 SOLUTIONS COST COMPETITIVE 44
6.3. THE USE OF STANDARDS TO GAIN MARKET ACCESS 47
6.4. PUBLIC PROCUREMENT AS DRIVER FOR LOW-CO_2 PRODUCTS 49
6.5. COMPETITIVE LOW-CO_2 SOLUTIONS IN A GLOBAL MARKET 51

7. ALIGNING THE ENERGY AND INDUSTRY TRANSITION AND ENABLING INFRASTRUCTURE FOR INDUSTRIAL TRANSITION 57

7.1. ALIGNING THE ENERGY AND INDUSTRY TRANSITION 57
7.2. DEVELOPING INFRASTRUCTURE TO ENABLE THE INDUSTRIAL TRANSITION 58

8. SCALING UP LOW-CO_2 INVESTMENTS AND AVOIDING HIGH-CARBON LOCK-INS 63

8.1. FINANCING TO SCALE UP INVESTMENTS 63
8.2. AVOIDING LOCK-INS AND SUPPORTING BROWNFIELD CONVERSION 64

9. AN INDUSTRIAL STRATEGY FOR CLIMATE NEUTRALITY 67

10. REFERENCES 75

11. LIST OF ABBREVIATIONS 79

ANNEX 1. OVERVIEW TABLE OF POLICY INSTRUMENTS 1

1. EXECUTIVE SUMMARY

This report builds upon the growing momentum for an EU industrial transition to net-zero amongst policy makers[1] and even industry[2], and sketches the blueprint of such an industrial strategy towards climate neutrality. The report is unique in the sense that its industrial strategy proposal transcends the novelty of individual instruments towards a more integrated structure that scrutinizes a broad set of policy instruments and provides ideas for making the whole policy set as tangible as possible. Any industrial strategy can neither be a solely supranational approach nor a solely national one, so the main focus of the report is instruments that are governed at the EU level set within the context of mixed competences on industrial policy.

The policy-side twin of the IT50 Material Economics-led research, this report identified policy options to address key challenges industry faces on the transition path to climate neutrality. It also indicates how this policy set can be integrated into an industrial strategy and what governance instruments could guide to a successful implementation. This report must be seen as a primer to a more detailed and comprehensive debate on the need, design, implementation and governance of a European industrial strategy for climate neutrality. As such, the report is not a *fait accompli* but will be further sophisticated over the course of the next six months to be presented as input to the incoming European Commission and Parliament.

Main challenges towards a climate-neutral industry

The transition to climate neutrality within 30 years for basic materials industry is substantial, especially when taking into account to the long investment cycles of these industries. Furthermore, this transition will happen in a highly competitive and dynamic international environment, with many of the basic materials industries being part of a global market. The transition would also come with benefits of leadership in innovative technologies, products and business models, with new robust efficient and circular value chains, and with the smart integration of the energy and industrial sectors.

For basic materials industries and their value chains to successfully move ahead with such a transition important challenges will first have to be addressed. Based on previous research[3], this report considers six main challenges:

- Innovation gaps from basic R&D towards the deployment of new technologies
- An insufficient circular and materials efficient economy
- Barriers to market entry for low-CO_2 solutions
- Lack of streamlining between the energy and industrial transition to climate neutrality and infrastructure needs for the transition

[1] European Commission, 2018a; In September 2018, the European Commissioned issued a long-term strategy for climate action which not only calls for net-zero by 2050, but also makes an unprecedented link between the energy and industrial transition.
[2] IES, 2018 ; Before that, an alliance of 11 energy intensive industries in Europe had called for an industrial strategy as part of their contribution to the long-term strategy.
[3] Material Economics, 2019; IES, 2018

- Possible bottlenecks in scaling up investments and the risk of high-carbon lock-ins
- The complexity of integrating different types of policy instruments, policy areas and competences into a cohesive (industrial) strategy

First, innovation needs will be substantial. They encompass a broad spectrum ranging from the creation and acceleration of new low-carbon production processes (many of which necessitate fundamentally different modes of production, in addition to novel feedstocks and/or core industrial processes), to innovation that applies not only to the value chains of basic materials industries but also to the energy systems that power them. Furthermore, the most promising low-CO_2 technologies will need to prove industrial scale demonstration by 2030 at the latest. Many of these still remain currently at the pilot or even earlier stage. Adequate innovation support is therefore required to bridge multiple innovation 'valleys of death'. This, in essence, requires rapid policy support to introduce and drive the scale-up of new low-CO_2 production routes and uses of materials.

Second, achieving enhanced levels of circularity and materials efficiency will be vital. Resource efficiency and circular economy measures could almost halve the 530 Mt CO_2/yr emitted by the basic materials sectors in the EU by 2050[4]. Some industrial sectors, like steel, are already well ahead in this area. But important challenges remain in other basic materials industries and their value chains, and in particular, with regard to maintaining the quality of basic materials in recycled product streams. Achieving enhanced levels of circularity while retaining the highest value is possible, but will require a combination of standards, regulations, fiscal measures, and the reduction of material waste, along with greater political ambition. The following key challenges are identified for developing a more resource efficient and circular economy for basic materials in Europe. For one, material value will need to be better retained by avoiding downgrading and contamination. This is critical to enable very high ratios of secondary to primary materials on the market. Secondly, the efficiency of new material use in manufacturing and construction will need to be improved. This is vital for providing the same material value to end consumers without wasting virgin materials. And finally, collection and recycling rates of basic materials have to be increased to ensure that the large, unexploited potentials for collection and recycling are tapped.

Third, low-CO_2 solutions will need to be able to compete with incumbent products from inside and outside the EU. The pathways to net-zero emissions developed by Material Economics[5] that require the use of new low-CO_2 production routes cost 20-30% more for steel and 20-80% for cement and chemicals. The CO_2 price introduced under the EU ETS might, in the short term, not be sufficient enough to cover this price difference and hence level the price between low-CO_2 production routes and the incumbent ones. Furthermore, that CO_2 opportunity cost through the EU ETS might not be fully passed through in product prices (e.g. for competitiveness reasons). Beyond cost-competitiveness other barriers for market access exist, such as existing standards preventing new products entering the market or unused opportunities in procurement and the lack of information on life cycle assessments of products.

[4] Material Economics, 2018
[5] Material Economics, 2019

Fourth, the industrial transition will require streamlining between the same climate neutral transition of the energy system and the development of enabling infrastructure. Higher levels of electrification in industry and the use of new low-CO_2 processes (e.g. H_2 produced via electrolysis) show that significant amounts of green electricity will be required. In a maximum case scenario, an additional 710 TWh per year is required for steel, cement and chemicals. For comparison, all of industry and manufacturing currently uses 1,000 TWh/yr. Achieving climate neutrality both in industry and power production will require proper planning and coordination to allow for such amounts of reliable, competitively priced and green electricity to power the industrial transition. To achieve climate neutrality, the most promising industrial processes will require the timely development and financing of adequate infrastructure (for e.g. H_2 and CO_2). Investments in new infrastructure would require significant amount of capital - to the order of EUR 16-31 Bn per year up to 2050[6]. This is particularly the case for CCS (and to a lesser extent CCU) and processes using low-CO_2 H_2. But also, supply and logistics chains for enhanced the use of biomass resources will need to be developed. Finally, infrastructure will be critical for ensuring the supply of and reliable accessibility to waste streams or secondary raw materials for industry. There currently exists a lack of knowledge and hence paucity of coordinated planning in this area. To avoid a catch-22 situation where investments in new process installations are delayed by lack of infrastructure or vice versa where new infrastructure is not viable due to lack of demand from new processes, a proactive approach will be needed. This includes foreseeing adequate financing instruments.

Fifth, to drive the transition to net-zero emissions for the basic materials, significant volumes of additional investment will be needed (25-60% increase) by basic materials producers[7]. The market and regulatory environment will need to ensure that companies can make those investments with an acceptable level of risk. It is also important that new investments do not lock-in high carbon pathways over their lifetime. Finally, it is likely that the transition will require significant amounts of brownfield conversions, which adds capital needs.

Finally, this transition will have to be carefully and smartly managed across all the before-mentioned challenges. A new governance system for the industrial transition is of order. Any future industrial strategy will essentially cover multiple areas (innovation, finance, energy, waste, competition, state aid, …) and will have to be implemented while taking into account the different and mixed levels of competence in the EU The continued importance of maintaining a competitive industrial base needs to be well aligned across all policy areas.

[6] Ibid.,,

[7] Ibid.,

Instruments to address the transition challenges

Innovation framework for a climate neutral industry

Europe's R&D framework is starting to address the important innovation challenges for industry. In some areas, further basic research will be required but also the large-scale demonstration of low-CO_2 projects, and later on, the incremental innovation to reduce the operational expenditure of new technologies. While Horizon Europe, the Innovation Fund, Invest EU and the Connecting Europe Facility are seen as part of a broader innovation architecture linking basic R&D to piloting, demonstration and later commercialisation; the governance or oversight required to ensure this linkage with the goal to create solid innovation chains is still poor. This is related to the fact that some of these instruments fall under different administrations in the European Commission. Robust and regular monitoring of progress of the state of innovation will be important together with the flexibility to reorient in case certain areas do not progress sufficiently.

Options to enhance innovation governance for industrial transition	Develop an industrial climate neutrality grand challenge under the EU's innovation flagship Horizon Europe in coordination with national industrial R&D programmes to address outstanding basic R&D gaps (in particular with focus or cost reduction of new technologies) both from supply side (process technologies) and demand side (materials efficiency, energy storage). Set up an industrial transition observatory to monitor progress and advice course corrections with regard to development and deployment of industria low-CO_2 innovations.
Options to accelerate technology market readiness by 2030	Development of one-stop-shops where project developers can get easier acces to blended finance. Investment platforms developed under the EFSI can be seen as an interesting example Supporting partial systems or supporting/enabling technologies, which do no mitigate greenhouse gas emissions on their own.

...ced circular economy package for basic materials

Achieving enhanced levels of circularity while retaining the highest value can be possible through a combination of standards, regulations, fiscal measures, and reducing material waste. Policy makers already have an existing framework under the EU's Waste Package and Circular Economy Action Plan. Policies must build on existing policy frameworks (being) established by the EU and by member states where possible while EU directives ...plemented in the strongest possible way. However, there must be the will to go ...ting policy in some cases in order to ensure that all basic materials are sufficiently well addressed and that policies are adequate for the challenge of achieving a GHG-neutral European materials sector. Following the three main challenges, a list of possible policy solutions has been developed.

Circular Economy and materials efficiency instruments	
Options for enhancing the quality of recycled materials to preserve material value	• Requiring recyclers of basic materials to do more precise sorting based on of the quality of materials in the end of life products that they receive. • Setting recycling quality targets on companies to increase the shares of high purity secondary basic materials in total recycling quantities. • Ban or tax the demolition of buildings and shredding of vehicles and heavy equipment. • New design requirements on products to facilitate high value recycling. • More meaningful fees and modulation rates ADF under EPR schemes to penalize difficult to recycle products. • Finance for pilots of innovative technologies that help to preserve material value during design, deconstruction processes, advanced recycling processes, and decontamination systems for de-contaminable waste. • Ensure that national waste taxation and EPR schemes incentivize decontamination and chemical recycling, for the relevant product niches. • Support workforce training and remove regulatory barriers to economies of scale. • Identify local regulatory barriers that can exist which block the development of economies of scale in recycling. • Facilitate the creation of pan EU and international markets for high quality secondary materials and product designs.
options for improving material efficiency in manufacturing and construction	• Promote development and early adoption of a portfolio of new, high potential technologies and production processes. • Fund plant refurbishment with more material efficient processes with a charge on consumers of material intensive products. • Support the sharing of information and training to reduce material waste. • Requiring companies to set goals and report on material efficiency. • Setting material efficiency standards to eliminate inefficient production practices.
Options for raising collection and recycling rates of old scrap	• Public procurement and private sector pledging systems to help ensure demand for increased supply of high quality (and currently uneconomic) recycled materials. • To incentivize private sector demand for high-grade secondary materials, governments in Europe should track and label basic materials along the value chain based on GHG content of production. • Creating a durable economic incentive to ensure that recycled products are relatively attractive for users. • Set material quality labelling requirements and require companies to provide quality guarantees for the sale of high purity recycled materials liable to be purchased for high value usages. • Include waste incinerators in the EU ETS or otherwise tax their emissions at the level of the EU ETS carbon price. • Regulations or tax incentives to generalise the recycling of cement from building sites. • Introducing or enlarging the number of basic material-containing products covered by deposit-refund systems. • Modulate ADFs and recycling targets on plastics to favour greater use of closed loop recycling (rather than incineration) of plastics. • Revise product bans of once-through or litter-prone products, as alternative become available. • Continue to simplify, harmonise, and refine national and local government recycling rules and labelling schemes. • Provide innovation support and develop meaningful economic incentives for chemical recycling of plastics.

Creating competitive lead markets for low-CO_2 solutions

To ensure that low-CO_2 solutions find a market and hence justify upstream investments and allow for incremental innovation and cost reductions, four areas can be considered: 1) instruments that make these options competitive through pricing support, 2) standards that facilitate access to the market, 3) using public procurement to gain market entry, and 4) the global trade environment.

Some low-CO_2 solutions e.g. basic materials produced with breakthrough technologies will be more expensive compared to production with incumbent technologies. This price difference can become smaller over time as more experience is gained with new production technologies and these become incrementally more cost-efficient. For this learning curve to materialise however, sufficient demand for low-CO_2 products must exist in the first place. Under the EU ETS, low-CO_2 processes will have a natural advantage, but this might not be sufficient and therefore additional (temporary) production subsidies could be considered.

Reforms in the standard setting procedures, reforms in the formulation of standards, and the promotion of voluntary standards/labelling/certifications, can help bring innovative products to the market. Procurement practices are still underutilized as a strategic tool to drive a low-CO_2 transition, for example in large infrastructure and buildings projects. European policy makers could improve public procurement practices across the EU by making better use of the existing Public Procurement Package, by improving coordination at the EU level and by linking public procurement to low-CO_2 standardisation.

Most European producers of basic materials compete on a global market or with producers in countries at the EU's border. It is hence not straightforward to bring low-CO_2 solutions to the market where they have to compete with products with a higher CO_2 footprint but at a lower price. The instruments to deal with this challenge, considered here, include the use of public procurement and standards, border adjustments measures, trade defence instruments and future Free Trade Agreements (FTAs), and the protection of Intellectual Property (IP) funded by the EU.

Instruments to create lead markets	
Making low-CO_2 solutions cost competitive	• Subsidies for low-CO_2 production technologies through premiums, contracts for difference or tax reductions and taking into account EU ETS impacts • Extension of EU ETS scope with low-CO_2 processes • Inclusion of consumption in the EU ETS to secure carbon price pass through
The use of standards to gain market access	• Reforms in standard setting procedure: introduce flexibility and streamline the legislative and standardisation process, ensure a better coordination between policy tools, involve experts from various stakeholder groups in the standards development process • Reforms in standard formulations: Inclusion of efficient materials use or labelling in building standards, redesign existing standards that hamper market access for low-CO_2 products, EU-wide database on the environmental footprint of energy intensive manufacturing products based on LCAs and be designed similarly to the Level(s) tool, Introduction of an Eco-Label for construction products, eco-design for construction products and extending the scope of the Eco-design to non-energy related products • Promotion of voluntary standards, labelling and certifications
Public procurement as driver for low-CO_2 products	• Make better use of the Public Procurement Package (2017) by improving coordination on EU level and by linking public procurement to low-CO_2 standardisation • Improve coordination on EU level: By setting up a permanent EU Public Procurement Task Force that works to enhance public procurement practices that are coherent with societal value for taxpayers' money • Obligatory sustainability quota in EU funding schemes • Earmark EU funding for collaborative projects on public procurement • Permanent EU program for training and application of "Innovation brokers" • Fiscal Incentives to reward successful and ambitious use of sustainable public procurement practices • Link low-CO_2 public procurement to low-CO_2 standardisation
Competitive low-CO_2 solutions in a global market	• Public Procurement: set greenhouse gas standards or benchmarks for the materials used in the construction or assembly processes applicable to both domestically produced as imported materials. • Standards: introduction of carbon content standards on important final goods (e.g. cars) considered for instance an extension of the eco-design directive towards embedded CO_2 emissions • Border adjustments: Detailed assessment of the technical, legal and practical applicability of this instrument • Assess possibility of updating trade defence instruments: use benchmarks in new Anti-Dumping Methodology which in theory also include assessments with regard to cost carried by producers to mitigate GHG emissions. Consider if the lack of climate protection measures in a certain industry in non-EU countries can be considered a trade-distorting subsidy (subsidation). Investigate use of safeguards as the legal option for introducing (temporary) border adjustment instruments • Free Trade Agreements: Avoid engaging in FTAs with parties that have not signed or ratified the Paris Agreement or have withdrawn from the agreement or within these FTA's insert a waiver for strategic industries that are subjected to carbon pricing in the EU. • Conditional IP investment protection: Restricting the application of EU (co-)funded climate protection IP outside the EU.

Aligning the energy and industry transition and enabling infrastructure for industrial transition

Managing and aligning the joint energy-industry transition will first require the development of an integrated strategy which has the goal to create a virtuous cycle between the energy and industrial transitions. It is recommended that a joint industry-energy inter-service taskforce be established within the European Commission and with input from Member State experts to develop such strategy. The strategy could include a more detailed combined impact assessment of the combined climate neutral transition of energy and industry sectors, instruments on the energy supply and demand side and possible regulatory changes to prevent high electricity prices from stalling the electrification in industry.

While there is the theoretical assumption that significant investments will be necessary to provide the necessary infrastructure for industrial transition a practical mapping of these needs is absent. It will therefore be important to start with this mapping first. Secondly, the infrastructure will likely have to be financed by both public and private sectors. There are existing EU instruments that could be used to facilitate financing, but also new instruments that might be able to assist here, such as investment bonds and innovation in public accounting. Finally, in large scale transitions there is a risk that economic cohesion is weakened. In particular, future infrastructure planning and developments can impact economic cohesion between economic regions in Europe. This will have to be taken into account and where possible avoided.

Aligning the Energy and industry transition	• Joint Industry-Energy Inter-Service Taskforce to develop a virtuous cycle between the energy and industry transitions. • Joint and forward-looking impact assessment to work through the transition from (sub)national level and identify possible issues related to the adequacy of the energy system • Supply side instruments: Green Power Purchase Agreements (PPA's) by industry can, if needed, be further stimulated at national and EU level. • Demand side instruments: New power market design rules to facilitate the development of new business models, further R&D support for industrial demand response and storage, and support to new technologies under the form of feed-in tariffs or contracts for difference type instruments. • Competitiveness during energy transition: Supporting the accelerated phase out o carbon intensive power production, A system of double allocation

Infrastructur mapping an planning	• Mapping infrastructure needs mapping and plan: to give give better insights into the capital needed for low-CO_2 infrastructure and indicate the priority areas and (need for) interconnections. Work bottom up from medium and large industrial clusters present in Europe • Infrastructure Plan: To look ahead with a 10-year foresight at the opportunity to (over time) connect more remote industrial regions and also identify possible regions or specific industrial sectors at risk of missing out on linking to infrastructure due to their remote location and how this can be remediated. • New EU-Wide Platform for Transition Infrastructure: consisting of industrial actors research and technology organisations (RTOs), industrial cluster representatives
Financing transition infrastructur	• Evaluate the need and scope of using new financing instruments (e.g. monetary financing via bonds) • Member States budgetary flexibility for a number of white listed public investments to be written off over a longer time period • A cohesive transition planning must also include assessments and solutions for areas and industries that cannot benefit from collective infrastructure.

Scaling up investments and avoiding high-carbon lock-in

The transition to a net-zero industry will require a significant increase in investments compared to today. Companies will only make these investments if the conditions are right. This includes having mature technologies at hand, a growing market for low-CO_2 solutions and infrastructure in place together with access to reliable, green and competitively priced energy. These enabling conditions will be necessary but might not be sufficient. A radical transformation of industry over a relative short time period (compared to the investment cycles) will likely require additional support to facilitate and accelerate the necessary investments on an EU-wide scale. Fiscal instruments can assist in guiding investments towards low-CO_2 solutions but also bigger (new) EU financing instruments such as investment platforms or even an industrial sovereign wealth fund can be considered.

It is possible that investments in (new) carbon intensive industrial process installations that happen after 2020 will still be operational in the 2040s and up to 2050. There is hence a risk that some of these investments will lock-in emissions for a long period. This might lead to higher mitigation costs or even stranded assets over time. To minimise this risk it could be considered to introduce a climate neutrality test at permitting or environmental impact assessment stage for new investments. The goal would not be to prevent new investments but to ensure these are designed in a way that allows for compatibility with Europe's 2050 climate goals.

In many cases the transition of industrial processes will occur at the same site, therefore brownfield conversion will become an important feature of Europe's industrial transition. Brownfield development will be more complex and expensive compared to the development of a new process plant on a greenfield site. Regulatory flexibility and access to the EU ETS modernisation fund can assist with these reconversion processes.

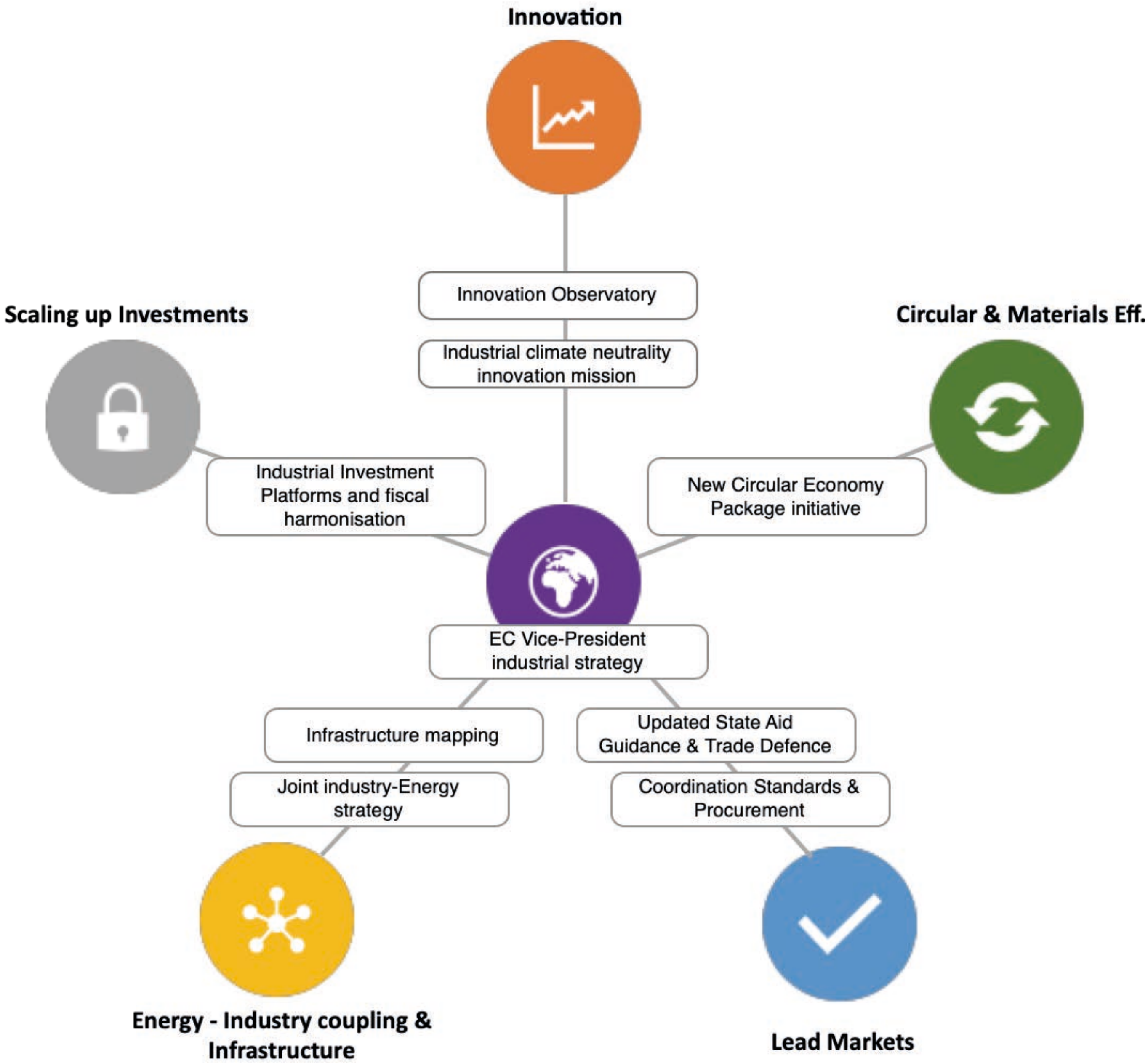
Financing to scale up investments	• Fiscal reorientation: Fiscal support to support and steer investments for climate friendly processes coordinated at EU level, e.g. as part of better corporate fiscal alignment between Member States • Industrial Investment Platforms for Carbon Neutral Industry: A one-stop-shop for financing large industrial demonstration projects, made from combined EU funds, national support and financing from private investors to provide loans and/or equity financing to the underlying projects (depending on their specific needs). • European Sovereign wealth fund: Could provide an optimal and future
brownfield conversion	assessment stage for new investments to ensure that investments are designed in a way compatible with Europe's 2050 climate goals. • Supporting brownfield conversion through the expansion of the EU ETS modernisation fund, allowing temporary flexibility in permitting, allowing for an accelerated depreciation of assets, and facilitating access to neighbouring terrains for expansion or new infrastructure required for the

Designing an industrial strategy for climate neutrality

This report aims to contribute to a broader debate on the need, design, implementation, and governance of a European industrial strategy for climate neutrality. To achieve net-0 emissions or climate neutrality for basic materials industry within the relatively short period of 30 years, there is clearly a need to fundamentally address all of the key challenges mentioned in (innovation, circularity, finance, infrastructure, market creation). But simply tackling each of these challenges on their own, and possibly at a different pace, will likely not work. Most of the areas that will need to be considered are, in one way or the other, connected. This flows from the logic of a major transformation of not only processes and products, but also value chains and even business models. It is also the main reason why an industrial strategy is needed.

Such industrial strategy will have to set a clear mission, it will in the end create a new industrial eco-system and must (per definition) be forward looking. It will, due to the complexity of dealing with many policy areas and different levels of competences, need integrated governance and leadership

An EU industrial strategy can hence include a mission-oriented innovation programme for industrial climate neutrality (from basic R&D to market), assisted by a transition observatory. It also should contain better integration of industry and energy transitions and the bottom up design of infrastructure needs. Materials efficiency and the circular economy will have to be fully aligned with climate targets and vice versa. This includes the development of new modelling tools that go beyond the classic energy system approach. But also, reorienting capital flows to low-CO_2 solutions will require a smart and integrated financing framework, using the existing instruments or creating new ones if needed. Finally, integrated governance and leadership through this process can come from a new dedicated responsibility for this transition process within the European Commission.



2. INTRODUCTION

Increased political momentum for climate ambition and a renewed approach to industry policy in Europe

The past year has seen increased momentum and interest in a new policy approach to heavy industry in Europe. Renewed thinking on what a European industrial transition to net-zero emissions could mean is being seriously considered amongst both the policy makers and industry stakeholders at the EU and national levels simultaneously. The European Commission published in November 2018 its strategic vision for long-term emission reductions, "A Clean Planet for All", where it strongly endorsed a net-zero vision for Europe by 2050 while also making an unprecedented link between the energy and industrial transitions. In March this year, EU member states called on the European Commission to present, by the end of 2019, a long-term vision for the EU's industrial future, with concrete measures to implement it.

Purpose of this report

In this context, this report seeks to build upon the momentum for an industrial strategy towards climate neutrality and outlines how it could look like. It assumes that a competitive net-zero emissions heavy industry is feasible and will have limited economic impact[8], but that the challenges basic material producing industries currently face need to be addressed through a sophisticated policy framework if they (basic materials industry) are to deliver on the Paris Agreement targets. It also indicates how these can be integrated into an industrial strategy and what governance instruments would be needed for its successful implementation.

The purpose of the report is to inspire the debate on a new integrated industrial climate strategy for Europe. The report is unique in the sense that the proposed industrial strategy goes beyond the newness of individual instruments towards a more integrated structure that scrutinizes a broad set of policy instruments, puts forth suggestions to introduce and further develop or to remedy policy solutions, and provides guidance on making the whole policy set as tangible as possible. It recognizes that any industrial strategy cannot take a solely supranational approach nor a solely national one. The main focus of the report are policy instruments that are governed at EU level, but within the context of industry policy being a mixed competence.

This report must be seen as an introduction to a more detailed and comprehensive debate on the need, design, implementation and governance of an integrated European industrial strategy for climate neutrality. As such, the report is not a final answer, but rather a contribution to a further detailed debate to be held with a broad set of stakeholders, policy makers at EU and national level, industry and civil society.

[8] Material Economics, 2019

Scope & approach

This report focuses on the European basic materials industries and related value chains, with a specific focus on the iron and steel, cement, and chemicals sectors building upon the findings in the "Industrial Transformation 2050 – Pathways to Net-Zero Emissions from EU Heavy Industry" report[9].

Through-out the process of developing this report, the preliminary findings have been discussed and tested with a number of industry stakeholders, NGO's and think tanks.

The report starts by first presenting the challenges that block basic materials industry's path to climate neutrality (Chapter 3). A set of six key challenges are outlined in detail. These are innovation challenges, the challenge of circularity and materials efficiency essential to meet net-0 by 2050, the challenges in rendering low-CO_2 solutions more competitive, challenges in delivering greater sector coupling and essential infrastructure, and governance challenges.

Next, the report presents for each of these areas a set of policy instruments that can used to address the challenges. Chapter 4 presents mechanisms/regulations that can help power the innovations which will help deliver the transition. The chapter looks closely at R&D, demonstration by 2030, supply and demand side measures, public sector role as well as the needed governance. Chapter 5 delves into measures which can promote greater circularity and materials efficiency while retaining the highest value possible. It looks at the role of standards, regulations, fiscal measures, and mechanisms for the reduction of material waste. Chapter 6 presents measures that could help create competitive lead markets for low-CO_2 solutions which could not only justify upstream investments but also allow for incremental innovation and cost reductions. The chapter considers four areas: pricing support, standards, public procurement, trade measures. Chapter 7 explores ways in which sector coupling between the energy and industry sectors could be achieved and the provision of the necessary infrastructure that industry will require to achieve net-zero. Chapter 8 presents a combination of factors to scale up low-CO_2 investments and avoiding high-carbon lock-ins. *Chapter 9 concludes the report with a possible blueprint of an industrial strategy and how this can be governed.*

[9] Ibid.,

3. Challenges on the pathways to a climate neutral industry

3.1. Introduction

The transition to climate neutrality within 30 years for basic materials industry is substantial, especially when taking into account the long investment cycles of these industries. Furthermore, this transition will happen in a highly competitive and dynamic international environment, with many of the basic materials industries being part of a global market. For these industries and their value chains to successfully move ahead with such transition important challenges will have to be addressed. Using previous research[10] this report considers six main challenges:

- Innovation gaps from basic Research and Development (R&D) to deployment of new technologies
- An insufficient circular and materials efficient economy
- Barriers to market entry for low-CO_2 solutions
- Lack of streamlining between the energy and industrial transition to climate neutrality and infrastructure needs for the transition
- Possible bottlenecks in scaling up of investments and the risk of high-carbon lock-ins
- The complexity of integrating different types of policy instruments, policy areas and competences into a cohesive (industrial) strategy

First, innovation needs are substantial. This encompasses a broad spectrum ranging from creating and accelerating new low-carbon production processes (many of which necessitate fundamentally different modes of production) in addition to novel feedstocks and/or core industrial processes, to innovations that apply not only to the value chains of basic materials industries but also to the energy systems that power them. Furthermore, the most promising low-CO_2 technologies will need to prove industrial scale demonstration by 2030 at the latest. Many of these are currently still at the pilot or even earlier stage. Adequate innovation support is therefore required to bridge multiple innovation valleys of death. This in essence requires rapid policy support to introduce and drive the scale-up of new low-CO_2 production routes and uses of materials.

Second, achieving enhanced levels of circularity and materials efficiency will be vital. Resource efficiency and circular economy measures could help almost halve the 530 Mt CO_2/year emitted by the basic materials sectors in the EU by 2050[11]. Some industrial sectors like steel are already well ahead in this area. However, important challenges remain in other basic materials industries and their value chains, and in particular, with regard to maintaining the quality of basic materials in recycled product streams. Achieving enhanced levels of circularity while retaining the highest value is possible, but will require a combination of standards, regulations, fiscal measures, and the reduction of material waste. In addition, greater political ambition will also be essential.

[10] Material Economics, 2019; IES, 2018

[11] Material Economics, 2018

Third, low-CO_2 solutions will need to be able to compete with existing products and processes. The CO_2 price introduced under the EU Emissions Trading System (ETS) might, in the short term, not be sufficient to realise this. Beyond cost-competitiveness, other barriers for market access exist, such as existing standards that prevent new products from entering the market.

Fourth, the industrial transition will require a new and/or enhanced infrastructure and a smart coupling with the energy transition This includes infrastructure for reliable and competitively priced low-carbon electricity, CCS, H_2 networks, biomass, and reliable accessibility of waste materials. The infrastructure that could enable the roll out of new processes across Europe is not in place as yet.

Fifth, to drive the transition to net-zero emissions for the basic materials large volumes of additional investments will be needed (+25% to 60%) by companies. The market and regulatory environments will need to ensure that companies can make those investments with an acceptable level of risk. It is also important that new investments do not lock-in high carbon pathways over their lifetime. Finally, it is likely that the transition will require significant amounts of brownfield conversions, which adds to risk and capital needs.

Finally, this transition will have to be carefully and smartly managed across all the afore-mentioned challenges. A new governance system for the industrial transition is of order. Any future industrial strategy will essentially cover multiple areas (innovation, finance, energy, waste, competition, state aid, …) and will have to be implemented while taking into account the different and mixed levels of competences in the EU. The continued importance of maintaining a competitive industrial base needs to be well aligned across all policy areas.

3.2. Innovation gaps from basic R&D to deployment of new technologies

Innovation will be a defining element of the transition to net-zero emissions by 2050 for basic materials industries and their value chains.

Important progress has been made in the research and development (R&D) of new industrial processes with significantly lower CO_2 emissions. This already allows the identification of the most relevant technology pathways for an industrial climate-neutral transition. However there still are important basic R&D challenges to be addressed for these transitions to materialise. These include the advancement of promising or possibly important technologies currently at low technology readiness levels (TRLs), and the focus on Operational Expenditure (OPEX) reduction of new processes through innovation and the development of key enabling technologies that would allow important progress across different industries. Further innovation is not only required in the supply side of basic materials but also on the demand side. Demand side innovation encompasses a broad area: new business models, digital solutions for material flows tracking, automation of materials handling, dismantling end-of-life products, and new lead markets for low-CO_2 products. Innovation challenges therefore apply to not only specific industries but to the wider value chains that rely on them. They also extend to the energy system in place which will feed them.

The second innovation challenge relates to the long investment cycles in basic materials industries, which can be 20-30 years. This implies that in order to meet 2050 climate neutrality goals the key process technologies need to be ready for deployment (TRL 8-9) by 2030 at the latest. While some of these technologies are currently in the process of being piloted or demonstrated, most of the low-CO_2 technologies in development still have to cross the hurdle towards pilot and large-scale demonstration. Therefore, across all the basic materials industries, 30-50 demo plants will have to become operational in the EU over the next decade to full cover the most important or currently most advanced technological options.

3.3. An insufficient circular and materials efficient economy

Creating a more resource-efficient, circular economy for the basic materials sector is essential for achieving the climate-neutrality goal of the Paris Agreement. The potential to reduce emissions in this way is enormous. In the EU, up to 296 Mt CO_2/year could be eliminated by 2050 through resource efficiency and circular economy measures for the steel, aluminium, plastics and cement sectors alone[12]. This is over half of the 530 Mt CO_2/year emitted by these basic materials sectors in the EU today.

The EU and its member states already have put a number of policies in place to promote resource efficiency and circularity for basic materials. However, additional policies and measures will be required – both at EU and member state level - to fully exploit the large emissions abatement potentials that exist. Three priority challenges are considered here.

Firstly, policy makers should focus on retaining the value in high-grade materials at the end of the product's life, not just recycling rates. This is important so that these materials can be recycled into a much wider range of high value applications, rather than downgraded into just a small subset of products. This is in turn essential for achieving and maintaining high rates of recycling in the future. For instance, a lot of primary steel and aluminium is recycled, but they are contaminated with other components, especially copper, at the end of their life[13]. Similar issues also arise for plastic products. Much plastic is simply not recycled or is "thermally recycled" through incineration (see below). However, there is significant downgrading of otherwise perfectly recyclable plastic types due to contamination of used plastics[14]. This contributes to the fact that only about 10% of the EU plastic needs are met through mechanically recycled plastics, whereas the potentials are closer to 55%[15]. An additional issue for plastics is that, even within a given plastics category, a multitude of different chemical polymers abound. Consequently, at end of life, plastics waste streams cannot be readily re-melted and directly re-used to produce equivalent quality plastic products.

Reducing material contamination can also help to reduce other sources of material losses during the recycling process. For example, there is often lost material through slagging when

[12] Material Economics, 2018

[13] This happens in part because cars are shredded, and the electrical and other components of the car are mixed in with the high purity steel content. A consequence of these practices is that high value materials are quickly downgraded to the point where they can no longer be re-used for the same purpose or other high value applications. This severely limits the potential to significantly increase ratio of secondary to primary production.

[14] Plastics can be contaminated at fabrication (e.g. because of adhesives, stabilisers or paints and other additives), during use (because of the products they contain), or at end of life collection (e.g. through being mixed with other plastic types when buildings are demolished, or cars are shredded).

[15] Material Economics, 2018

materials are re-melted during the recycling process[16]. These losses could be reduced by having less contaminated feedstock to re-melt or by tailoring re-melting activities to specific targeted purity streams of secondary materials.

A second challenge is improving material efficiency of production process, i.e. during the manufacturing and construction of goods for the final consumer. So-called “new scrap rates” – i.e. the share of new primary materials that are essentially “left on the factory floor” and which never make it into final products – are very high for some basic material products. For example, in the automotive sector, up to 30% of primary steel does not make it into the body of the car but is instead returned as new scrap to be re-melted (Material Economics, 2018). This is a major share of primary steel production that simply provides no service to the consumer and is essentially wasted. Similarly, in the building sector, construction companies will often over-specify material requirements, which in turn leads to high rates of materials wastage[17]. Overcoming these inefficiencies could therefore go a long way to reducing material waste in construction.

The third challenge relates to the prioritisation of increasing collection, re-use and recycling rates of “old scrap” at the end of a product’s life. Some basic materials, such as steel have relatively high recycling rates (around 85%). However, for other products, such as certain types of plastics, aluminium and cement and concrete, a lot could be done to improve the simple collection of “old scrap” and thereby increase current recycling rates.

Plastics is perhaps the most glaring example of this. Despite official statistics suggesting that 30% of plastics are recycled in the EU, it overstates the reality. Much of this is recycled plastics is low quality “thermal recycling” where potentially recyclable plastics are burned for energy. Much plastic is also lost through misallocation of waste to landfill or dumping. Thus, only around 10% of the total demand for plastics in the EU is met through secondary plastics production. This need not be the case. Technically speaking, up to 56% of plastic volumes could be mechanically recycled or reused, with the recovered material value paying for much of the cost. Another 11% could potentially be chemically recycled (i.e. by breaking down plastics in their chemical components and reconstituting new plastic polymers)[18].

Cement and concrete have to date not been recycled at all, rather they are generally crushed and either dumped or transformed into low grade “aggregates” for other construction purposes[19].

Despite being an extremely resource intensive material to produce, in Europe 25-30% of aluminium is generally not recovered after each use cycle, although levels vary across regions and product categories[20]. In general, recycling rates are higher for aluminium used in the

[16] About 4-5% of steel and 2-3% of aluminium is estimated to be lost through these process inefficiencies (Material Economics, 2018).
[17] Moynihan (2014), for instance, studies the utilisation ratio of steel beams and columns in UK buildings and finds that these sections potentials for material efficiencies of up to 50% could be achieved on average, by better adapting the size sections to the maximal loads they are required to bear, without compromising safety or performance. He finds that, for steel, the highest potentials exist in a building’s steel superstructure. This systematic over-specification is often due to so-called “rationalisation” practices, as, to save on labour costs, builders will seek to save on construction time by using common sized sections throughout a structure, rather than adapting the structure to actual load-bearing needs.
[18] Material Economics, 2018
[19] However, recent innovations, such as SmartCrusher technology, shows that, with the right policy incentives, up to 50% of cement could be efficiently re-separated from concrete during demolition and re-used as cementitious material in new constructions (Slimbreker, 2019).
[20] Material Economics, 2018

construction and automotive sectors, but much lower for aluminium used in consumer goods. Like plastics, much of this is misallocated to general waste, is contaminated, or dumped. As recycled aluminium requires only 5% of the energy needed to make primary material, and over 70% of aluminium is imported in Europe, better collection and recycling represents a major opportunity for policy makers to achieve several goals at once[21].

3.4. Barriers to market entry for low-CO_2 solutions

The nascent growth of low-CO_2 solutions faces a host of challenges which impede snowballing into incremental innovation and cost reduction. Some low-CO_2 solutions e.g. basic materials produced with breakthrough technologies, are for the time being and will for the foreseeable future remain more expensive compared to production with incumbent technologies. The pathways to net-zero emissions developed by Material Economics[22] that require the use of new low-CO_2 production routes cost 20-30% more for steel and 20-80% more for cement and chemicals. The CO_2 price introduced under the EU ETS might, in the short term, not be sufficient to cover this price difference and hence level the price between low-CO_2 production routes and the incumbent ones. Furthermore, that CO_2 opportunity cost through the EU ETS might not be fully passed through in product prices (e.g. for competitiveness reasons). Beyond cost-competitiveness, other barriers for market access exist such as existing standards preventing new products from entering the market or unused opportunities in procurement and the lack of information on life cycle assessments of products.

Furthermore, existing standards or regulations can stand in the way of new low-CO_2 solutions from entering the market easily. Standards can also be pro-actively applied to facilitate access to the market. Consumers might not be willing to take the risk and work with new low-CO_2 products given their unfamiliarity with the products. Some instruments, such as public procurement, are not used to their full potential to indeed bring innovative solutions to the market and hence create consumer trust in these low-CO_2 options.

The good news is that while changing to new low-CO_2 processes in basic manufacturing can increase costs for producers significantly, the end consumer might barely notice a difference in the price of final goods produced with low-CO_2 technologies. Consumer prices of cars, houses, packaged goods, etc. would increase by less than 1% to pay for more expensive materials produced with new low-CO_2 processes [23]. This shows that instruments that create market for low-CO_2 solutions could benefit the producer of these solutions while having a negligible impact on the economy as a whole.

3.5. Lack of streamlining between the energy and industrial transition to climate neutrality and infrastructure needs for the transition

The industrial transition will require streamlining between the same climate-neutral transitions of the energy system and the development of enabling infrastructure. Higher levels

[21] OEA, n.d.
[22] Material Economics, 2019
[23] Ibid.,

of electrification in industry and the use of new low-CO_2 processes (e.g. H_2 produced via electrolysis) show that significant amounts of green electricity will be required. In a maximum case scenario, an additional 710 TWh per year will be required for steel, cement and chemicals. For comparison, all of industry and manufacturing currently uses 1,000 TWh/year. Achieving climate neutrality both in industry and power production will require proper planning and coordination to allow for such amounts of reliable, competitively priced and non-volatile green electricity to power the industrial transition.

The most promising industrial processes to achieve climate neutrality will require the timely development and financing of adequate infrastructure (for e.g. H_2 and CO_2). Investments in new infrastructure would require significant amount of capital - to the order of EUR 16-31 billion (Bn) per year up to 2050[24]. This is particularly the case for CCS (and to a lesser extent CCU) and processes using low-CO_2 H_2. But also, supply and logistics chains for the enhanced use of biomass resources will need to be developed. Finally, infrastructure will be critical for ensuring the supply of and reliable accessibility to waste streams or secondary raw materials for industry. There currently exists a lack of knowledge and hence coordinated planning in this area. To avoid a catch-22 situation where investments in new process installations are delayed by lack of infrastructure or vice versa where new infrastructure is not viable due to lack of demand from new processes, a proactive approach will be needed. This includes foreseeing adequate financing instruments.

3.6. Possible bottlenecks in scaling up of investments and the risk of high-carbon lock-in

To drive the heavy industry’s transition to net-zero emissions, large volumes of additional investments (+25-60%) will be needed by companies. The public sector needs to ensure that companies can make those investments with an acceptable level of risk. The starting point is always a credible long-term/stable framework to ensure a future business case. Moreover, direct investment support may also be needed for a variety of reasons.

First, companies will need to make critical decisions about capital and assets much before 2030 and such early investment will prove crucial given the long investment cycles that basic materials industries have. Second, industrial low-CO_2 assets require large investments in new production capacity as they last decades and are seldom commutable.

Third, the first wave of company investors (before 2030) will face a first-mover disadvantage given that low-CO_2 solutions would be priced at a larger Capital Expenditure (CAPEX) compared to already mature technologies, or if they were commercially disruptive. Fourth, retrofitting brownfield sites with new low-CO_2 solutions would come with added complexity and costs in adapting to the existing wider production system (unless infrastructure upgrades are synchronised). Existing assets might thus also (temporarily) operate in parallel with new processes. And finally, policy and regulatory barriers would need to be cleared relating to extensive changes to industrial sites and infrastructure, risk of investment distortion by capital grants, state aid guidelines which may be problematic, and the inertia and ambiguity with regard to permitting rules.

[24] Ibid.,

A significant challenge is the successful evasion of a possible high-carbon lock-in through new investments that happen over the next years. Given the long lifetime of these investments, it is likely that a plant constructed today is still operational in the period 2040-2050. Furthermore, the transition of most of the existing installations will go through a brownfield conversion process. This adds risk and capital costs to the transition.

3.7. The complexity of integrating different types of policy instruments, policy areas and competences into a cohesive (industrial) strategy

In the end, the challenges listed above will have to come together in a cohesive policy framework. This is not straightforward given the wide range of policy areas that need to be covered and the fact that some competences are split between the EU and its member states.

It would be wrong to just focus on remediating the externalities caused by greenhouse gas (GHG) emissions. The EU ETS, currently the main instrument to mitigate industrial GHG emissions in the EU, is an insufficient means to this end. On its own, carbon pricing also does not provide sufficient incentives for innovation, nor does it address market failures that hold back many circular economy solutions. The transition to a climate-neutral basic materials industry and related value chains will also involve the reshaping and reorganisation of existing markets, value and supply chains. Hence, a more comprehensive strategy will be needed.

Achieving such change will require integrated governance and leadership, and additional instruments to facilitate this transition.

Innovation for a climate neutral industry

- *Set an industrial climate neutrality mission under the EU's innovation.*
- *Set up an industrial transition observatory to monitor progress and advice course corrections with regard to development and deployment of industrial low-CO_2 innovations.*
- *Develop one-stop-shops where project developers can get easier access to blended finance.*

4. Innovation for a climate neutral industry

4.1. Introduction

This chapter will first map some of the main outstanding R&D gaps that could become the priority foci of existing and future EU and national industrial R&D programmes. It next looks at how the bridge from piloting to demonstration to commercialisation of new process technologies can be further facilitated. Finally, some options are proposed to facilitate the governance of industrial innovation towards climate neutrality with the goal of enhancing this process.

4.2. Outstanding R&D challenges

One of the main technology challenges relates to the electrification of high temperature furnaces, replacing natural gas or other fuels. This will be an essential technology in most of the energy intensive industries (e.g. chemicals, ceramics, glass, cement, …) to achieve deep emission reductions. In addition, new electrification technologies will need to show significant efficiency improvement to offset the low cost of heating with e.g. natural gas[25].

CO_2-free H_2 production will play an important role in steel and chemicals transition. Currently most industrial H_2 is produced with Steam Methane Reforming (SMR). Alternative processes to produce H_2 without CO_2 emissions (e.g. electrolysis, CCS) are becoming available for industrial producers but some are still in early stages of development (e.g. methane pyrolysis). Main challenge will be optimisation with the goal of reducing costs and closing the gap with SMR. But also, reduction in the size and space taken up by H_2 production installations together with scaling up the sizes will be important[26].

CO_2 utilisation and/or storage can become important future mitigation technologies. However, cost reductions of these technologies will be essential for these to disrupt existing process technologies. In the case of CO_2 utilisations, major barriers exist with regard to OPEX, in particular related to high energy use (for capturing CO_2 and high H_2 inputs). It is therefore doubtful that Carbon Capture and Utilisation (CCU) will become a mainstream technology for commodity and high value chemicals due to higher costs, but it can break into niche markets for specialties.

For both Carbon Capture and Storage (CCS) and Carbon Capture and Usage (CCU), a high purity CO_2 waste stream is essential. This means that high CO_2 concentrated waste streams from (e.g. ammonia production) will be the most interesting routes to consider. Further research in systems that increase process efficiency and high concentrated CO_2 streams and in improving current post-combustion technologies will be important.

Another possible focal point for R&D is system integration of different new technologies into a single system. For instance, the production of olefins from CO_2 will require the integration

[25] IES, 2018 ; European Copper Institute & Leonardo Energy, 2018
[26] IES, 2018 ; Dechema, 2017

of CO_2 capturing, H_2 and CO_2 transformation to methanol and next conversion of methanol to olefins.

There are also important R&D challenges related to higher materials efficiency and circular use of materials. Chemical recycling or recycling polymers (e.g. plastics) back to monomers will be an essential technology for a circular and net-zero economy. Multiple technology options[27] are possible but the goal will be to develop cost-effective processes that can deal with multiple feedstocks (e.g. different plastics types and biomass). Methods to purify steel scrap from contaminants such as copper could increase the yield of high-quality secondary steel. Upcycling concrete waste would reduce the need for primary materials in new concrete production, but this is still in the early stages of research[28]. Further improvements in technologies for industrial symbiosis can help with the valorisation of industrial waste streams and hence reduce the need of primary materials. Finally, technologies that allow industrial producers to play an active role in energy storage and demand side management will prove to be essential in the joint transition of the energy and industrial sectors.

Not only the production processes will require further R&D, there is a need for innovation across the value chain. This includes enhanced use of digital technologies to sort and track materials but also improvements in product design. The latter can involve designing products for disassembly but also simplification of (mixed) materials use and researching higher and different functionality with less materials intensity.

Across all these R&D challenges, it is important to stress the possible value of key enabling and general-purpose technologies and R&D that can have a broad range of applications. As mentioned before, high temperature heat electrification technologies can be applied across multiple industries. But also, investing in basic research on catalysts (e.g. new materials and physical structure (nano-tech[29])) can lead to applications in basic chemicals, H_2, CCUS and batteries/storage. Designing new materials in this area can likely make use or even be the killer application of quantum computing[30]. The establishment of advanced material laboratories making use of state of the art digital technologies (e.g. machine learning and distributed ledger technologies[31]) can accelerate their development.

Innovation for the transition to a climate neutral industry will not only be technological. There is a need to further explore new business models and possibilities of value creation along the value chains. Early identification of new skills needed in a transforming industry will be important so that education and training can adapt in time. New technologies will also require a better way of assessing their climate impact. In this context it is recommended that research in life-cycle accounting (LCA) for GHG emissions take into account the technological changes that are underway in industry and value chains.

[27] Ragaert et. al., 2017, p. 25-35
[28] Slimbreker, 2019
[29] Michael Berger, 2009
[30] Mc Ardle et al, 2018
[31] IBM, 2018

4.3. Make key technologies ready for deployment by 2030

Demonstration is an important stage of the innovation process of low-CO_2 process technologies. It is very difficult to anticipate how full-scale systems will operate based only on the performance of smaller-scale prototypes. Innovating companies must therefore carry the cost and risk of building and operating a full-scale, first-of-a-kind demonstration project - a process that often takes several years and substantial sums of capital - before being able to move to a commercial basis[32]. These costs and risks can make it very difficult or impossible for a single company to shoulder.

The EU ETS innovation fund

The main instrument to bridge the pilot/demonstration to commercialisation gap will be the EU ETS innovation fund. The innovation fund will make available around EUR 10 Bn for the demonstration of breakthrough technologies in the energy and industrial sectors in the period 2020-2030. The fund solves many issues that hampered its predecessor (NER300), in particular the lack of upfront financing. First of all, the fund will give project developers early access to capital, even before the construction of the demonstration technology. Secondly, the innovation fund will also cover part of the (possibly) higher OPEX compared to incumbent technologies. Thirdly, the fund will allow blended finance with other EU financing instruments (e.g. Invest EU). Finally, the set-up of the innovation fund contains support at an early stage for the development of project proposals.

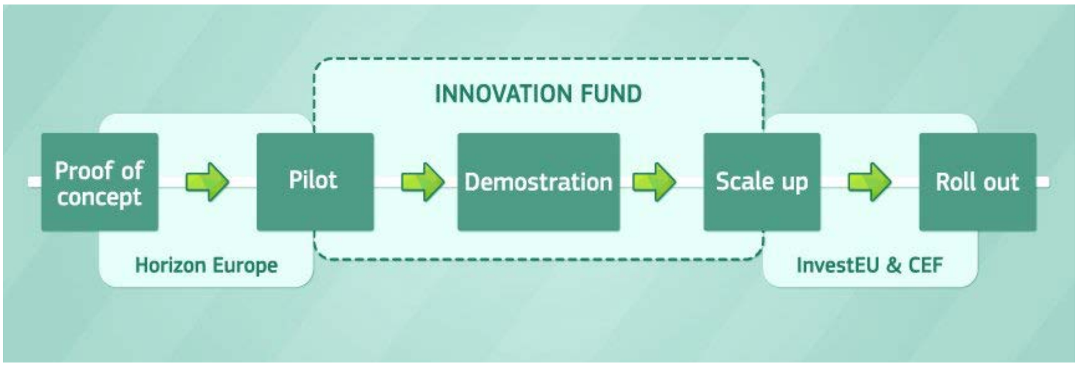


Figure 1: *Possible EU industrial innovation financing instruments from proof of concept to roll out.*
Source: European Commission, 2019

While the European Commission has a broader innovation architecture in mind when setting up the innovation fund, practical implementation is not there yet. Early stage innovation will be funded by Horizon Europe with the innovation fund stepping in when (much) higher levels of capital are required to scale up towards pilot and demonstration levels. Further rollout and deployment of technologies that are successfully demonstrated will be supported by Invest EU and the Connecting Europe Facility, the latter to focus on necessary infrastructure for new technologies[33].

The innovation fund is a critical step towards realising 30-50 industrial low-CO_2 demonstration plants by 2030. However, some elements (most of which are) related to the broader innovation will need to be addressed. This includes:

[32] David M. Hart, 2017, p. 4
[33] European Commissions, 2019a

- Simplification of blended finance (e.g. one-stop-shop for financing)
- Support for critical sub-systems for low-CO_2 innovation
- Elimination of regulatory barriers that might prevent the timely scaling up of innovations.

One-stop-shop financing

Most demonstration projects will be financed from different sources (e.g. Innovation Fund, other EU funds, member state support, own capital, …). Finding financial closure can be time consuming and can delay the implementation of projects significantly. It is therefore recommended to further investigate the development of one-stop-shops where project developers can get easier access to blended finance. Investment platforms developed under the EFSI can be seen as an interesting example (see also chapter 8).

Financing of enabling sub-systems

There is a risk that EU industrial low-CO_2 finance focuses only on end-to-end projects, which deliver a complete functional solution. Some industrial low-CO_2 solutions will consist of different critical innovations which when put together will significantly reduce emissions. While it is important to ensure full system functionality, one must also consider that some components will have to be demonstrated first before they can be integrated. Therefore, supporting partial systems or supporting technologies which do not mitigate GHG emissions on their own will remain important.

Dealing with regulatory barriers for demonstration technologies

Even in the presence of sufficient financial support for low-CO_2 solutions, other barriers might exist that hamper their demonstration. There might be issues related to permitting (e.g. total production capacity exceeding the permit), uncertainty on actual GHG mitigation during the testing phase or absence of infrastructure that would allow the transport, storage or utilisation of CO_2 emissions. To prevent these issues from stalling the project development, low-regulatory zones for testing or even a temporary and well-defined exemption under the EU ETS could be considered. However, this regulatory flexibility must be limited in time and can only be allowed under well-defined and exceptional conditions.

4.4. Enhanced innovation governance for industrial transition

Industrial transition observatory

As mentioned in the previous sections, there is need for better governance of industrial innovation challenges towards climate neutrality. An industrial innovation mission under, for e.g. Horizon Europe, must also consider how innovation at lower TRLs can graduate to commercialisation and next diffusion. An EU observatory on industrial transition to climate neutrality could therefore be established. Its goal would be to monitor how the innovation challenges progress along the full innovation chain. It can develop a database to track the different technologies under development and identify bottlenecks, roadblocks or dead ends. Once every two years, an assessment report, including policy recommendations, could be published. This assessment would take place in the form of consultation with research institutes, industry and the public sector. In this context, the development of accredited TRL passports can be considered, demonstrating the graduation from one TRL to the next. Such accreditation could facilitate access to funding by reducing the repetition of technological due diligence when moving from one funding instrument to the next.

Bringing the industrial transition R&D challenges together under a grand challenge

This broad range of outstanding R&D challenges should best feature under a Horizon Europe 'grand challenge' such as 'a climate-neutral industry by 2050'. A renewed SPIRE public private partnership (PPP) could be an important implementing instrument in this context. Some additional elements will need to be considered. It is important to align national R&D initiatives with such an EU level grand challenge. This would imply ensuring that there is a joint vision between member states, research institutes and industry on the design and implementation of such an R&D mission. The programme will need a set of Key Performance Indicators (KPI's) that can be monitored and if needed adjusted to ensure that the overall innovation goals are met. Finally, the challenge will have to be embedded in a broader industrial transition strategy. This is not only important for ensuring that innovations are ready for deployment by 2030 (see next section), but also that new technologies get access to the market and are able to disrupt existing production and value chains (see chapter 6).

OVERVIEW TABLE

Innovation Instruments	
Options to enhance innovation governance for industrial transition	• Develop an industrial climate neutrality grand challenge under the EU's innovation flagship Horizon Europe in coordination with national industrial R&D programmes to address outstanding basic R&D gaps (in particular with focus on cost reduction of new technologies) both from supply side (process technologies) and demand side (materials efficiency, energy storage). • Set up an industrial transition observatory to monitor progress and advice course corrections with regard to development and deployment of industrial low-CO_2 innovations.
Options to accelerate technology market readiness by 2030	• Development of one-stop-shops where project developers can get easier access to blended finance. Investment platforms developed under the EFSI can be seen as an interesting example • Supporting partial systems or supporting/enabling technologies, which do not mitigate greenhouse gas emissions on their own. • Elimination of regulatory barriers that might prevent the timely scaling up of innovations. Low-regulatory zones for testing could be considered or even a temporary and well-defined exemption under the EU ETS.

An enhanced circular economy package for basic materials

- *Develop an updated circular economy package for basic materials consisting of*
- *Instruments enhancing the quality of recycled materials to preserve material value*
- *Instruments for improving material efficiency in manufacturing and construction*
- *Instruments that help raising collection and recycling rates of old scrap*

5. An enhanced circular economy package for basic materials

5.1. Introduction

This chapter presents a range of policy options that could help address each of the three main challenges (as discussed in chapter 3) for developing a more resource efficient and circular economy for basic materials in Europe:

- Retaining material value by avoiding downgrading and contamination. This is critical to enable very high ratios of secondary to primary materials on the market.
- Improving the efficiency of new material use in manufacturing and construction. This is vital for providing the same material value to end consumers without wasting virgin materials.
- Increasing collection and recycling rates of basic materials. This ensures that the large unexploited potentials of collection and recycling are tapped.

The intention is not to suggest that all policies discussed below should be implemented together. Rather, the aim is to help structure a discussion on the kinds of policies that are needed and can be adopted to unlock the key priority areas described above. Ultimately, a sub-set of these (and potentially other) policy ideas to create an integrated and complementary package of policies that address the key enabling conditions will need to be selected.

5.2. Policy options for enhancing the quality of recycled materials to preserve material value

Several policy options exist that could help generate a better preservation of material value at end-of-life and thus facilitate very high rates of total recycling of basic materials. Some of the most interesting options include:

Requiring the recyclers of basic materials to do more precise sorting based on of the quality of materials in end-of-life products they receive.

This would require, for instance, recyclers to separate steel, aluminium or plastic scrap into different purity categories that correspond to the demands of remelters and remanufacturers. They could, in addition, be required to track and communicate the amounts of the different qualities of recycled materials delivered to subsequent actors along the recycling value chain. This way, it would be easier for product producers to be able to identify and use high-grade secondary materials to re-produce higher value goods for sale. Tracking would also make secondary material users be better able to highlight that the products they produce using these high-grade materials came from high-value recycling based on circular economy principles.

Setting recycling quality targets on companies to increase the shares of high purity secondary basic materials in total recycling quantities.

These could be done as an extension of existing targets linked to Enlarged Producer Responsibility (EPR) schemes. Targets could be set and then gradually increased to improve the overall quality of recycled materials over time, to allow time for adjustment of capital stock in the value chain. Advanced disposal fees (ADFs) under existing EPR schemes could be increased to finance the incremental cost of improving the infrastructure and technologies used by recyclers in order to meet the targets.

Ban or tax the demolition of buildings and shredding of vehicles and heavy equipment.

Governments could create disincentives or perhaps ban the demolition of buildings and shredding of motor vehicles and heavy machinery. Instead, these products would be required to be dismantled and sorted into relevant product categories to limit end-of-life contamination before being sold to recyclers. These requirements could also include the mandatory separation of concrete into cement, sand and other aggregates for recycling as part of this process. This could help guarantee the deployment of new and affordable technologies for doing so.

New design requirements for products to facilitate high-value recycling.

For example, to facilitate deconstruction that is cost-effective and limits contamination as much as possible, new "design for deconstruction" requirements could be placed on new buildings, cars and other products where deconstruction practices are key to increasing the quality of secondary materials. Similarly, products with plastics or aluminium could have design requirements to further limit the number of polymers and chemical compounds used in order to facilitate recycling. Rules could possibly seek to limit the unnecessary, avoidable use of contaminants (e.g. adhesives, the use of dark coloured colorants, etc.) at the fabrication phase.

More meaningful fees and modulation rates of ADFs under EPR schemes to penalize difficult-to-recycle products.

Existing EPR schemes in Europe generally provide far too little incentives for product designers to undertake the expense and effort of re-designing their products to enable high value recycling. ADF fees should not only be increased substantially to pay for more sophisticated recycling technologies, but also modulated to a much larger extent for individual companies based on the resource efficiency and circularity characteristics of their products. Criteria could focus on:

a) Whether the product itself comes from secondary materials (thus creating higher value and demand for secondary materials), and
b) The ease of re-use, remanufacturing or high-value recyclability of the product.

Finance for pilots of innovative technologies that help to preserve material value during design, deconstruction processes, advanced recycling processes, and decontamination systems for de-contaminable waste.

Existing recycling systems lead to large amounts of contamination in part because labour is relatively expensive in Europe and the recycling technologies that take the place of labour have limitations in their ability to identify, sort and track waste streams to preserve material value. However, new technologies are emerging - often linked to advances in robotics, digital tracking technologies, chemical recycling of plastic hydrocarbons, carbon capture and use from biomass, etc - that can help to improve the status quo. Governments could thus see the circular economy as part of their industrial strategy and extend support to innovative technologies at the pilot and early commercialisation phases.

Ensure that national waste taxation and EPR schemes incentivize decontamination and chemical recycling for relevant product niches.

There are various possibilities of overcoming the contamination of certain kinds of basic material products. In general, it is better to avoid contamination through product design norms and standards regarding processes for end-of-life treatment. In some cases, this will not be enough and decontamination or chemical recycling is the next best option. It is therefore important that these options are incentivized for relevant product niches (e.g. certain kinds of plastics). This requires governments to reflect upon both innovation policies to support the relevant technologies (some of which are immature) and to design ADFs and EPR schemes in a way which incentivizes and pays for the cost of decontamination and/or chemical recycling.

Support workforce training and remove regulatory barriers to economies of scale.

Governments will also need to invest in skills development and training in order to have a circular economy-ready workforce – skilled enough for instance to deconstruct buildings safely and cost-efficiently, to design products for circularity, to work with the latest technologies to achieve sorting and tracking of different grades of materials. Much like the scale-up of the workforce needed to undertakeenergy efficiency retrofits, this is likely to require adapting technical training processes to turn out students or retrain workers in order to develop these skills.

Identify existing local regulatory barriers which block the development of economies of scale in recycling.

For instance, plastic waste may need to be sent to large-scale sites to achieve cost competitiveness in deploying the best available technology for sorting and high-value recycling. Sometimes regulatory barriers, like a lack of clarity over ownership of municipal plastic waste or local approval of large-scale sites, can create barriers to such economies of scale.

Facilitate the creation of pan-EU and international markets for high quality secondary materials and product designs.

There are international recycling value chains for many basic materials, both within Europe and in terms of EU-to-non-EU material flows. This is a crucial dimension to bear in mind in terms of efforts required to improve design and reduce end-of-life contamination of materials, especially because economies of scale and comparative advantages in both technology and cost are important to achieving scale. It will also be important that international flows deliver high quality designs and end-of-life treatment that is similar to the highest possible EU standards. Otherwise, there may be a risk of waste leakage.

One way to advance this issue in Europe could be by harmonizing "end of waste" criteria across EU member states, in order to facilitate a secondary market for raw materials. Internationally, one option could be to support reforms to the Basel Convention, or other new circular economy cooperation agreements with key trading partners, in order to promote the generalization of high-quality material product design and high-quality global co-processing opportunities. In specific cases, leakage risks may need to be dealt with via limits on exports of waste (and standards on product imports) for countries not adopting standards equivalent to the EU's. However, a full analysis of these issues is beyond the scope of this report.

5.3. Policy options for improving material efficiency in manufacturing and construction

Promote development and early adoption of a portfolio of new, high potential technologies and production processes.

A crucial part of increasing material efficiency is replacing existing technologies with more efficient ones. Many emerging or existing technologies, such as 3D printing, prefabrication of integrated components of buildings, use of Building Information Models (BIMs), materials pass-porting, use of new alternative materials, etc., can contribute significantly to enhancing material efficiency in production. Not all of these technologies, however, are currently mature or cost-competitive enough to replace existing processes. Governments could therefore seek to speed up learning and bring down cost by supporting pilots or early stage commercialisation of these technologies linked to applications in the manufacturing and construction sectors. This could be done as part of a broader industrial strategy in the EU and its member states to gain leadership in these technologies that will likely play an important role in the future economy.

Fund plant refurbishment which run on more material efficient processes through a charge on large consumers of material intensive products.

For more efficient technologies to become commercially viable, there will need to be economic incentives that reward greater efficiency. The EU ETS is unlikely to provide this as carbon prices often cannot be passed on completely (or at all) to buyers of basic materials along the value chain because basic materials producers face international competition and must often apply international prices. However, governments could create other incentives for downstream users of basic materials.

One option could be to apply a small 'materials charge' on the consumption of those goods which use high amounts of basic materials (e.g. cars, trucks, machinery, buildings, etc) based perhaps on a weight/volume ratio of the product. However, the charge should not be set high enough to lead to perverse incentives which result in change in material use purely based on weight (e.g. between steel and aluminium). The collected money could then subsidise the upgrading and early stage commercialisation of material efficient factories and production processes. Companies could be eligible for funds to cover incremental CAPEX (but not OPEX) of materially efficient production lines and process technologies when they invest in new or refurbish existing sites. The receipt of funds could be a competitive tender-based process and reward those process with the highest potential to be scaled up and dramatically reduce materials consumption in the future.

Support the sharing of information and training to reduce material waste.
Governments could facilitate the transfer of knowledge, skills and best practises at a low cost in various ways. This could include:

- Requiring companies in relevant sectors (and over a certain size) to undertake material efficiency audits (as is done for energy efficiency), especially prior to either a major refurbishment of brownfield site or investment in a greenfield site.
- Empowering national agencies aiming at achieving energy efficiency to also focus on material efficiency and provide technical support to government bodies, companies, and consumers to promote material efficiency of basic materials. Tasks could include, for instance, publishing and disseminating studies of best practice cases of the most materials efficient plants and processes, overseeing efficiency implementation of material efficiency policies, etc.
- Training construction engineers and building site managers on best practices to eliminate waste and over-specification of materials in building, production process or product design.

Requiring companies to set goals and report on material efficiency.
The reporting of material efficiency information and setting of targets is crucial to building the capacity of companies to go beyond the status quo. One option could be to require companies in the same sector to report on their material efficiency (e.g. the tonnes of material used per volume of product, and/or energy-weighted tonnes of materials per volume of product[34]). This would force companies to have detailed information on material use and also to investigate ways to reduce it. A second step could be to publicise these data and publicly rank companies producing similar products based on performance.

Setting material efficiency standards to eliminate inefficient production practices.
Once information is gathered on the best and worst performers in terms of material efficiency, governments could potentially use policies like Eco-design, vehicle emissions or energy performance standards, or building codes, to put regulatory standards in place. These would aim to eliminate the most inefficient practices after it gets established that more efficient practices are available and commercially viable.

Building engineers for instance will often over-specify structural requirements by up to 50% or more to save labour costs for construction companies. Governments could potentially require that structural materials not be over-specified by more than 20%. Also, governments could potentially require basic materials companies to accept the return of excess materials purchased, for example, building materials companies to accept the return of excess materials purchased for construction – a common cause of over-use of materials.

[34] The latter variable could potentially help to correct for the different energy intensities of materials with different weights/volume ratios.

5.4. Policy options for raising collection and recycling rates of old scrap

Increasing collection rates of old scrap can be achieved by a number of measures, many of which can be complementary to, or extensions of the measures listed above to limit downgrading of recycled materials. For instance, design that limits contamination can help to reduce the amount of product that goes to landfill or to incineration. Similarly, mandatory deconstruction of buildings or mandatory separation of cement from concrete's components at end-of-life could increase collection and recycling rates of "old scrap" from concrete structures.

In 2018, the EU adopted a waste package which sets out new rules for waste management and establishes legally binding targets for recycling, including a landfill reduction target, and minimum requirements for all EPR schemes. However, better enforcement and implementation will be required since less than 30% of the annual plastic waste in Europe is recycled of which 40% is exported, mainly to Asia. The rest is landfilled, incinerated or leaked into the environment. The revised waste directive also requires more stringent reporting by member states in terms of accuracy, comparability and distinction between open loop down-cycling and true recycling (distinction in recycling end-use could also be useful for future policy making). However, a number of other measures could further help achieve even higher rates of old scrap recycling. Some of the highest potential measures and priorities include:

Public procurement and private sector pledging systems to help ensure demand for increased supply of high quality (and currently uneconomic) recycled materials.

A key issue for raising recycling rates is ensuring demand to offtake the new supply – otherwise the recycled material has little value and recycling activities are dis-incentivised by market forces. One option to do this is through public procurement of innovative circular economy products. Where the issue is one of generating experience, local value chains, and consumer confidence, public procurement could be helpful. Another option to generate confidence in the demand for secondary materials could be by building on the existing pledging system that the EU[35] has helped to create on secondary plastics. If pledges are done in a credible way, they can help to reassure investors in collection of old scrap of demand, at least during the early phases of market development.

To incentivize private sector demand for high-grade secondary materials, governments in Europe should track and label basic materials along the value chain based on GHG content of production.

It is unlikely that official life-cycle CO_2 accounting systems will be able to determine how to score different materials[36]. However, the second-best alternative is to track and label both primary and basic materials products based on their Scope 2 production emissions. Even for products with a significant level of indirect electricity emissions, this would be possible to a significant degree of accuracy. Doing so would help to allow eco-responsible companies to source their materials from low carbon suppliers, thus favouring demand for high shares of recycled content, for recycling using renewable energy, and/or the use of innovative low carbon processes for primary production. In the longer term, such a system could help

[35] European Commission, 2018b

[36] Due to the near-impossibility of getting consensus on the issue amongst decision-makers and the complexities of scope 3 emissions.

prepare the creation of future low-or zero-carbon basic material product standards for a net-zero world (i.e. once decarbonized production processes have reached sufficient maturity).

Creating a durable economic incentive to ensure that recycled products are relatively attractive for users.

In the longer term, however, other incentives will be needed to ensure that the market for recycled materials takes off. One option is to address the relative prices of primary and secondary goods. This might be done by creating obligations for recycling certificates based on mass balance accounting systems and requiring users of certain materials (e.g. cement, steel, aluminium, plastics) to achieve certain quotas for secondary material use. Another long-term option might be to explore obligations for all semi-finished and finished products to contain x% of recycled materials by a certain date (e.g. all plastics produced/used in EU could contain 50% recycled material/feedstock by 2030 and 70-80% by 2050). Such systems would however require the verification of flows crossing the EU border, which would need to be investigated further. Another alternative could be a downstream charge on primary materials that helps to internalize externalities associated with primary material use for certain materials.

Set material quality labelling requirements and require companies to provide quality guarantees for the sale of high purity recycled materials likely to be purchased for high-value usages.

This would help to reassure purchasers of recycled materials that the products they are purchasing are of the necessary purity for use as intended. It would thus also help to overcome the risk of a lack of demand due to quality concerns.

Include waste incinerators in the EU ETS or otherwise tax their emissions at the level of the EU ETS carbon price.

Much potentially re-usable and recyclable waste is incinerated. This could be prevented by shifting incentives against incineration. Another key challenge is that CCU is emerging as a potential option for some industries like plastics as a way to reduce their upstream emissions. However, this creates a risk of regulatory arbitrage and carbon leakage: companies could in theory avoid paying a carbon price when carbon would otherwise be emitted by putting it into plastics instead, only to avoid paying a charge when the carbon is released at incineration at end-of-life. One option to tackle these concerns with a single policy could be to include waste incinerators in the EU ETS, or, if not, then to tax them at a meaningful level equivalent to the social cost of carbon and other local environmental externalities from waste incineration.

Regulations or tax incentives to generalise the recycling of cement from building sites.

This could be done through mandatory separation of concrete components wherever cement is likely to still be reusable as a binder. Given that current technologies now exist, there could a new requirement that, as a default rule, cement that can be expected to be active if separated from concrete, must be separated from concrete and recycled as cement. If regulations are initially a rather heavy-handed approach, taxes on disposal without cement recycling could be imposed.

Introducing or enlarging the number of basic material-containing products covered by deposit-refund systems.

Deposit refund schemes[37] for plastic, aluminium or glass products work by creating a transaction with the consumer, thus promoting recycling and helping to reinforce the idea amongst consumers that correct treatment and allocation of end-of-life waste is important. Such schemes already exist in many northern European countries for some products, such as glass or plastic bottles. This can not only reduce misallocated waste but also facilitate closed loop recycling of certain containers. The schemes can sometimes be combined with taxes on non-recycled containers or contributions from retailers and/or recycling of funds from unclaimed deposits to fund themselves.

Modulate ADFs and recycling targets on plastics to favour greater use of closed loop recycling (rather than incineration) of plastics.

Most of the recycled plastic is recycled "thermally", i.e. plastic burned in incinerators. Often this is done due to contamination of products at design, during use, or disposal. Much stronger incentives for plastic product designers to design for closed loop recyclability is necessary. Policy targets for plastic recycling will also need to be defined so that thermal recycling is not counted as part of total "recycled" plastic, and recycling enterprises are dis-incentivised from thermal recycling except in unavoidable cases.

Revise product bans of single-use or litter-prone products as alternative become available.

As the EU has already shown with single-use plastics, in some cases there may be new alternatives that can be used instead of once-through/singe-use plastic or aluminium options. Governments should therefore continually review the list of once-through consumer goods that could be targets for product bans, as new alternatives become available.

Continue to simplify, harmonise, and refine national and local government recycling rules and labelling schemes to simplify waste separation for customers.

Most consumers still struggle to understand what goes in which bin. Another condition for keeping plastics out of landfill is by making rules for disposal simpler for consumers of plastic containers and packaging and requiring less separation prior to end of life collection.

Provide innovation support and develop meaningful economic incentives for chemical recycling of plastics.

Material Economics[38] notes significant potential for chemical recycling of plastics which cannot otherwise be mechanically recycled. Support for the trialling and development of innovative chemical recycling solutions may be needed to help bring this technology forward as a back-stop solution. Moreover, to develop fully, chemical recycling would need to become more economically advantageous than incineration or landfill or other low-value recycling for recyclers. In practice, this may not always emerge as a solution based on market incentives. Policy targets and mandates for recycling entities would probably therefore need to reflect upon the inclusion of chemical recycling as an option to be prioritised above landfill,

[37] Consumers pay a small deposit for purchasing a product with a plastic or aluminium or glass container and can have it refunded upon return to either retailers or collection machines.
[38] Material Economics, 2018

incineration and potentially low-value mechanical recycling options. Ensuring that incentives match the hierarchy of alternatives to maximise the preservation of material value is therefore key.

OVERVIEW TABLE

Circular Economy and materials efficiency instruments	
Options for enhancing the quality of recycled materials to preserve material value	• Requiring recyclers of basic materials to do more precise sorting based on of the quality of materials in the end of life products that they receive. • Setting recycling quality targets on companies to increase the shares of high purity secondary basic materials in total recycling quantities. • Ban or tax the demolition of buildings and shredding of vehicles and heavy equipment. • New design requirements on products to facilitate high value recycling. • More meaningful fees and modulation rates ADF under EPR schemes to penalize difficult to recycle products. • Finance for pilots of innovative technologies that help to preserve material value during design, deconstruction processes, advanced recycling processes, and decontamination systems for de-contaminable waste. • Ensure that national waste taxation and EPR schemes incentivize decontamination and chemical recycling, for the relevant product niches. • Support workforce training and remove regulatory barriers to economies of scale. • Identify local regulatory barriers that can exist which block the development of economies of scale in recycling. • Facilitate the creation of pan EU and international markets for high quality secondary materials and product designs.
options for improving material efficiency in manufacturing and construction	• Promote development and early adoption of a portfolio of new, high potential technologies and production processes. • Fund plant refurbishment with more material efficient processes with a charge on consumers of material intensive products. • Support the sharing of information and training to reduce material waste. • Requiring companies to set goals and report on material efficiency. • Setting material efficiency standards to eliminate inefficient production practices.
Options for raising collection and recycling rates of old scrap	• Public procurement and private sector pledging systems to help ensure demand for increased supply of high quality (and currently uneconomic) recycled materials. • To incentivize private sector demand for high-grade secondary materials, governments in Europe should track and label basic materials along the value chain based on GHG content of production. • Creating a durable economic incentive to ensure that recycled products are relatively attractive for users. • Set material quality labelling requirements and require companies to provide quality guarantees for the sale of high purity recycled materials liable to be purchased for high value usages. • Include waste incinerators in the EU ETS or otherwise tax their emissions at the level of the EU ETS carbon price. • Regulations or tax incentives to generalise the recycling of cement from building sites. • Introducing or enlarging the number of basic material-containing products covered by deposit-refund systems.

	• Modulate ADFs and recycling targets on plastics to favour greater use of closed loop recycling (rather than incineration) of plastics. • Revise product bans of once-through or litter-prone products, as alternative become available. • Continue to simplify, harmonise, and refine national and local government recycling rules and labelling schemes. • Provide innovation support and develop meaningful economic incentives for chemical recycling of plastics.

Creating competitive lead-markets for low-CO_2 solutions

- *Assist with development and coordination of (national) support instruments for low-CO_2 production solutions*
- *Remove existing barriers for low-CO_2 solutions in standard setting and standard formulations*
- *Make better use of EU procurement package to promote low-CO_2 solutions, improve coordination on procurement in the EU and link procurement to low-CO_2 standardisation*
- *Consider a smart set of policies to protect EU industry in transition such as green public procurement and trade defence instruments if possible and where necessary.*

6. Creating competitive lead-markets for low-CO_2 solutions

6.1. Introduction

To ensure that low-CO_2 solutions find a market and hence justify upstream investments and allow for incremental innovation and cost reductions four areas can be considered. First of all, instruments that make these options competitive through pricing support. Secondly by looking at standards that facilitate access to the market. Thirdly by using public procurement to gain market entry and finally by considering the global trade environment.

6.2. Making low-CO_2 solutions cost competitive

Financial support for low-CO_2 production technologies

Some low-CO_2 solutions e.g. basic materials produced with breakthrough technologies will be more expensive compared to production with incumbent technologies. This price difference can become smaller over time as more experience is gained with new production technologies and these become incrementally more cost-efficient. For this learning curve to materialise however, sufficient demand for the low-CO_2 products must exist in the first place.

Under the EU ETS, low-CO_2 processes will have a natural advantage, but this might not be sufficient. First of all, the CO_2 price is not always or not always fully passed through, in particular for products that compete on a global market and therefore products with lower CO_2 costs might not see an economic advantage. Secondly, low-CO_2 products might still be more expensive even if the CO_2 cost under the EU ETS is fully passed through. This points to the need for additional instruments that help producers to launch low-CO_2 solutions at a cost competitive price.

One option is to support the production of basic materials (e.g. steel, chemicals, cement) with significantly lower emissions. At least two different mechanisms can be considered, First, producers of basic materials using new processes with low or no CO_2 emissions can get a fixed premium per unit (e.g. tonne) produced. Such support would be calculated as the price difference between the production of materials with incumbent processes and the production of the same with low-CO_2 processes. In practice, different premiums will have to be applied for different materials and likely for the different alternative processes. Fixing such premium for a longer period does risk subsidising the new technologies too much or too little due to market price fluctuations of basic materials.

Second, a low-carbon project could sign a contract for difference with a national public authority on the carbon price for the scale of emissions saved compared to the benchmark of a conventional technology. This secures a stable price per tonne emission savings delivered by the plant and thus stabilizes the revenue stream, making it bankable for financing incremental investment costs. It also secures the operation of a climate friendly production process against carbon price uncertainties. If desired, the reference price (strike price) of the project-based contract for difference can be set above current carbon price levels to provide a credible signal of government expectations regarding long-term carbon price developments. Third, rather than providing support linked to operation of low-carbon processes the investment can be supported through tax credits. Companies can deduct the amount from the annual corporate taxation and may also be allowed to carry over these tax credits to a later year. While less targeted, tax credit-based systems are attractive for policy makers that may not need to make explicit the funding made available and more attractive for large incumbent companies as they can better utilize tax credits than smaller or new entrant companies.

Implementing these types of production support will not be straightforward. First of all, all of these support mechanisms need to be anchored at the national level – linked to national funding options, the capacity of countries to underwrite contracts for difference, and national taxation systems. Hence mechanisms to provide early convergence are desirable and could be linked to EU state aid guidelines and clearing processes or requirements to qualify for complementing EU innovation funding.

Secondly, designing these instruments can be technically challenging. Given the fact that a carbon price is already in place in the EU, incremental innovations in existing installations should be excluded from subsidies because they could benefit from surplus allowances when emissions fall below allocation. It may also be warranted to focus the support on processes and materials compatible with 2050 net carbon neutrality scenarios and therefore exclude incremental innovations in existing installations (e.g. require at least -50% emissions compared to benchmark). New breakthrough process installations will likely be considered new entrants to the EU ETS, making them eligible for freely allocated allowances. The possible valorisation of the difference between CO_2 emissions and allocation based on ETS benchmarks will have to be taken into account when considering additional production subsidies.

In reality, things will be even more complicated. Not all breakthrough technologies will be in the form of new stand-alone processes. In some cases, it will be innovative technologies that are retrofitted into existing installations already covered by the EU ETS. Also, in this case, additional production subsidies will have to be measured against possible benefits arising from a surplus in allowances resulting from the new technologies.

Last but not least, some new low-CO_2 production technologies producing the same products might fall outside of the scope of the EU ETS. For instance, alternative routes to produce H_2 are likely not covered by the EU ETS as are some new techniques to produce bulk chemicals. These new processes will hence not be eligible for free allowances or benefits from a lower CO_2 exposure. It could hence be recommended that the *scope of the EU ETS is reviewed* with an eye on including new process technologies that are in the pipeline. This would lessen the extent of production subsidies needed for these innovative processes.

It is hence clear that the impact on EU ETS free allocation must be a factor to be taken into account when considering additional production subsidies, in particular possible benefits arising from lower exposure to EU carbon pricing or even the value of possible surplus of allowances. Only when possible benefits under the EU ETS do not suffice to cover additional production costs additional support can be considered. Production subsidies must also be limited in time. They must cover a period long enough to make the investment in new processes economically justifiable but must avoid windfall profits. It is therefore recommended that technology costs are evaluated on a regular or even case by case basis. A first of a kind installation will require higher support compared to the second and third of a kind.

To avoid regulatory uncertainty following differentiated implementation of the above type of measures at member state level, it is recommended that the European Commission, as part of *new environmental state aid guidelines*, provides a clear and stringent framework (including technical requirements) under which such production subsidies are allowed.

Inclusion of consumption in the EU ETS to secure carbon price pass through

While providing support for low-CO_2 technologies is necessary for innovation, it is not sufficient to create demand and therefore a business case for investing in innovation. An important issue emerging from the experience across emission trading systems worldwide is that the pass-through of the CO_2 price is limited for basic materials due to a combination of two effects. First, basic materials are traded or can be traded internationally. Producers that increase prices of steel, cement or plastic to reflect carbon costs to the order of for example EUR 50 per tonne would likely risk significant market shares to international competitors. To avoid the risk of such re-location of production (carbon leakage) free allowances are allocated proportional to production volumes in recent years and conditional on activity level thresholds, thus further reducing incentives for carbon price pass through.

Inclusion of consumption in the EU ETS works by eliminating the pass-through of opportunity costs completely through output-based allocation and by reinstating the carbon price at the end of the value chain.

First, to mute pass through of opportunity costs of CO_2 allowances, free allowance allocation at the benchmark level is directly linked to production volumes. A steel producer obtains roughly two allowances for every ton of steel corresponding to the emissions of a best available steel plant. With allowance allocation no longer linked to historic but to current production volumes, producers no longer have the opportunity to reduce production and sell the freely allocated allowances. Without this opportunity, producers will no longer pass the opportunity cost of freely allocated allowances to product prices. Producers only need to acquire allowances to cover emissions above the benchmark level, corresponding to typical inefficiencies of 5-10% and will at most pass these costs to material prices. Such a dynamic (or output-based) allocation of allowances is already practiced for material production covered in the emission trading system in the West Coast of North-America as well as in intensity-based allocation systems in Chinese emission trading pilots.

To reinstate a muted carbon price pass-through, a consumption charge is levied for materials delivered to European consumers. For a car with 0.5 tons of steel, this charge would be calculated based on the benchmark emission rate (ca. 2 tons of CO_2/ tonne of steel) and the average CO_2 allowance price of the preceding year. At a carbon price level of EUR 50 per tonne CO_2, the charge for the steel in the specific car would thus be EUR 50. Such a charge applies to all cars sold in Europe – irrespective of the origin of the car or of the steel in the car, or of the production process of the steel. The administrative implementation builds on procedures established for other consumption charges. Monitoring and compliance mechanisms are comparatively simple, as no party can receive payments from the system (the usual channel for VAT fraud). Thus, public and private administrative efforts are also moderate. With the design as consumption charge, WTO compatibility can also be ensured. As a mechanism to reinstate the full carbon price pass through including the link to EU ETS benchmark, EU ETS allowance price and allocation of proceeds to national trust funds, the consumption charge can be integrated into EU ETS environmental regulation, perhaps in the context of review provisions in the preamble of the EU ETS directive.

The coverage can be limited to materials responsible for large carbon emissions, if all materials are covered that compete in major applications. Focus could for example be on steel, aluminium and cement(clinker) as well as plastics, pulp and paper.

The distributional effects of any full carbon cost pass through can be addressed with a per head reimbursement of a part of the charge to citizens. This would turn the system into a "climate deposit"– paid with the use of carbon intensive materials – which benefits poorer households with lower levels of material consumption as they will obtain the same repayment as households with larger material purchases.

Overall, the system ensures full carbon price incentives for producers - through the upstream ETS – and for actors in the value chain - through the consumption charge. In addition, it avoids uncertainty about future carbon-leakage protection. This makes EU ETS stronger and more credible, in increasing the risk of continued reliance on carbon intensive options and in creating market opportunities for carbon friendly choices. In addition, some of the revenues acquired from the consumption charge (climate deposit) can be dedicated to cover incremental costs of innovative low-carbon processes and materials such as the production subsidies that were mentioned before.

6.3. The use of standards to gain market access

Standards[39] play an important role in ensuring that products entering the market are safe and fit for purpose. Standardisation as a policy instrument can support market uptake of low-CO_2 products by enabling them to access the European single market through updated product standards, by promoting low-emitting products (e.g. through labelling or green public procurement criteria), or by removing high-emitting products from the market (e.g. through Eco-design and CO_2 inclusion criteria). However, the level of ambition of many European standards is currently relatively low, as most of their focus lies on safety and functionality rather than environmental considerations. Furthermore, existing standards have different levels of impact and environmental relevance depending on whether they are used in EU or national regulations, as compared to when they codify industry practices in a certain sector. Significant improvements could be implemented through reforms in the standard setting procedures, reforms in formulation of standards and through the promotion of voluntary standards, labelling and certifications.

Reforms in standard setting procedure

The latest "EU Standardisation Package" launched in 2016 calls for a single and adaptive standardisation policy. Yet, the administrative burden of the standardisation process can

[39] European Commission, 2019b

hamper innovative low-CO_2 products from entering the market, due to the long and cumbersome procedure of standard-setting, as well as the influence of incumbents.

Innovation requires flexibility and a swift legislative and standardisation procedure. Yet, standard-setting through recognised standardisation bodies such as CEN and CENELEC often takes several years. Moreover, these standards are, in practice, not revised often enough to ensure that they are up to date with technological innovations. By introducing flexibility, streamlining the legislative and standardisation process and ensuring a better coordination between policy tools, the administrative burden for newcomers and general resistance to change can be limited.

Today, most European standards are developed behind closed doors[40], and a seat at the table can be purchased for a fee. Similarly, the developed standards are available behind a pay-wall[41]. This lack of transparency is a hurdle for small, innovative firms who are not yet established on the market. Consequently, incumbent materials producers may often have a strong influence over the standardization procedure, which can hamper innovation. A requirement to involve experts from various stakeholder groups in the stardard development procedure could prevent a lock-in towards business-as-usual and foster innovation.

Reforms in standard formulations

The inclusion of efficient materials use or labelling in building standards can enable new demand-driven business models to emerge in the basic materials industries.

Existing standards that hamper market access for low-CO_2 products must be redesigned and formulated so that they do not hamper low-CO_2 innovation. Performance-based standards are successfully applied for some products and allow for such innovations to be measured in the same way as existing products[42]. However, standards for example for cementitious products (EN 197-1) are prescriptive rather than performance based[43], which excludes low-CO_2 innovations in favour of existing products[44].

Data-collection of LCA-based environmental footprint of products would be facilitated through the introduction of an EU-wide database on the environmental footprint of energy intensive manufacturing products. Such a database could be based on LCAs and be designed analogous to the Level(s) tool for measuring building sustainability performance in the construction sectors[45]. The gathered data could be used in standards or labelling schemes (see below).

There is currently no LCA-based EU instrument available to "score" the best-performing construction products based on their environmental performance. The introduction of an Eco-Label for construction products could improve transparency and drive competition based on low-CO_2 criteria. Furthermore, mandatory carbon inclusion criteria can include transparency

---

[40] CEN/CENLEC, 2019a
[41] CEN/CENLEC, 2019b
[42] Swiss Federal Institute of Technology (ETHZ), 2018. p.48
[43] Wesseling & Van der Vooren, 2016
[44] Kemp et al, 2017
[45] European Commission, 2019c

towards customers. The ongoing work on LEVEL(s)[46] a voluntary reporting framework that provides a common "sustainable" language for the buildings sector can lead to such a common LCA instrument. It offers a set of simple metrics for measuring the sustainability performance of buildings throughout their life cycle. It encourages life cycle thinking at a full building level and is a comprehensive toolkit for developing, monitoring and operations, and also supports improvement from design to end-of-life. This approach can facilitate the use of labels or criteria by public procurers wishing to promote low-CO_2 solutions, which is discussed in further detail in section 6.4.

Ecodesign requirements could be adopted for construction products with an impact on energy consumption (e.g. insulation, windows) and the scope of the Eco-design Directive should be extended to cover non-energy related products. By introducing Ecodesign requirements for construction products, a benchmark can exclude the worst-performing products from the market and promote upward innovation in the sector. This can be complemented by a mandatory Energy Label on relevant products (e.g. windows).

Promotion of voluntary standards, labelling and certifications

Provided the criteria are ambitious and regularly reviewed to fit with potential technological developments, voluntary schemes beyond the *de facto* binding EU construction product standards have the potential to drive best practices and create an incentive for industrial actors to improve their environmental performance.

These can be private labels developed by the industry itself (see e.g. Responsible Steel[47]) or by third-party actors (see e.g. Blue Angel[48]). However, they remain voluntary and their success depends on how ambitiously the standard is formulated, as well as how popular the scheme is.

6.4. Public procurement as driver for low-CO_2 products

The EU legal framework for public procurement allows for procurement based on low-CO_2 criteria, and member states are free to increase their ambition beyond EU recommendations. Some countries have adopted a more ambitious procurement strategy, and some best practices of low-CO_2 procurement can be found, for example, in The Netherlands[49][50] and Sweden[51]. However, such practices are still underutilized as a strategic tool to drive a low-CO_2 transition, for example in large infrastructure and buildings projects[52]. European policy makers could improve public procurement practices across the EU by making better use of the existing Public Procurement Package, by improving coordination on the EU level, and by linking public procurement to low-CO_2 standardisation.

[46] JRC, 2017
[47] Responsible Steel, 2019
[48] Blue Angel – The German Ecolabel, 2019
[49] DuboCalc, 2019
[50] CO_2 Performace Ladder, 2019
[51] See Upphandlingsmyndigheten, 2015
[52] IISD, 2016

Make better use of the Public Procurement Package (2017)

The European Commission acknowledges green and circular public procurement as a driver of the transition towards a circular economy and sustainable development[53]. Existing policies and instruments must be used more frequently to ensure dissemination of best practices and to make innovative and green public procurement common across all member states.

Additionally, it could be made mandatory in tenders to define "value-for-money" as "value-for-money across the lifecycle of the asset" i(n tender specifications), for example, by using Most Economically Advantageous Tender (MEAT) definitions[54].

Moreover, performance-based bidding must be further incentivized. Current public procurement norms do not encourage public procurers to think in terms of innovation or sustainability when they construct their tenders. For example, current practices generally focus on formulating tenders that ask suppliers to deliver a product (e.g. a bridge), rather than a performance (e.g. transporting cars across a river), even if the latter would enable inclusion of innovations with a lower climate impact. It would be useful to make it mandatory for member states to develop and use performance-based procurement tools for assessment of bids (see for example DuboCalc[55] and the CO_2-performance ladder[56], both developed and used in the Netherlands and the C- E+ label developed in France[57]), by requiring member states to promote the use of existing tools; or to develop member state-specific tools if existing tools are not applicable in the member state.

Improve coordination on EU level

There are many different initiatives in place already, but they all take different perspective on the same issue. There is an urgent need for a permanent EU Public Procurement Task Force that works to enhance public procurement practices that are coherent with societal value for taxpayers' money. The task force should be permanent, and function similarly to the current Public Procurement Working Group that is in place to carry out the Public Procurement Action Plan in the context of EFSI 2014-2020[58]. The task force should aim to improve EU-level work on public procurement, provide a coherent standing point to member states and local actors, and support knowledge building among procurers.

Rendering it obligatory to include a sustainability quota in EU funding schemes, such as in purchases of large-scale projects (e.g. "Projects of this scale must have at least XX% of their materials from sustainable sources") would go a long way. Infrastructure projects that are financed in part by European Investment Bank (EIB) funds or with EU infrastructure funds, should be obliged to take into account sustainability criteria. Furthermore, the new Multiannual Financial Framework (MFF) 2021-2027[59] must include an ambitiously set minimum quota for sustainable spending and put strong emphasis on the value of low-CO_2 innovation in EU public procurement.

---

[53] European Commission, 2019d
[54] European Commission, 2015, p.44 | European Commission's (not yet mandatory) "Guidance for use of MEAT"
[55] DuboCalc, 2019
[56] CO2 Performace Ladder, 2019
[57] http://www.batiment-energiecarbone.fr
[58] European Commission, 2019e
[59] Ibid.,

A chunk of EU funding should furthermore be earmarked for collaborative projects on public procurement. Knowledge and confidence among procurers across the EU could be improved, through mentorship programmes, national and international trainings and EU-wide campaigns. Investigating EU-level "matchmaking" projects, similarly to the national initiative Green Deals[60] would also be favourable. There is therefore a need to earmark funding for projects in which procurers undertake a collaborative approach through the full procurement cycle[61], as demonstrated for example in the Netherlands[62].

A permanent EU program for training and application of "Innovation brokers" (a third-party EU service that can provide assistance and guidance in the procurement process) must be put in place[63]. The concept can build upon the existing two-year project on innovation brokers, funded by COSME 2018-2020[64].

Furthermore, the successful and ambitious use of sustainable public procurement practices must be rewarded through financial instruments. For example, fiscal incentives (e.g. tax deduction on innovative or green products) could change risk averse procurement practices and encourage more ambitious use of incumbent legislation at the EU, national and regional levels. The same mechanisms would also be compatible with bilateral trade agreements that would enable further market upscaling of low-CO_2 innovations.

Link low-CO_2 public procurement to low-CO_2 standardisation

The aforementioned standardisation reforms and public procurement are closely interlinked. Even in cases where accurate and useful consumer information have generated adequate awareness of low-CO_2 benefits, there is often the fear of using new, not-so-widely-tested products. European and national legislations must be designed to help Europe overcome this risk-awareness in order to both support and upscale the uptake of low-CO_2 innovations in the basic materials sector. Using low-CO_2 standards in public procurement can provide guidance on how to overcome this risk-awareness.

6.5. Competitive low-CO_2 solutions in a global market

Most European producers of basic materials compete in a global market or with producers in countries at the EU's border. It is hence not straightforward to bring low-CO_2 solutions to the market where they have to compete with products with a higher CO_2 footprint but at a lower price. The instruments to deal with this challenge, considered here, include:

- The use of public procurement and standards, building upon the previous sections,
- Border adjustments,
- The EU's trade defence instruments and future Free Trade Agreements (FTAs), and
- Protection of Intellectual Property (IP) funded by the EU.

[60] Green Deal, 2019
[61] Examples of innovation in all steps of the procurement cycle see: Wuennenberg & Casier, 2018
[62] See also Ministerie van Infrastructuur en Waterstaat, 2015 for examples of performance-based collaborative approach from the Netherlands:
[63] IISD, 2016
[64] European Commission, 2019f

Public Procurement

Keeping or creating a level playing field for low-CO_2 products will be important in order to stimulate investments in new products and processes in Europe. Public procurement can be an important starting point. Public authorities can, when procuring infrastructure, buildings or other goods, set GHG standards or benchmarks for the materials that are used in the construction or assembly processes. For instance, all materials used could be produced with CO_2-eq emissions x% below the EU ETS benchmark. This standard would apply identically to both domestically produced as we all as imported materials. This approach is currently being developed in the state of California[65].

Standards

A more comprehensive approach would be the introduction of carbon content standards on important final goods (e.g. cars). Such standard would set a limit on the CO_2 intensity or absolute CO_2 emissions of the materials used in the construction or assembly. This would not only create local demand for low-CO_2 products but also be applicable to imported goods. Instruments that could be considered include for instance an extension of the eco-design directive towards embedded CO_2 emissions (see 6.3.). A similar or more comprehensive standard can be set to include over-all materials efficiency and use of recycled materials. Designing these standards can be technically challenging and will require a solid certification and accreditation system, in particular to monitor the embedded carbon in imported goods. However, the introduction of the REACH (the registration, evaluation, authorisation and restriction of chemicals) directive has shown that the EU can impose complex certifications on a wide range of materials including imports.

Border adjustments

Adjustments for EU internal carbon pricing at the border has been debated for over a decade but did not progress either politically or practically. Currently, the main instruments to protect trade exposed sectors from international distortion of competition due to the EU ETS are free allocation and compensation for indirect costs (i.e. increase in electricity prices due to EU ETS). Hence, a border tariff on imported materials that simply charges the equivalent of the EU ETS carbon price would overshoot.

Theoretically, the benchmarking approach for free allocation could be extended to imports, with importers being obliged to purchase or pay for allowances if their products have a higher CO_2 intensity compared to the EU ETS benchmark or benefiting if the intensity is lower. However, this will require a credible certification system for the CO_2 intensity of imported goods. It will also be impossible to apply it to all imports which contain materials produced by sectors covered by the EU ETS. It could be applied to basic materials such as steel, cement and basic chemicals. However, even this would be challenging due to the wide range of products (e.g. different steel types) that already exist within this limited scope. It is therefore recommended for the European Commission to first perform an exhaustive feasibility study on how to extend the EU ETS to imported goods. This would include assessing the technical requirements, the legal design including WTO rules compliance and the pareto optimal coverage of imports. As mentioned before, via the 'inclusion of consumption in the EU ETS' a rudimentary application of this system would apply to a selection of imports.

[65] Gov. of California, 2017-18

As mentioned before the ‘inclusion of consumption in the EU ETS’ would introduce a basic tariff applicable to goods sold inside the EU, but would not differentiate between the CO_2 intensity of the materials itself, e.g. the consumers pay the same tariff regardless of whether the material is produced with low or high CO_2 intense processes. It would, however, stimulate a less materials intensive consumption.

Trade defence instruments and future FTA’s

Europe’s trade defence instruments have recently been modernised and now do include elements related to environmental protection. The three main instruments in trade defence (i.e. anti-dumping, anti-subsidies and safeguards) could be further refined and extended to include climate protection[66].

Dumping occurs when manufacturers from a non-EU country sell goods in the EU below the sales prices in their domestic market or below the cost of production. If the Commission can establish – through an investigation – that this is happening, it may correct any damage to EU companies by imposing anti-dumping measures A new dumping methodology is used when it is not appropriate to use domestic prices or costs due to significant distortions resulting from state intervention. In such instances other benchmarks reflecting undistorted costs of production and sale will be used. These could include benchmarks, or corresponding costs of production and sale in an appropriate representative country with a similar level of economic development as the exporting country. These benchmarks could in theory also include assessments with regard to cost carried by producers to mitigate greenhouse gas emissions. This principle has already been established in the acceptance of ‘price undertakings’, i.e. where an exporting producer gives a commitment to raise its export prices as an alternative to paying duties, where the price rise eliminates the injurious effect of the dumping or subsidisation. The calculation of the injury margin (i.e. the duty level which would be sufficient to remove the injury suffered by the EU industry) will better reflect the cost of social and environmental standards within the European Union. The cost of production also includes costs that EU producers incur when complying with multilateral environmental agreements and with important International Labour Organisation conventions. Furthermore, when circumstances change in exporting countries relating to social and environmental standards the Commission can initiate interim reviews. For instance, where a country withdraws from an agreement, such as the Paris climate agreement, an interim review of the measures could be appropriate, and undertakings can be terminated.

Subsidisation[67] happens when a non-EU government provides financial assistance to companies to produce or export goods. The Commission is allowed to counteract any trade-distorting effects of these subsidies on the EU market – after an investigation into whether the subsidy is unfair and injuring EU companies. Future review of trade defence instruments could consider if the lack of climate protection measures in a certain industry in non-EU countries can be considered a trade-distorting subsidy since it relieves these producers from internalising an external cost related to climate change.

[66] European Commission, 2018c

The third trade defence instrument, safeguards, are not taken to address unfair trade practices. Rather they are concerned with imports of a certain product that increase so suddenly and sharply that EU producers can't reasonably be expected to adapt immediately to the changed trade situation. It can be argued that 'carbon leakage' could be an example of such increase in imports of certain products. However, this will have to be proven first and fulfil all the criteria[68] to be applicable. Safeguards could, if conditions are demonstrated, be the legal option for introducing (temporary) border adjustment instruments, including the argument that EU industry will require time to adjust or transform e.g. through innovation and investments.

Keeping a level playing field does also imply not facilitating easier access to the European market for products from countries that have not signed or ratified the Paris Agreement or have withdrawn from the agreement. In practice this could mean not engaging in Free Trade Agreements (FTA's) with these parties or within these FTA's inserting a waiver for strategic industries that are subjected to carbon pricing in the EU. The EU also has a string of high-ambition FTA negotiations underway with some of the biggest markets i.e. India, ASEAN, Australia-New Zealand and even the US (contravening the above-mentioned point), they focus mainly on reducing duties but remain weak on aligning climate protection measures.

Conditional IP investment protection

Finally, a significant amount of EU public money (e.g. Horizon 2020, Horizon Europe) is being used to develop intellectual property (IP) in the area of innovative low-CO_2 industrial processes. Some of these new processes will be more efficient and hence more competitive compared to incumbent technologies. While it would be beneficial for global climate protection to see these technologies diffuse globally, they should not be used outside the EU to gain a competitive advantage compared to European producers due to the absence of national climate policies. In this regard, the default approach could be that EU (co-)funded climate protection IP cannot be applied outside the EU unless there is a bilateral agreement with country of destination to do so. This agreement can, but in the case of developing and least developed countries does not necessarily have to, contain provisions to secure similar or equivalent climate protection measures. The United States applies such restrictive use of publicly financed R&D (e.g. in energy innovation) as part of the US COMPETES act and the Advanced Research Projects Agency – Energy.

[68] EU has to show that the increase in imports is sharp, due to unforeseen developments, causing (or threatening) serious injury to domestic industry and that safeguards are in the interest of the EU. Furthermore, safeguards will apply to all such imports from all countries.

OVERVIEW TABLE:

Instruments to create lead markets	
Making low-CO_2 solutions cost competitive	• Subsidies for low-CO_2 production technologies through premiums, contracts for difference or tax reductions and taking into account EU ETS impacts • Extension of EU ETS scope with low-CO_2 processes • Inclusion of consumption in the EU ETS to secure carbon price pass through
The use of standards to gain market access	• Reforms in standard setting procedure: introduce flexibility and streamline the legislative and standardisation process, ensure a better coordination between policy tools, involve experts from various stakeholder groups in the standards development process • Reforms in standard formulations: Inclusion of efficient materials use or labelling in building standards, redesign existing standards that hamper market access for low-CO_2 products, EU-wide database on the environmental footprint of energy intensive manufacturing products based on LCAs and be designed similarly to the Level(s) tool, Introduction of an Eco-Label for construction products, eco-design for construction products and extending the scope of the Eco-design to non-energy related products • Promotion of voluntary standards, labelling and certifications
Public procurement as driver for low-CO_2 products	• Make better use of the Public Procurement Package (2017) by improving coordination on EU level and by linking public procurement to low-CO_2 standardisation • Improve coordination on EU level: By setting up a permanent EU Public Procurement Task Force that works to enhance public procurement practices that are coherent with societal value for taxpayers' money • Obligatory sustainability quota in EU funding schemes • Earmark EU funding for collaborative projects on public procurement • Permanent EU program for training and application of "Innovation brokers" • Fiscal Incentives to reward successful and ambitious use of sustainable public procurement practices • Link low-CO_2 public procurement to low-CO_2 standardisation
Competitive low-CO_2 solutions in a global market	• Public Procurement: set greenhouse gas standards or benchmarks for the materials used in the construction or assembly processes applicable to both domestically produced as imported materials. • Standards: introduction of carbon content standards on important final goods (e.g. cars) considered for instance an extension of the eco-design directive towards embedded CO2 emissions • Border adjustments: Detailed assessment of the technical, legal and practical applicability of this instrument • Assess possibility of updating trade defence instruments: use benchmarks in new Anti-Dumping Methodology which in theory also include assessments with regard to cost carried by producers to mitigate GHG emissions. Consider if the lack of climate protection measures in a certain industry in non-EU countries can be considered a trade-distorting subsidy (subsidation). Investigate use of safeguards as the legal option for introducing (temporary) border adjustment instruments • Free Trade Agreements: Avoid engaging in FTAs with parties that have not signed or ratified the Paris Agreement or have withdrawn from the agreement or within these FTA's insert a waiver for strategic industries that are subjected to carbon pricing in the EU. • Conditional IP investment protection: Restricting the application of EU (co-)funded climate protection IP outside the EU.

Aligning the energy and industry transition and enabling infrastructure for industrial transition

- *Develop joint industry-energy transition strategy including a joint impact assessment*
- *Further develop or refine supply and demand side instruments to secure sufficient, adequate and competitive electrification of industry*
- *Map the needs for transition infrastructure, starting bottom-up from large industrial clusters*
- *Formulate a strategic infrastructure investment plan*
- *Ensure economic cohesion in Europe during transition*

7. Aligning the energy and industry transition and enabling infrastructure for industrial transition

7.1. Aligning the Energy and industry transition

The transition of industry will have an important impact on the energy sector with industrial electricity demand increasing significantly and industrial demand (direct and indirect) becoming the single largest electricity consumer over the next decades. On the other hand, the transition of the power sector towards high levels of renewable energy can impact industry on e.g. with regard to cost and reliability. Both transitions will occur over the same period.

Managing this joint transition will require the development of an integrated strategy which has the goal to create a virtuous cycle between the energy and industrial transitions. Otherwise said, how can both sectors assist each other to facilitate the transition to a climate-neutral industrial-energy system? It is recommended that a joint industry-energy inter-service taskforce be established within the European Commission, and, together with (input from) member state experts, develop such an integrated strategy which can contain the following elements:

- A detailed impact assessment of the industrial transition on the energy sector and vice versa at national, regional and EU levels,
- Assess supply side instruments that can facilitate higher, reliable and competitively priced access to renewable energy for industry,
- Look at support for demand side instruments that can help the development of new industrial business models in an energy system with high levels of renewable energy, and
- Provide solutions for the competitiveness of electro-intensive processes during the transition period.

Joint and forward-looking impact assessment

Such joint impact assessment would work through the transition from a (sub)national level and identify possible issues related to the adequacy of the energy system, taking into account the likely higher electricity demand from industrial sectors. This includes security of supply, greening of electricity supply, possible grid capacity and infrastructure bottlenecks, etc. Ideally, this assessment of the coupled sectoral transition should become a part of the next round of national energy and climate plans (NECPs). As with the NECPs, it is important to also assess the transition at regional level. The information provided by member states would help identify the required additional national and regional investments and investments supported by for e.g. the Connecting Europe Facility.

Supply side instruments

Because industry can or will be the future driver of additional electricity demand it is important to consider facilitating industrial purchase of low-carbon electricity. Green Power Purchase Agreements (PPA's) by industry are becoming more popular given their longer-term nature and hence a form of price predictability. For energy investors, these are attractive because they represent a guaranteed purchase for a longer time and hence reduce the risk and cost of capital. It is relevant to further investigate how these types of longer-term contracts can be further stimulated at national and EU level. Furthermore, over time new industrial-energy business models might arise such as industrial production of H_2 or ammonia linked to offshore wind production.

Demand side instruments

On the demand side, it is likely that industry will start playing an important role in energy services such as demand response and (seasonal) energy storage. These new business models will be extremely important for industry to face energy production which can be more intermittent and/or with a higher price volatility. New power market design rules can facilitate the development of these business models. Further R&D support for industrial demand response and storage (e.g. power to X) will be essential to accelerate their development and commercial maturity. Before some of the newer technologies in these areas are mature enough, support can be provided under the form of feed-in tariffs or contracts for difference type of instruments or financing support under one of the EU's financing instruments.

Competitiveness during the energy transition

The transition period towards climate neutral industrial and energy sectors will have to be managed carefully. On the one hand, industrial electrification will have to increase. On the other hand, there is a risk that electricity costs increase (e.g. due to higher indirect costs under the EU ETS or the costs of new investments passed through). Interestingly, an accelerated phase-out of carbon-intensive power production could limit the exposure to higher indirect costs and thereby the compensation to be given under the EU ETS. Hence, supporting the accelerated phase-out of carbon-intensive power production could, if managed properly, reduce the exposure to indirect CO_2 costs.

In some of the Chinese pilot emissions trading systems, direct and indirect (i.e. emissions related to electricity consumption) emissions allowances are given to industry, together with an allocation to power producers. This double allocation was mainly done because of fixed price setting for power producers and therefore power producers did not have a major incentive to reduce emissions regardless of the emission intensity of power production. Such system can be interesting for industry since it could give operators the opportunity to purchase low-CO_2 electricity compared to the average emissions in the country and thus valorise the surplus allowances.

Finally, if additional taxes or charges are included in the power prices (which is not always the case for electro-intensive consumers), member states could consider moving these charges to the general budget. However, doing this could have a significant distributional effect since non-energy intensive consumers will have to pay more.

7.2. Developing infrastructure to enable the industrial transition

While it is safe to assume that significant investments will be necessary to provide the necessary infrastructure for industrial transition, a practical mapping of these needs remains absent. It will therefore be important to start with this first. Secondly, the infrastructure will likely have to be financed by both the public and private sectors. There are existing but also new instruments that might be able to assist here. Finally, in large scale transitions there is a risk that economic cohesion is weakened. In particular, future infrastructure planning and developments can impact economic cohesion between economic regions in Europe. This will have to be taken into account and where possible avoided.

Mapping infrastructure needs

It is recommended that in the immediate future (next few years), a first industrial transition infrastructure mapping and plan for Europe be developed. This mapping exercise will not only give better insights into the capital needed for low-CO_2 infrastructure but also indicate the priority areas and (need for) interconnections.

To assess the infrastructure needs it would make sense to start working bottom up from medium and large industrial clusters present in Europe. These clusters could offer local economies of scale (for e.g. CO_2 transport, H_2 production and transport) through several companies at the same location or at short distance that would be able to use these. It is likely that these industrial clusters themselves have mapped infrastructure options. The next step in mapping would be to look at linking clusters inside a region or country and assess the possibilities of cross-border infrastructure linkages. There exist several industrial clusters with (cross-border) infrastructure linkages in the EU, the largest of which lies between Belgium, The Netherlands, Germany and France[69]. Regional coordination centres (such as the trilateral strategy between Flanders, Netherlands and Northrhein Westfalen) could coordinate the identification of the most optimal international infrastructure linkages. Their role is also to synchronise cluster transition to ensure that transition pathways in one cluster don't prevent scaling up across the interregional cluster. The plan will finally have to look at the opportunity to (over time) connect more remote industrial regions and also identify possible regions or specific industrial sectors at risk of missing out on infrastructure opportunities (arising from greater inter-linking) due to their remote location and ways of remedying it. The infrastructure plan will have to look ahead for the next 10 years with regard to urgent infrastructure needs and must do this within the scope of a 30-year transition pathway. Due to emerging technologies it will be necessary to update the plan on a regular basis (e.g. every 5 years at first). One of the main outputs of this plan will be the identification of priority industrial projects of common interest.

To ensure high quality outputs and broad acceptance of the results, a new EU-wide platform consisting of industrial actors, research and technology organisations (RTOs), industrial cluster representatives and technology and infrastructure providers should be established to offer active guidance with regard to the mapping and planning of transition infrastructure.

Financing transition infrastructure

Because no single company or sector will be able to provide the capital for these infrastructure investments on their own, instruments will have to be developed to assist with enabling the finance. Existing EU instruments include, in particular, Invest EU, the Connecting Europe Facility (CEF), the European Regional Development Fund (ERDF) and European Social Fund (ESF). It would be recommended to develop a possible financing architecture for industrial

[69] Strane, 2016

transition infrastructure to enhance transparency and access for member states and regions that might require support.

EU monetary financing via bonds can also be considered. The EU could give the EIB a mandate and guidelines to finance industrial transition infrastructure investments. The EIB could then issue bonds to obtain the resources necessary to fund these investments. Next, the European Central Bank (ECB) can step in by buying the EIB bonds at a pace dictated by the expiration of the old bonds on its balance sheet. This way, the ECB would create "money for climate investments" without fuelling inflation. At the same time, it would create the possibility for the EIB to increase its borrowing in capital markets without endangering its AAA credit rating status.[70] [71]

Regardless of additional EU support, member states will likely need more budgetary flexibility. These capital intense investments might strain or even cause temporary deficits in member states' budgets. One of the reasons for this extraordinary impact is the public accounting rule which demands public sector investments be written off in the year they happen. It would therefore be recommended to allow the creation of separate national capital accounts[72] from the overall public sector accounts for a number of white listed public investments. The investments located under this account can then be written off over a longer time period.

A cohesive transition

There is a risk that through focussing on existing industrial clusters or inter-connected clusters and hence profiting from economies of scale, certain regions or types of industries not located in or nearby these clusters might be left behind. Therefore, EU industrial transition infrastructure planning must also include assessments and solutions for areas and industries that cannot benefit from collective infrastructure. This can entail looking at alternative technology pathways that do not require important new infrastructure investments or by looking at alternative logistical solutions. It can also lead to the consideration of transitioning to different processes in the value chain (e.g. change from primary to secondary steel production).

In any case, this key aspect of an EU wide industrial transition must be carefully considered from the start.

[70] De Grauwe P., 2019
[71] Wyns T., 2016
[72] De Grauwe P., 2018

OVERVIEW TABLE

Options to align industry and energy transitions and transition infrastructure	
Aligning the Energy and industry transition	• Joint Industry-Energy Inter-Service Taskforce to develop a virtuous cycle between the energy and industry transitions. • Joint and forward-looking impact assessment to work through the transition from a (sub)national level and identify possible issues related to the adequacy of the energy system • Supply side instruments: Green Power Purchase Agreements (PPA's) by industry can, if needed, be further stimulated at national and EU level. • Demand side instruments: New power market design rules to facilitate the development of new business models, further R&D support for industrial demand response and storage, and support to new technologies under the form of feed-in tariffs or contracts for difference type instruments. • Competitiveness during energy transition: Supporting the accelerated phase out of carbon intensive power production, A system of double allocation
Infrastructure mapping and planning	• Mapping infrastructure needs mapping and plan: to give give better insights into the capital needed for low-CO_2 infrastructure and indicate the priority areas and (need for) interconnections. Work bottom up from medium and large industrial clusters present in Europe • Infrastructure Plan: To look ahead with a 10-year foresight at the opportunity to (over time) connect more remote industrial regions and also identify possible regions or specific industrial sectors at risk of missing out on linking to infrastructure due to their remote location and how this can be remediated. • New EU-Wide Platform for Transition Infrastructure: consisting of industrial actors, research and technology organisations (RTOs), industrial cluster representatives and technology and infrastructure providers to offer active guidance with regard to the mapping and planning of transition infrastructure.
Financing transition infrastructure	• Evaluate the need and scope of using new financing instruments (e.g. monetary financing via bonds) • Member States budgetary flexibility for a number of white listed public investments to be written off over a longer time period • A cohesive transition planning must also include assessments and solutions for areas and industries that cannot benefit from collective infrastructure.

Scaling up low-CO_2 investments and avoiding high-carbon lock-ins

- *Enable fiscal interventions facilitating investments in low-CO_2 solutions*
- *Consider the use of industrial investment platforms to facilitate access to low-cost finance*
- *Use environmental permits and impact assessments as a transition instrument to lower risk of high-carbon lock-in*
- *Use the EU ETS modernisation fund as mechanism to finance brownfield conversion*

8. Scaling up low-CO_2 investments and avoiding high-carbon lock-ins

8.1. Financing to scale up investments

The transition to a net-zero industry will require a significant increase in investments compared to today. Companies will only make these investments if the conditions are right. This includes having mature technologies at hand (chapter 4), ensuring a growing market for low-CO_2 solutions (chapter 6) and having infrastructure in place together with access to reliable, CO_2-free and competitively priced energy (chapter 7). These enabling conditions will be necessary but might not be sufficient. A radical transformation of industry over a relatively short time period (compared to the investment cycles) will likely require additional support to facilitate and accelerate the necessary investments on an EU-wide scale.

Fiscal reorientation

Fiscal support can aid and steer investments for climate friendly processes. This could include allowing an accelerated depreciation of low-CO_2 production assets. The consequence would be that corporate taxation will be lower due to a deduction of taxation in the early years of the new asset. This can be beneficial for companies with a weaker or vulnerable balance sheet. In general, higher tax credits or reduction of corporate taxation due to investments in low-CO_2 production assets would offer an incentive for direct investments. Ideally, such fiscal reform would be coordinated at the EU level (e.g. as part of better corporate fiscal alignment between member states), and further guidance on how member states could use this instrument to stimulate investments in low-CO_2 industrial process installations would be a part of new or reviewed state aid guidelines.

Industrial Investment Platforms

The cost of capital (WACC) for investments is an important element in deciding when and where investments take place. The cost of capital for (new) low-CO_2 investments can be higher due to higher technology risks or uncertainty in relation to the market and regulatory environment.

Instruments to facilitate investment capital such as the EIB's Innovfin and Invest EU can help secure financial closure. At the national level, the role of national promotional banks remains important. Given the size of the challenge it is worth considering the development of larger and more dedicated instruments at the EU level.

One example could be the development of an Industrial Investment Platform for carbon-neutral industry. Investment platforms were first introduced under the European Fund for Strategic Investments (EFSI) and are investment facilities which pool smaller and/or higher-risk projects by geographic location or sector. This approach helps to better share risk, make it easier to attract private investors and eventually unlock financing for individual projects. An investment platform can combine EU funds, national support and financing from private investors. The platform itself can then provide loans and/or equity financing to the underlying projects, depending on their specific needs. The current investment platforms are set up by sponsors or project promoters, which may be public authorities or National Promotional Banks and Institutions, social sector players or private stakeholders. The Commission and the EIB could provide advice on the setting up of platforms, in particular through the European Investment Advisory Hub. Investment platforms could also perform the function of a one-stop-shop for financing large industrial demonstration projects, e.g. in combination with grant or debt-based financing from the Innovation Fund[73].

Broader and more ambitious instruments for industrial transformation can be considered too. For instance, the establishment of a *European Sovereign wealth fund* could provide an optimal and future-oriented way of developing strategic sectors with a strong focus on innovation. This publicly-owned or supported investment vehicle can be a strategic tool to achieve competitive advantages for industries and value chains part of the transition to a climate-neutral economy[74].

Special Purpose Vehicles for off-balance sheet financing

Capital intensive investments can be a burden on the balance sheets of companies. For companies that operate in cyclical markets (e.g. steel production) this can lead to very strict demands on expected rates of return. Through the use of Special Purpose Vehicles e.g. sanctioned or supported by the EIB, companies could. Be allowed to create separate entities that own the new low-CO_2 assets. This type of off-balance sheet financing would limit the exposure of the parent companies and can hence help accelerate investments in climate friendly assets with a longer payback time.

8.2. Avoiding lock-ins and supporting brownfield conversion

Environmental impact assessments and permits as a transition instrument

It is possible that investments in (new) carbon intensive industrial process installations that happen after 2020 will still be operational in the 2040s, and even up to 2050. There is hence a risk that some of these investments will lock-in emissions for a long period. This might lead to higher mitigation costs or even stranded assets over time. To minimise this risk, it could be considered to introduce a climate neutrality test at permitting or an environmental impact assessment stage for new investments. The goal would not be to prevent new investments but to ensure that they're designed in a way that allow compatibility with Europe's 2050 climate goals. In practice, an environmental permit could contain conditions such as:

- A climate-neutral transition plan at site level: The project developer will need to demonstrate via a step-wise approach that within a certain timeframe, well before 2050, deep emission reductions can be implemented at the site,
- Mitigation options to be considered at first major retrofit: Which show the preferred type of technological options that are being considered at the time of the first major retrofit (e.g within 10-15 years),
- Requirements for the plant design that would facilitate these retrofits: Demonstrating that the current plant design is compatible with the above-mentioned low-CO2 retrofits, and

[73] European Commission, n.d., 2
[74] EPSC, 2019

- Requirements regarding location and access to infrastructure for the new installations: Ensuring that the location of the plant is compatible with (planned) infrastructure to accommodate possible low-CO2 technologies (e.g. electrification, CO2 capture, …)

While no additional mitigation requirements on top of the EU ETS would be required, the above-mentioned elements could become a condition to receive a permit to operate.

Supporting brownfield conversion

In many cases the transition of industrial processes to low-CO_2 options will occur at the same site. Therefore, brownfield conversion will become an important feature of Europe's industrial transition. Brownfield development will be more complex and expensive compared to the development of a new process plant on a greenfield site. The following elements could facilitate such conversions:

- The expansion of the EU ETS modernisation fund to a *brownfield conversion fund for industrial transition*. This fund would cover part of the additional CAPEX required to prepare the site for low-CO_2 process installations. It can cover part of the demolition, clean-up costs or additional costs due to the connection to new infrastructure or compensation for economic losses due to temporary stops in production,
- Allow temporary flexibility in permitting e.g. at times when incumbent and new installations operate together and don't cause undue economic losses through early closure of incumbent installations or start-up issues with new process installations,
- Allow for an accelerated depreciation of assets to bring tax relief when large investments happen, and
- Facilitate access to neighbouring terrains for expansion of installations or new infrastructure required for the operation of new process installations.

OVERVIEW TABLE

Instruments to scale up investments and avoid high-carbon lock-in	
Financing to scale up investments	• Fiscal reorientation: Fiscal support to support and steer investments for climate friendly processes coordinated at EU level, e.g. as part of better corporate fiscal alignment between Member States • Industrial Investment Platforms for Carbon Neutral Industry: A one-stop-shop for financing large industrial demonstration projects, made from combined EU funds, national support and financing from private investors to provide loans and/or equity financing to the underlying projects (depending on their specific needs). • European Sovereign wealth fund: Could provide an optimal and future-oriented way of developing strategic sectors with a strong focus on innovation.
Avoiding lock-ins and supporting brownfield conversion	• Environmental impact assessments and permits as a transition instrument that are a climate neutrality test at permitting or environmental impact assessment stage for new investments to ensure that investments are designed in a way compatible with Europe's 2050 climate goals. • Supporting brownfield conversion through the expansion of the EU ETS modernisation fund, allowing temporary flexibility in permitting, allowing for an accelerated depreciation of assets, and facilitating access to neighbouring terrains for expansion or new infrastructure required for the operation of new process installations.

An industrial strategy for climate neutrality

- *Align innovation, lead markets, circular economy, infrastructure and investment instruments into a comprehensive industrial strategy.*

- *This strategy will have to be mission oriented, with low-carbon innovation and deployment at its heart.*

- *It will have to go beyond maintaining existing industrial relationships and value-chains and strive towards an innovative new industrial ecosystem.*

- *The strategy must be forward looking with a focus on creating and shaping new markets and business models.*

- *It must be protective of industrial value chains in transition.*

- *Finally, a long-term transformation of this scale will require solid and integrated governance and leadership to be successful.*

9. An industrial strategy for climate neutrality

This report had the goal to provide a preliminary and therefore indicative and incomplete answers to the main challenges related to the transition to a climate-neutral basic materials industry (with a focus on steel, cement and chemicals) and related value chains.

Creating a climate -neutral basic materials industry, including its value chains, will be a daunting task. It can be seen as one of society's grand challenges. It would be erroneous to simply focus on remediating the externalities caused by GHG emissions. The EU ETS, currently the main instrument to mitigate industrial GHG emissions, is an insufficient means to this end. On its own, carbon pricing also does not provide sufficient incentives for innovation, nor does it address market failures that hold back many circular economy solutions.

A successful transition will have to address important basic R&D challenges and also facilitate the large-scale demonstration of these innovations. The transition will have to work along the full value chain of the basic materials industries. This implies moving away from linear consumption models to a high level of circularity and materials efficiency and related new business models. For new low-CO_2 solutions to succeed, lead markets will have to be created and investments will need to be scaled up. Finally, the transition will have to be carefully managed in a global and competitive environment and will have to be aligned with the similarly ambitious transition of the energy sector.

Interestingly, both the challenges and possible policy responses mentioned in this report are strongly connected. Investing in R&D for low-CO_2 process emissions will not make much sense if there is no roadmap towards demonstration and commercialisation of the technologies. New products and processes will only become more efficient and competitive through large scale deployment if there is a (lead) market established first. New business models will not emerge if the transition is not considered along the full value chain with a focus on materials efficiency and circularity and new roles for industry in a transitioning energy system. New products and process might not succeed if they are not, at least temporarily, shielded from international competition. Finally, large capital flows towards EU-wide deployment of low-CO_2 solutions will not materialise if all the preceding elements are not addressed.

These crucial connections point to the need for a comprehensive industrial strategy. What could be the guiding principles of such a strategy and how do they relate to the policy solutions formulated in this report?

The strategy will have to be mission oriented, with low-carbon innovation and deployment at its heart. It will have to go beyond maintaining existing industrial relationships and value-chains and strive towards an innovative new industrial ecosystem. The strategy must be forward looking with a focus on creating and shaping new markets and business models. It must be protective of industrial value chains in transition. Finally, a long-term transformation of this scale will require solid and integrated governance and leadership to be successful.

Setting a Mission across the valleys of death

Europe's R&D framework is starting to address the important innovation challenges for an industrial transition to climate neutrality. In some areas, further basic research will be required but also the large-scale demonstration of low-CO_2 technologies and later on the incremental innovation to reduce the operational expenditure of new technologies. While Horizon Europe, the Innovation Fund, Invest EU and the Connecting Europe Facility are seen as part of a broader innovation architecture linking basic R&D to piloting, demonstration and later commercialisation; the governance or oversight to ensure this linkage with the goal to create solid innovation chains is still absent. This is related to the fact that some of these instruments fall under different administrations in the European Commission. Robust and regular monitoring of the state of innovation progress will be important, together with the flexibility to reorient in case certain areas do not progress sufficiently.

Innovation will have to focus as much on the demand side (i.e. the consumption of materials in the value chain) as the supply side (i.e. the production of basic materials). The challenge of a climate neutral basic materials industry and value chains will not be realised without high levels of materials efficiency and circularity.

Finally, this grand challenge of industrial climate neutrality must also maximise the opportunities arising from the broader innovation environment given that some new key enabling technologies (e.g. machine learning, distributed ledger technology, 5G networks and quantum computing) can have killer applications in this area.

Raising a new industrial ecosystem

As mentioned before, an industrial climate-neutral transition cannot focus solely on reducing emissions from industrial processes. It will likely entail a reshaping of industrial value and supply chains. For instance, current value chains will become future supply chains and new business models will change the existing relationships between basic materials producers, producers of semi- and finished goods and the final consumer. A climate-neutral economy in 2050 will therefore be based on a quite different industrial ecosystem.

This new ecosystem will have to be much less materials-intensive and highly circular where possible. The next decade will hence be crucial to set up an ambitious regulatory environment in relation to the life-cycle of basic materials. There are a number of important enabling conditions that need to be met in order to unlock the potential in this area. Furthermore, a wide range of policy options exists that could in principle help to create these conditions, in various ways. Policy makers already have an existing framework under the EU's Waste Package and Circular Economy Action Plan. However, the challenge now is to extend and complete this work with respect to the whole basic materials sector (not just plastics). Policies must build on existing policy frameworks (being) established by the EU and by member states where possible, and to implement EU directives in the strongest way possible. However, they must also be willing to go beyond existing policy in some cases in order to ensure that all basic materials are sufficiently addressed and that policies are adequate enough to tackle the challenge of achieving a GHG-neutral European materials sector. It will be also crucial to ensure that policy packages designed in Europe do not leave open loopholes or create perverse incentives to offshore the problem. In the medium-and longer-term, there are significant industrial policy and security advantages for Europe to incubate highly efficient circular economy systems domestically. However, in the short term, the integrated nature of these markets must be borne in mind in designing effective policy packages.

The industrial ecosystem change will not only occur through (efficient and circular) value chains, there will be cross sectoral transitions that will need to be managed too. The move towards higher levels of direct and indirect electrification in industry together with the climate neutral transition of the energy system itself will require an integrated strategy which has the goal of creating a virtuous cycle between the energy and industrial transitions. This includes a dedicated joint climate-neutral transition impact assessment between these sectors. It is relevant to further investigate how certain types of longer-term contracts for green electricity (e.g. PPAs) can be further stimulated at national and EU levels. From the demand side, it is likely that industry will start playing an important role in energy services such as demand response and (seasonal) energy storage. These new business models will be extremely important for industry to face energy production which can be more intermittent and/or with a higher price volatility. New power market design rules can facilitate the development of these business models. Furthermore, R&D support for industrial demand response and storage (e.g. power to X) will be important to accelerate their development and commercial maturity. The transition period towards climate-neutral industrial and energy sectors will have to be managed carefully. On the one hand, industrial electrification will have to increase. On the other hand, there is a risk that electricity costs increase (e.g. due to higher indirect costs under the EU ETS or the costs of new investments passed through). Interestingly, an accelerated phase out of carbon-intensive power production could limit exposure to higher indirect costs and hence the compensation to be given under the EU ETS. Therefore, supporting the accelerated phase-out of carbon-intensive power production could, if managed properly, reduce the exposure to indirect CO_2 costs.

Forward looking policies

An industrial strategy must focus on the markets of the future. If these do not exist or are not mature but deemed essential for the transition, they will have to be created or shaped. New low-CO_2 processes, products and business models are in many cases at this moment not economically viable. A cocktail of instruments can be deployed to create lead markets for these.

This can include the use of production subsidies beyond or in combination with the EU ETS carbon pricing. Equally important is the design and use of standards to remove barriers to market entry or to create a new market. Public procurement can be a powerful instrument to give low-CO_2 solutions a chance to be deployed at larger scale and hence accelerate their developments and learning curves. It would also be key to make the wider market familiar and gain trust in these products and services.

The industrial transition will require foreseeing a supporting infrastructure and logistics. If this infrastructure (e.g. H_2, CO_2, biomass, waste, …) is not present in time, the necessary changes in the production and value chains will not be able to materialise. This will hence require early planning and investments. As soon as possible, a bottom-up assessment will need to be made by regional industrial clusters and implementation should start soon afterwards. Financing will require public sector intervention.

A safety net will have to be developed to prevent investments that become stranded or are incompatible with long-term climate targets. Environmental permits and impact assessments can become an early warning system for this purpose. The aim is not to prevent new investments, but to ensure their compatibility with long-term goals. Because the transition towards climate-neutral processes will in most cases happen at the same plant site, it will be important to support brownfield conversions both through adjusted regulations and financial support (e.g. the EU ETS modernisation fund).

Finally, major capital flows will need to be (re-)oriented towards new low-CO_2 process installations. The materialisation of these flows and, in particular, private capital will primarily depend on setting the right market and regulatory environment for these low-CO_2 solutions. But, due to the scale of investments needed, public interventions might be required. These can facilitate low-CO_2 investments by fiscal interventions (e.g. higher tax reduction and allowing accelerated depreciation) and by the creation of investment instruments which reduce the cost of capital through patient financing and risk sharing. The introduction of industrial investment platforms (under invest EU) or even an industrial sovereign wealth fund could be considered.

A protective Europe during the transition

Many of Europe's basic materials industries operate in a global market. While new processes, products, business models and value chains can over time give the EU's industry a competitive edge, especially in these new areas, the transition process can also expose European producers to international competitors that do not face the risks and costs associated with this process. This can lead to a loss of competitiveness.

The EU should be ready to protect the materials industries and their value chains during the transition. In practice this would mean striving for a higher level of consistency between Europe's climate protection ambitions and its trade policy, including and in particular the trade defence instruments. The competitive advantage that the EU might gain through publicly supported IP must be better valorised and cannot be used e.g. by unconditional deployment outside of the EU, to harm Europe's competitiveness.

Integrated governance and leadership

The transition to a climate-neutral industry can require interventions in a broad range of policy areas such as R&D, finance, climate, energy, state aid, trade, procurement and product standards. It will also cover competences that are located at sub-national, national, regional and EU levels. This implies that a significant number of actors and stakeholders will need to be involved. Most importantly, all the challenges mentioned in this report will need to be tackled in a synchronised manner to be successful.
Therefore, an industrial strategy for climate neutrality will require integrated governance, but also leadership.

In the area of innovation for a climate-neutral industrial transition, there is a need for a more mission-oriented approach. This mean setting out the broad challenge and working along key home-work problems that will need to be solved. It will require monitoring of progress along the TRLs and market readiness of different technology pathways. Therefore, the establishment of an ***industrial transition observatory*** could be considered. This platform would bring together the relevant private and public sector actors in this area and would evaluate the state of progress at regular time intervals. It would highlight areas where progress is lacking and bring forward recommendations to keep the transition on track. It would also be recommended to include assessments that go beyond the innovation stages. To fundamentally assess the state of progress on industrial transition, a set of indicators or even KPI's would be required that include investment sizes and financing gaps of low-CO_2 solutions, impact on trade flows and competitiveness, identification of regulatory barriers, and assessments of the performance of policies and instruments. In general, it is recommended that the many EU instruments that currently monitor EU innovation and competitiveness be further streamlined and integrated.

Facilitating the transition will require support from the public sector, beyond R&D financing. To avoid uneven national support systems for low-CO_2 solutions and possible related regulatory uncertainty due to lack of state aid guidance, it is relevant to ***pro-actively revise EU state aid guidelines*** related to the industrial climate-neutral transition. This includes establishing whether and how member states could implement production support for low-CO_2 production processes. This comprises fine-tuning the relationship between possible advantages under the EU ETS (e.g. lower exposure to CO_2 prices) and additional support needed to gain market entry for low-CO_2 solutions. Ideally, EU level fiscal reform in the area of corporate taxation leads to further harmonisation which includes options to reduce taxation related to low-CO_2 investments.

The industrial and energy transitions cannot be addressed separately anymore. Neither will they succeed without better coordination of policies and measures. It is therefore recommended to establish an ***inter-service industry-energy task force***. Its main task would be to come up with a detailed impact assessment informed by the European Commission's long-term strategy towards climate neutrality and, based on this, develop a strategy that seeks to maximise possible synergies between higher levels of industrial electrification and the greening of energy supply - both from the demand, supply sides. This strategy will have to be informed by how member states via their national energy and climate plans and long-term climate strategies seek to address this challenge, and from elements included in the new EU energy market design.

Policies related to circular economy and materials efficiency will have to be further expanded and integrated with climate and energy goals. Furthermore, these instruments will have to not only address the negative externalities related to loss of materials seeping out of the value chains, but also focus on the development of a new industrial materials ecosystem via emerging business models that preserve or create higher value added. Knowing that high levels of circularity and materials efficiency will be crucial to realise climate-neutrality, it will be necessary to expand the current energy system modelling used to determine long-term strategies with an ***integrated EU materials-energy system model***. Such a model will better assess the possible material losses from key value chains and can begin integrating life-cycle assessments of key material flows. It is recommended that the development of such a model be tendered on short notice and allowed to become 'open source' so as to permit short-term upgrading and refining.

In the area of financing, further integration or concertation would be required. Currently there exists a host of instruments which can or will be useful to facilitate financing of the industrial transition (e.g. Innovation Fund, Invest EU, Connecting Europe Facility, Horizon Europe). It is important to design a broader and consistent ***Industrial transition financing architecture*** that would specify the roles of different funding streams and, more importantly, streamline the application of these instruments. Ideally, one-stop-shop financing instruments should be introduced for large and complex industrial projects. In this context it would be worth considering the facilitation of a conduit of national financing instruments towards larger EU instruments, e.g. through national promotional banks. An example of this can be the establishment of regional or thematic ***industrial investment platforms***. The industrial transition observatory mentioned before can play a role in the early identification of financing gaps and come up with recommendations to reduce these. Finally, member states will require budgetary flexibility to allow them to facilitate financing of critical infrastructure for the industrial and energy transitions. These capital-intensive investments might strain or even cause temporary deficits in member states' budgets. One of the reasons for this extraordinary impact is the public accounting rule which demands public sector investments be written off in the year they happen. It would therefore be recommended to allow the creation of ***separate national capital accounts*** from the overall public sector account for a number of white listed public investments. The investments located under this account can then be written off over a longer time period.

Infrastructure development to facilitate the industrial and energy transition will be one of the more complex challenges, in particular because all the specific needs are not known yet. However, also here, proactive and integrated governance is needed, because without the timely deployment of infrastructure, the transition would stall. It would be smart to develop an (updateable) ***10-year EU infrastructure plan*** for industrial transition as part of a long-term infrastructure strategy. The coordination of this plan can happen via the European Commission, but it will depend on specific inputs from member states. It is likely that first infrastructure needs will be assessed at the level of local industrial clusters. This information will be relevant to assess possible linkages between industrial clusters in different regions and between industrial clusters and new energy infrastructure. The information gathered during this process can help identify priority industrial projects of common interest (to be financed via the CEF). In this context, it is relevant to assist member states with large industrial clusters establish ***regional coordination centres***, that have the task to streamline the transition and ensure that synergies between clusters are fully maximised. Finally, it will be relevant to ***ensure continued economic cohesion*** between member states and regions during the transition. There is a risk that remote regions or industrial production sites that are not part of large clusters will face additional challenges. For instance, they might not have access to CO_2 or H_2 networks. Any future planning for infrastructure for a climate-neutral transition will need to take this into account.

While Europe's trade policy has become more inclusive of elements related to environmental and climate protection, further integration should be considered, especially during the industrial transition phase. It is likely that some industrial sectors and value chains will become more vulnerable at the time new processes are developed, new products seek markets and new business models are explored. It is important to not only keep monitoring the competitiveness of industrial value chains in Europe vis-à-vis the rest of world but to also explore how ***climate protection and trade defence can be further aligned***. Furthermore, future FTAs cannot be allowed to increase the exposure of EU sectors that are already exposed to possible climate protection- induced investment leakage. This implies that upwards regulatory alignment on climate protection, with the EU's regulatory framework as the benchmark, should become part of the critical elements in FTA negotiations. If this is not possible, waivers for these sectors could be considered, allowing the EU to still impose climate policy related instruments on imported goods.

Finally, ensuring all the above possible initiatives are implemented and/or coordinated will require a high level of oversight within the European Commission. In this regard, the Energy Union could be used as an example through the appointment of a ***European Commission vice-president responsible for industrial transition.*** The role of this Commissioner would be to ensure guidance and coordination of the activities of the different Directorate Generals and be the focal point for activities at member state level. This implies reaching out to the responsible ministries in EU member states to facilitate access to instruments, as well as gathering information from regional and national industrial transition initiatives. In particular, coordination of R&D, financing, and infrastructure initiatives at national and EU levels will be beneficial. In addition, due to such oversight, bottlenecks related to EU or other regulations can also be detected and mitigated at an early stage.

This report aims to contribute to a broader debate on the need, design, implementation, and governance of a European industrial strategy for climate neutrality. To achieve net-zero emissions or climate neutrality for basic materials industry within the relative short period of 30 years, there is clearly a need to fundamentally address all of the key challenges mentioned in the report (innovation, circularity, finance, infrastructure, market creation). But simply tackling each of these challenges on their own, maybe at a different pace, will likely not work. Most of the areas that will need to be considered are connected in one way or the other. This flows from the logic of a major transformation of not only processes and products but also value chains and even business models. It is also the main reason why an industrial strategy is needed.

Such industrial strategy will have to set a clear mission, seek to create a new industrial eco-system, and must (per definition) be forward-looking. It will, due to the complexity of dealing with many policy areas and different levels of competences, need integrated governance and leadership. An EU industrial strategy can hence include a mission-oriented innovation programme for industrial climate neutrality (from basic R&D to market), assisted by a transition observatory. It also should contain better integration of the industry and energy transitions, and the bottom-up design of infrastructure needs. Materials efficiency and the circular economy will have to be fully aligned with climate targets and vice versa. This includes the development of new modelling tools that go beyond the classic energy system approach. But also, reorienting capital flows to low-CO_2 solutions will require a smart and integrated financing framework, using existing instruments or creating new ones if needed. Finally, sustained, integrated governance and leadership can come from a new dedicated responsibility for this transition process within the European Commission.

OVERVIEW STRUCTURE

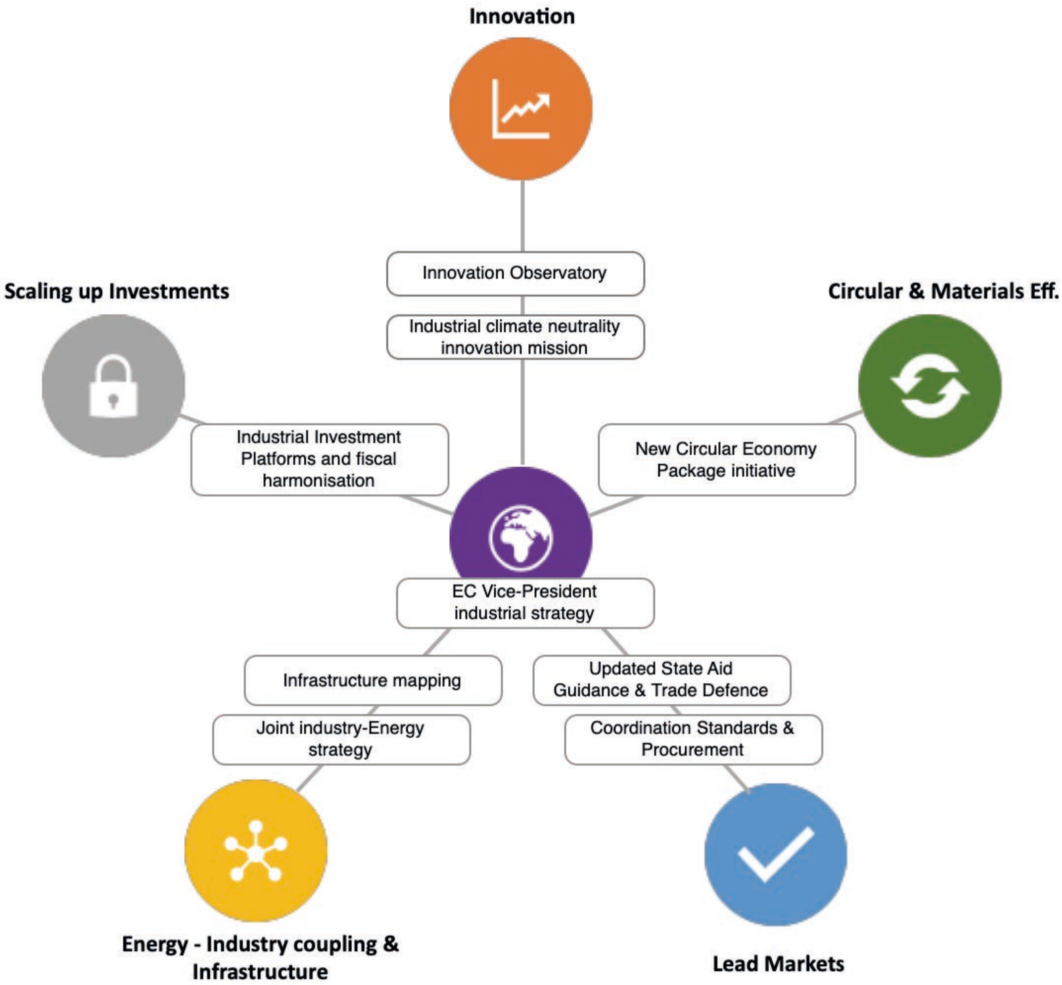


Figure 2: Structure of the proposed European industrial strategy for climate neutrality

10. References

Blue Angel – The German Ecolabel (2019). Homepage. Available at:https://www.blauer-engel.de/en

CEN/CENLEC, (2019a), Get Involved, Available at: https://www.cencenelec.eu/standards/GetInvolved/Pages/default.aspx

CEN/CENLEC, (2019b), Obtaining Standards, Available at: https://www.cencenelec.eu/standards/ENpurchase/Pages/default.aspx

CO2 Performace Ladder (2019). Homepage. Available at: https://www.skao.nl/home_en

David M. Hart, (2017), Across the "Second Valley of Death": Designing Successful Energy Demonstration Projects, p. 4

De Grauwe P., (2019), Green money without inflation, Available at: https://escoriallaan.blogspot.com

De Grauwe P., (2018), Who should pay for the cost of climate policies, Available at: https://escoriallaan.blogspot.com

Dechema, (2017). Low carbon energy and feedstock for the European chemical industry. [online] Available at: https://dechema.de/dechema_media/Downloads/Positionspapiere/Technology_study_Low_carbon_energy_and_ feedstock_for_the_European_chemical_industry.pdf

DuboCalc (2019). Homepage. Available at: https://www.dubocalc.nl/en/

Ecofys, (2017), Status and prospects of coprocessing of waste in EU cement plants, Available at: https://cembureau.eu/media/1612/2017-05-11_ecofys_publication_alternativefuels_report.pdf

EPSC, (2019), EU INDUSTRIAL POLICY AFTER SIEMENS-ALSTOM Finding a new balance between openness and protection, Available at: https://ec.europa.eu/epsc/sites/epsc/files/epsc_industrial-policy.pdf

European Commission, (n.d.,1), Carbon Capture and Storage, Available at: https://ec.europa.eu/energy/en/topics/oil-gas-and-coal/carbon-capture-and-storage

European Commission, (n.d., 2), Investment Platforms, Available at: https://ec.europa.eu/commission/sites/beta-political/files/investment_platforms_factsheet_en.pdf

European Commission, (2015), PUBLIC PROCUREMENT GUIDANCE FOR PRACTITIONERS: on the avoidance of the most common errors in projects funded by the European Structural and Investment Funds, p.44, Available at: https://ec.europa.eu/regional_policy/sources/docgener/informat/2014/guidance_public_proc_en.pdf

European Commission, (2018a), A Clean Planet for all A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, Available at: https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf

European Commission, (2018b) A Europe Strategy for Plastics in a Circular Economy, European Commission. http://ec.europa.eu/environment/waste/plastic_waste.htm

European Commission, (2018c), EUROPE'S TRADE DEFENCE INSTRUMENTS NOW STRONGER AND MORE EFFECTIVE, Available at: http://trade.ec.europa.eu/doclib/docs/2018/june/tradoc_156921.pdf

European Commissions, (2019a), COMMISSION DELEGATED REGULATION (EU) …/... of 26.2.2019 supplementing Directive 2003/87/EC of the European Parliament and of the Council with regard to the operation of the Innovation Fund

European Commission, (2019b), EU product requirements. Available at: https://ec.europa.eu/info/business-economy-euro/product-safety-and-requirements/eu-product-requirements_en

European Commission, (2019c), Level(s) Building sustainability performance. Available at. http://ec.europa.eu/environment/eussd/buildings.htm

European Commission (2019d). Public procurement strategy. Available at: https://ec.europa.eu/growth/single-market/public-procurement/strategy_en

European Commission (2019e). PUBLIC PROCUREMENT ACTION PLAN In the context of the use of ESI Funds 2013-2020. Available at: https://ec.europa.eu/regional_policy/sources/docgener/informat/2014/action_plan_pp.pdf

European Commission, (2019f), Innovation Procurement Brokers. Available at:http://innovation-procurement.org/innobrokers/

European Council, (2018a), Press release: Waste management and recycling: Council adopts new rules, Available at: https://www.consilium.europa.eu/en/press/press-releases/2018/05/22/waste-management-and-recycling-council-adopts-new-rules/

European Council, (2018b), DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency, Available at: http://data.consilium.europa.eu/doc/document/PE-4-2018-INIT/en/pdf

European Copper Institute & Leonardo Energy, (2018), (presentation) Electrification as decarbonisation route for industry

European Observatory for Clusters and Industrial Change, (2018), European Cluster Policy Forum Towards modern cluster policy for industrial change and growth, Input Paper, Available at: https://www.interregeurope.eu/fileadmin/user_upload/tx_tevprojects/library/file_1530101428.pdf pg.22

Eurelectric (2018). Decarbonization pathways. EU electrification and decarbonization scenario modelling - synthesis of key findings. [online] Available at: https://cdn.eurelectric.org/media/3172/decarbonisation-pathways-electrificatinopart-study-results-h-AD171CCC.pdf

Foliente, Greg. (2000). Developments in performance-based building codes and standards. Forest Products Journal. 50. 12-21., Available at:

https://www.researchgate.net/publication/285970302_Developments_in_performance-based_building_codes_and_standards

Global CCS Institute, (2018), Global Status Report, Available at: https://www.globalccsinstitute.com/resources/global-status-report/

Gov. of California, (2017-18), AB-262 Public contracts: bid specifications: Buy Clean California Act, Available at: https://leginfo.legislature.ca.gov/faces/billCompareClient.xhtml?bill_id=201720180AB262

Green Deal (2019). Homepage. Available at: https://www.greendeals.nl/english

IBM White paper, 2018, Blockchain can help transform supply chain networks in the chemicals and petroleum industry.

IES, (2018). Wyns, T., Khandekar, G., Robson, I., “Industrial Value Chain: A Bridge Towards a Carbon Neutral Europe”, Europe’s Energy Intensive Industries contribution to the EU Strategy for long-term EU greenhouse gas emissions reductions, IES-VUB, Available at ies.be

IISD (2016). Low-Carbon Innovation For Sustainable Infrastructure The Role Of Public Procurement. Available at: http://i2-4c.eu/wp-content/uploads/2018/03/Low-Carbon-Innovation-for-Sustainable-Infrastructure-The-role-of-public-procurement_v2.2_web.pdf

JRC, (2017), JRC presents Level(s), a common language for sustainable buildings, Available at: http://www.buildup.eu/en/news/jrc-presents-levels-common-language-sustainable-buildings

Kemp et al (2017). The innovation trajectory of eco-cement in the Netherlands: a co-evolution analysis. International Economics and Economic Policy. Available at: https://link.springer.com/article/10.1007/s10368-017-0384-4

Material Economics AB (2018), The Circular Economy, http://materialeconomics.com/latest-updates/the-circular-economy

Material Economics (2019). Industrial Transformation 2050 - Pathways to Net-Zero Emissions from EU Heavy Industry.

Mc Ardle et al, (2018), Quantum computational chemistry, https://arxiv.org/abs/1808.10402

Michael Berger, (2009), Improved nanotechnology catalysts bring clean energy applications closer.

Ministerie van Infrastructuur en Waterstaat, (2015), Handreiking prestatiemeten Rijkswaterstaat : kwaliteit van het samenwerkingsproces centraal. Report in Dutch. Available at: http://publicaties.minienm.nl/documenten/prestatiemeten

Moynihan, M. C. (2014). Material Efficiency in Construction. UIT Cambridge.

OEA (n.d.) Aluminium Recycling in Europe: The Road to High Quality Products, OEA and EEA. http://greenbuilding.world-aluminium.org/uploads/media/1256563914European_Recycling_Brochure-1.pdf

Portstrategy, (2017), The Port of Rotterdam Authority

Ragaert K., Delva L., Van Geem K., (2017), Mechanical and chemical recycling of solid plastic waste, Waste Management p. 25-35

Responsible Steel (2019). Homepage. Available at: https://www.responsiblesteel.org/

Slimbreker (2019) Why smart crushers? Webpage at: https://www.slimbreker.nl/why-smartcrushers.html?msh [1] Material

STRANE (2016). EPOS Tool Market Study. [online] Available at: https://www.spire2030.eu/sites/default/files/users/user222/Epos-docs/D6.1%20-%20website%20public%20summary.pdf

Swiss Federal Institute of Technology (ETHZ) (2018). A SUSTAINABLE FUTURE FOR THE EUROPEAN CEMENT AND CONCRETE INDUSTRY Technology assessment for full decarbonisation of the industry by 2050. Page 48. Available at: https://europeanclimate.org/wp-content/uploads/2018/10/AB_SP_Decarbonisation_report.pdf

UN University, (2015), Discarded Electronics Mismanaged within Europe Equals ~10 Times the Volume of E-waste Exported, Available at: https://unu.edu/media-relations/releases/discarded-electronics-mismanaged-in-europe-is-10x-volume-of-e-waste-exports.html

Upphandlingsmyndigheten (2015). Sustainable Public Procurement: Criteria. Available at: https://www.upphandlingsmyndigheten.se/en/sustainable-public-procurement/sustainable-procurement-criteria/about-the-criteria/

Watkins, E., & Schweitzer, J.P., (2018), Moving towards a circular economy for plastics in the EU by 2030, Institute For European Environmental Policy (IEEP)

Wesseling & Van der Vooren (2016). Lock-in of mature innovation systems: the transformation toward clean concrete in the Netherlands. Journal for Cleaner Production. Available at: https://www.sciencedirect.com/science/article/pii/S095965261631263X

Wuennenberg, L., & Casier, L., (2018), LOW-CARBON INNOVATION FOR SUSTAINABLE INFRASTRUCTURE THE ROLE OF PUBLIC PROCUREMENT, i24c, Available at: http://i2-4c.eu/wp-content/uploads/2018/03/Low-Carbon-Innovation-for-Sustainable-Infrastructure-The-role-of-public-procurement_v2.2_web.pdf

Wyns T., (2016), Mission Oriented Quantitative Easing, Available at: https://drive.google.com/file/d/0B6XEN6SiVDYqWXBkLS1ZRHNSa0E/view

11. List of Abbreviations

Adfs	Advanced disposal fees
Bn	Billion
C&DW	Construction and Demolition Waste
CAPEX	Capital expenditure
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
CCUS	Carbon Capture, Utilisation and Storage
CO_2	Carbon dioxide
CO_2eq	Carbon dioxide equivalent
DRI	Direct-reduced Iron
EIB	European Investment Bank
EIF	European Investment Fund
EJ	Exajoule (10^{18} J)
EPR	Enlarged Producer Responsibility
EU ETS	EU Emissions Trading System
EU	European Union
EUR	Euros
E-Waste	Electronic Waste
GHG	Greenhouse Gases (CO_2, CH_4, N_2O, O_3, CFCs, HFCs)
GSCM	Green Supply Chain Management
GVA	Gross Value Added
GW	Gigawatt
H_2	Hydrogen
Ktoe	Kilotonne of Oil Equivalent
kWh	kilowatt hours
kW	Kilowatt
LCOE	Levelized Cost of Energy
LPG	Liquified Petroleum Gas
MFF	Multiannual Financial Framework
Mt	Million Tonnes
MWh	Megawatt hour
NCEPs	National Energy and Climate Plans
OPEX	Operational expenditure
p.a.	Per annum
PPA	Power Purchase Agreement
PPP	Public-Private-Partnership
PVC	Polyvinyl Chloride
R&D	Research and Development
SILC	Sustainable Industries Low Carbon
SME	Small and Medium-sized Enterprises
SMR	Methane Steam Reforming
SPIRE	Sustainable Process Industry through Resource and Energy Efficiency
TBM	Take Back Management
TRL	Technology Readiness level (see Annex I)
TWh	Terawatt hour (10^6 MWh)
WACC	Weighted Average Cost of Capital

Annex 1. Overview Table of Policy Instruments

Innovation Gaps	
Options to enhance innovation governance for industrial transition	• Develop an industrial climate neutrality grand challenge under the EU's innovation flagship Horizon Europe in coordination with national industrial R&D programmes to address outstanding basic R&D gaps (in particular with focus on cost reduction of new technologies) both from supply side (process technologies) and demand side (materials efficiency, energy storage). • Set up an industrial transition observatory to monitor progress and advice course corrections with regard to development and deployment of industrial low-CO_2 innovations.
Options to accelerate technology market readiness by 2030	• Development of one-stop-shops where project developers can get easier access to blended finance. Investment platforms developed under the EFSI can be seen as an interesting example • Supporting partial systems or supporting/enabling technologies, which do not mitigate greenhouse gas emissions on their own. • Elimination of regulatory barriers that might prevent the timely scaling up of innovations. Low-regulatory zones for testing could be considered or even a temporary and well-defined exemption under the EU ETS.
Circular Economy and Materials efficiency	
Options for enhancing the quality of recycled materials to preserve material value	• Requiring the recyclers of basic materials to do more precise sorting, based on of the quality of materials in the end of life products that they receive. • Setting recycling quality targets on companies to increase the shares of high purity secondary basic materials in total recycling quantities. • Ban or tax the demolition of buildings and shredding of vehicles and heavy equipment. • New design requirements on products to facilitate high value recycling. • More meaningful fees and modulation rates of Advanced Disposal Fees under Extended Producer Responsibility schemes to penalize difficult to recycle products. • Finance for pilots of innovative technologies that help to preserve material value during design, deconstruction processes, advanced recycling processes, and decontamination systems for de-contaminable waste. • Ensure that national waste taxation and EPR schemes incentivize decontamination and chemical recycling, for the relevant product niches. • Support workforce training and remove regulatory barriers to economies of scale. • Identify local regulatory barriers that can exist which block the development of economies of scale in recycling. • Facilitate the creation of pan EU and international markets for high quality secondary materials and product designs.
options for improving material efficiency in manufacturing and construction	• Promote development and early adoption of a portfolio of new, high potential technologies and production processes. • Fund plant refurbishment with more material efficient processes with a charge on consumers of material intensive products. • Support the sharing of information and training to reduce material waste. • Requiring companies to set goals and report on material efficiency. • Setting material efficiency standards to eliminate inefficient production practices.
Options for raising collection and recycling rates of old scrap	• Public procurement and private sector pledging systems to help ensure demand for increased supply of high quality (and currently uneconomic) recycled materials. • To incentivize private sector demand for high-grade secondary materials, governments in Europe should track and label basic materials along the value chain based on GHG content of production. • Creating a durable economic incentive to ensure that recycled products are relatively attractive for users. • Set material quality labelling requirements and require companies to provide quality guarantees for the sale of high purity recycled materials liable to be purchased for high value usages.

	• Include waste incinerators in the EU ETS or otherwise tax their emissions at the level of the EU ETS carbon price. • Regulations or tax incentives to generalise the recycling of cement from building sites. • Introducing or enlarging the number of basic material-containing products covered by deposit-refund systems. • Modulate ADFs and recycling targets on plastics to favour greater use of closed loop recycling (rather than incineration) of plastics. • Revise product bans of once-through or litter-prone products, as alternative become available. • Continue to simplify, harmonise, and refine national and local government recycling rules and labelling schemes so that consumers find it as easy as possible to identify how to allocate waste into different bins. • Provide innovation support and develop meaningful economic incentives for chemical recycling of plastics.
Creating lead markets for low-CO_2 solutions	
Making low-CO_2 solutions cost competitive	• Subsidies for low-CO_2 production technologies through premiums, contracts for difference or tax reductions and taking into account EU ETS impacts • Extension of EU ETS scope with low-CO_2 processes • Inclusion of consumption in the EU ETS to secure carbon price pass through
The use of standards to gain market access	• Reforms in standard setting procedure: introduce flexibility and streamline the legislative and standardisation process, ensure a better coordination between policy tools, involve experts from various stakeholder groups in the standards development process • Reforms in standard formulations: Inclusion of efficient materials use or labelling in building standards, redesign existing standards that hamper market access for low-CO_2 products, EU-wide database on the environmental footprint of energy intensive manufacturing products based on LCAs and be designed similarly to the Level(s) tool, Introduction of an Eco-Label for construction products, eco-design for construction products and extending the scope of the Eco-design to non-energy related products • Promotion of voluntary standards, labelling and certifications
Public procurement as driver for low-CO_2 products	• Make better use of the Public Procurement Package (2017) by improving coordination on EU level and by linking public procurement to low-CO_2 standardisation • Improve coordination on EU level: By setting up a permanent EU Public Procurement Task Force that works to enhance public procurement practices that are coherent with societal value for taxpayers' money • Obligatory sustainability quota in EU funding schemes • Earmark EU funding for collaborative projects on public procurement • Permanent EU program for training and application of "Innovation brokers" • Fiscal Incentives to reward successful and ambitious use of sustainable public procurement practices • Link low-CO_2 public procurement to low-CO_2 standardisation
Competitive low-CO_2 solutions in a global market	• Public Procurement: set greenhouse gas standards or benchmarks for the materials used in the construction or assembly processes applicable to both domestically produced as imported materials. • Standards: introduction of carbon content standards on important final goods (e.g. cars) considered for instance an extension of the eco-design directive towards embedded CO_2 emissions • Border adjustments: Detailed assessment of the technical, legal and practical applicability of this instrument • Assess possibility of Updating EU Trade Defence Instruments: use benchmarks in new Anti-Dumping Methodology which in theory also include assessments with regard to cost carried by producers to mitigate GHG emissions. Consider if the lack of climate protection measures in a certain industry in non-EU countries can be considered a trade-distorting subsidy (subsidation). Investigate use of safeguards as the legal option for introducing (temporary) border adjustment instruments • Free Trade Agreements: Avoid engaging in FTAs with parties that have not signed or ratified the Paris Agreement or have withdrawn from the agreement or within these FTA's insert a waiver for strategic industries that are subjected to carbon pricing in the EU. • Conditional IP investment protection: Restricting the application of EU (co-)funded climate protection IP outside the EU.

Aligning industry and energy transitions and transition infrastructure	
Aligning the Energy and industry transition	• Joint Industry-Energy Inter-Service Taskforce to develop a virtuous cycle between the energy and industry transitions. • Joint and forward-looking impact assessment to work through the transition from a (sub)national level and identify possible issues related to the adequacy of the energy system • Supply side instruments: Green Power Purchase Agreements (PPA's) by industry can, if needed, be further stimulated at national and EU level. • Demand side instruments: New power market design rules to facilitate the development of new business models, further R&D support for industrial demand response and storage, and support to new technologies under the form of feed-in tariffs or contracts for difference type instruments. • Competitiveness during energy transition: Supporting the accelerated phase out of carbon intensive power production, A system of double allocation
Infrastructure mapping and planning	• Mapping infrastructure needs mapping and plan: to give give better insights into the capital needed for low-CO_2 infrastructure and indicate the priority areas and (need for) interconnections. Work bottom up from medium and large industrial clusters present in Europe • Infrastructure Plan: To look ahead with a 10-year foresight at the opportunity to (over time) connect more remote industrial regions and also identify possible regions or specific industrial sectors at risk of missing out on linking to infrastructure due to their remote location and how this can be remediated. • New EU-Wide Platform for Transition Infrastructure: consisting of industrial actors, research and technology organisations (RTOs), industrial cluster representatives and technology and infrastructure providers to offer active guidance with regard to the mapping and planning of transition infrastructure.
Financing transition infrastructure	• Evaluate the need and scope of using new financing instruments (e.g. monetary financing via bonds) • Member States budgetary flexibility for a number of white listed public investments to be written off over a longer time period • A cohesive transition planning must also include assessments and solutions for areas and industries that cannot benefit from collective infrastructure.
Scaling up investments and avoiding high-carbon lock-in	
Financing to scale up investments	• Fiscal reorientation: Fiscal support to support and steer investments for climate friendly processes coordinated at EU level, e.g. as part of better corporate fiscal alignment between Member States • Industrial Investment Platforms for Carbon Neutral Industry: A one-stop-shop for financing large industrial demonstration projects, made from combined EU funds, national support and financing from private investors to provide loans and/or equity financing to the underlying projects (depending on their specific needs). • European Sovereign wealth fund: Could provide an optimal and future-oriented way of developing strategic sectors with a strong focus on innovation. • Special Purpose Vehicles for off-balance sheet financing sanctioned or supported by the European Investment Bank, could allow companies to create separate entities that own the new low-CO_2 assets.
Avoiding lock-ins and supporting brownfield conversion	• Environmental impact assessments and permits as a transition instrument that are a climate neutrality test at permitting or environmental impact assessment stage for new investments to ensure that investments are designed in a way compatible with Europe's 2050 climate goals. • Supporting brownfield conversion through the expansion of the EU ETS modernisation fund, allowing temporary flexibility in permitting, allowing for an accelerated depreciation of assets, and facilitating access to neighbouring terrains for expansion or new infrastructure required for the operation of new process installations.

Contact:

Tomas Wyns
Senior Researcher - IES-VUB
IT50 Policy Project Lead
Tomas.wyns@vub.be

Gauri Khandekar
Project and Doctoral Researcher - IES-VUB
IT50 Policy Project Coordinator
Gauri.khandekar@vub.be