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Mutual Learning Exercise on Industrial decarbonisation

Final report

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Mutual Learning Exercise on Industrial Decarbonisation. Final report

European Commission
Directorate-General for Research and Innovation
Directorate A — ERA & Innovation
Unit A.1 — Semester & Country Intelligence
Contact (Horizon Europe PSF coordination team):
Magda De CARLI, Head of Unit A.1
Stéphane VANKALCK, PSF Head of Sector, Unit A.1
Annamaria ZONNO, PSF Coordinator of the MLE on Industrial Decarbonisation, Unit A.1
Email Magda.DE-CARLI@ec.europa.eu
Stephane.VANKALCK@ec.europa.eu
Annamaria.ZONNO@ec.europa.eu
RTD-PUBLICATIONS@ec.europa.eu
European Commission
B-1049 Brussels

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Mutual Learning Exercise on Industrial Decarbonisation

Final Report

Main author:

Ludo Diels

Contributors:

Daniela Angione

Ignacio-Martin Jimenez

Karl-Heinz Leitner

Žaneta Stasiškienė

Petri Vasara

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Directorate-General for Research and Innovation
Horizon Europe Policy Support Facility

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List of Acronyms

BAT: Best Available Techniques

CAPEX: Capital Expenditures

CCUS: Carbon Capture, Use, and Storage

CDP: Carbon Disclosure Project

CEN: The European Committee for Standardisation

CGRI: Circularity Gap Reporting Initiative

CO2: Carbon Dioxide

CCfD: Carbon Contract for Difference

DU: Delivery Unit

EC: European Commission

ECOP: European Communities of Practice

ELFM: Enhanced Landfill Mining

EIC: European Innovation Council

EII: Energy-Intensive Industries

ESG: Environmental, Social, and Governance

ETS: Emissions Trading System

EU: European Union

FOAK: First Of A Kind

GBER: General Block Exemption Regulation

GPP: Green Public Procurement

GHG: Greenhouse Gas Emissions

H4C: Hub for Circular Economy

IA: Innovation Actions

IEA: International Energy Agency

IPCC: Intergovernmental Panel on Climate Change

JU: Joint Undertaking

Lt-LEDS: Long-Term Low Emission Development Strategy

MLE: Mutual Learning Exercise

MOU: Memorandum of Understanding

MS: Member States

NECP: National Energy and Climate Plan

NGO: Non-Governmental Organisation

OITB: Open Innovation Test Beds

OPEX: Operational Expenditure

PPP: Public Private Partnership

PSF: Policy Support Facility

RIA: Research and Innovation Actions

RRF: Recovery and Resilience Facility

R&I: Research and Innovation

REPower EU: European initiative for energy transition

SME: Small and Medium-sized Enterprise

TRL: Technology Readiness Level

WGA: Whole-of-Government Approach

EXECUTIVE SUMMARY

The process industry encompasses various sectors with high energy and carbon intensity, forming the backbone of many value chains. Despite representing about 500,000 companies and creating millions of jobs, it emits 750 million tons of CO2 annually, accounting for 13% of European emissions. To align with the Green Deal Agenda and reduce emissions, the process industry must shift to renewable energy sources, improve efficiency, and adopt circular approaches. European regulations, like the Net Zero Industry Act and Critical Raw Materials Act, aim to accelerate the transition to low-carbon technologies, but competition from other countries poses challenges. Governments need to align their national energy and climate plans with EU targets and update them to reflect the revised legislation. At present, the pace of deployment and the transition of innovations to full industrial scale remain insufficient given the ambitious objectives. There is a pressing challenge to accelerate the adoption of new technologies and address the existing barriers hindering industry investment.

The MLE on Industrial Decarbonisation, launched in April 2023, addressed this challenge by facilitating knowledge exchange among participating countries, guiding policy makers in developing sector-specific strategies and mobilising investments in low-carbon technologies. In addition, the MLE is designed to offer best practices and frameworks for stimulating both private and public investments in low-carbon technologies. This initiative is crucial for empowering nations to tackle the task of curbing carbon emissions within the industrial realm and transitioning towards a more sustainable future. Hence, 12 European countries followed the call for interest to participate in the Industrial Decarbonisation MLE and committed in early 2023 to participate in the specific MLE. These countries are: Austria, Belgium, Finland, Georgia, Latvia, Lithuania, Portugal, Slovenia, Slovakia, Spain, Sweden, and Türkiye.

The MLE was organised around four thematic areas:

- The first theme focussed on national roadmaps and strategy development for low-carbon technologies in energy-intensive industries, along with sector-specific decarbonisation programs.

- The second theme covered the themes policies and financing which included the design and impact of national support programs, initiatives, and financing mechanisms for research and innovation (R&I) investments in low-carbon technologies.

- The third theme dealt with the engagement of actors and aimed to improve future interactions through sharing best practices and insights from engagement with key stakeholders and government institutions.

- Finally, the theme of framework conditions revolved around the regulatory impact on R&I and deployment cycles and focused on directives such as the Waste Framework Directive and the Industrial Emissions Directive and the role of technology infrastructures and data aspects, including standardisation and monitoring.

For each of the themes, a workshop was organised with input from various experts from both the public and private sectors and in a variety of formats to share experiences and discuss opportunities and ways to address the identified challenges.

A number of policy recommendations have been formulated on the basis of the thematic reports, presentations and discussions at the four meetings. These recommendations show significant coherence across the different themes discussed at each meeting. They are

grouped under key seven areas that emerged as commonly important and recurring in the discussions across the meetings.

The main policy recommendations cover seven main areas and can be summarised as follows:

1. Enhance the roadmap development process

All participating MLE countries have made or are in the process of preparing roadmaps as important instrument to design specific policies for the promotion of industrial decarbonisation. These roadmaps are also important to allow the completion and finalisation of the National Energy and Climate Plan (NECPs) to be approved mid-2024.

It is important to regularly update roadmaps and strategies to remain aligned with evolving opportunities and challenges and to exploit feedback and evaluation loops as part of planning processes. This process also necessitates better alignment between national strategies and European-level activities to maximise impact by considering local conditions regarding energy, resources, and waste management. Member States also advocate for an updated list of available technologies, facilitating a forward-looking mechanism for continuously upgrading Best Available Techniques (BAT) over the long term.

Most of the participating countries are aware of state-aid instruments. However, it is recommended to align the coordination process between the national level and funding opportunities on the European level (e.g., information about aid schemes, use of Resilience and Recovery Plan).

2. Enhance the engagement of relevant stakeholders and speed up implementation by establishing de-risking instruments

There is a need for a strong engagement of all industrial sectors covering all types of stakeholders on the regional, national and European level to implement strategies and roadmaps and particularly for further enhancing the involvement with public-private partnerships at the European level, with SMEs, CSOs, Citizens and Municipalities. In addition, it is also important to cover all energy-intensive manufacturing sectors and align with other sectors, particularly the energy sector, as this is the crucial factor in the further development of sustainable ecosystems. Enhancing the collaboration between science and business needs a further push as well. An important driver can be the set-up of joint research infrastructures such as Open Innovation Test Beds (OITBs) which can be spread over Europe.

There is a strong need for de-risking instruments for companies to invest in demonstrators and First-of-a-Kind (FOAKs) plants which are required for industrial decarbonisation. In the upscaling approach, most attention is currently focused on CAPEX, whereas OPEX is increasing strongly in demo plants and certainly FOAKs. EU and national funding programs should aim to support both CAPEX and OPEX costs. Particularly, Carbon Contracts for Differences (CCfDs) can ensure a strong and stable carbon price signal that reduces the financing costs and risks of zero-emission investments, leading to their commercialisation and large-scale use. A step-by-step, outcome-based approach should accelerate innovation and lead to FOAK and full deployment through a test phase in a regulatory sandbox. A uniform funding instrument should be presented at EU level to avoid a wide variety of instrument in the different member states.

3. Improve monitoring and the collection and use of appropriate data

While all roadmaps have defined the need for investment, only rough estimation are given for the specific investment needs. In addition, public and private projects funding should prioritise on process but also products and their use, durability and potential for circularity in various industries to further encourage the adoption of low-carbon products. Hence, an impact monitoring system should be established in alignment with ESG-reporting, which allow to synchronise investment policies with banking and investor priorities aiming to identify appropriate requirements for demonstration FOAK plants at both national and regional levels. Better impact modelling should be, together with efficiency estimations, integrated in the final R&I policy by creating knowledge from data and sound evidence for decision making. Better data also support prioritisation and smart specialisation based on ex ante monitoring and adjustments at regional and interregional level.

4. Enhance coordination and collaboration

It was observed that roadmapping is often set up by one dedicated ministry which is even different among the member states. The MLE showed the importance of fostering interconnectedness between roadmaps across countries and enabling valuable knowledge exchange and mutual learning in the industrial decarbonisation and roadmap development process. However, there is a need for models that can investigate the best European value chains, based on innovation, existing logistics and existing assets and explore new assets. It is recommended to explore ways to smoothly enable and coordinate Inter-Ministerial collaboration on the national level via the appointment of ministerial contact points.

While most national roadmaps and strategies focus on industrial symbiosis and sectoral coupling, there is a great potential to set up integrated industrial hubs based on supportive logistics, energy storage systems and focus on refurbishing existing or creating new industrial parks with an own agenda.

5. Establish supportive regulatory frameworks

Throughout the MLE discussions, it became evident that regulation plays a significant role in driving decarbonization efforts. However, the continuous changes in regulation appear to impede decisions regarding full deployment of new technological solutions. The role of standardisation, regulatory sandboxes and public procurement can be highlighted as key elements to establish supportive, predictive and stable frameworks. Countries need to contribute strongly to the technical committees on standardisation for industrial decarbonisation. With respect to regulatory sandboxes it is recommended, to integrate both sandbox experimentation and step-by-step implementation, reinforced by innovative financing models that prioritise outcomes over processes. In order to support the development of green markets, public procurement (e.g., green steel, renewable plastics) can strongly help the initial steps in finding and creating a market for the new products or products made by more sustainable processes. In addition, there is a need for establishing long-term targets for companies in a stable environment with prior indications of possible exemptions.

6. Expand communication efforts to reach the wider community

Discussions showed a lack of communication and transparency in providing information on strategies and roadmaps in the wider social context, resulting in a deficit of trust among customers and citizens. It is recommended to disseminate roadmaps to the general public through narrative storytelling. Communication should prioritise on clarity, consistency, and transparency and follow a participative rather than a lobbying approach. Effective

communication can unify diverse stakeholders which enables them to collectively work towards the common goal of achieving carbon neutrality. Move away from lobbying towards a participative approach will create a new energy in the joint development of a new green future, both at regional/national and EC level.

7. Develop the necessary human skills

Only a few MLE countries already have started to develop specific plans to address the shortage of skilled workers to fill jobs for future activities and the need for re-skilling and up-skilling in relation to future technologies. Thus, each country or region should carry out a Green Skills Needs Assessment in order to tailor educational programmes and initiatives and to encourage greater collaboration between academia and industry. This includes aligning curricula and qualifications to better accommodate the development of future skills within the contexts of digitalization and decarbonization transitions.

On top of the seven policy recommendations, the MLE identified a strong need for a framework action plan. Such an action plan should be based on mapping and monitoring activities of ongoing research projects (TRL>5), demonstration plants, and FOAKs at European and national/regional level. In addition, a community of practice should be set up to focus in particular on how to speed up the permission process for major demonstration and investment projects. It also should consider permitting with countries contributing to technical committees on standardisation.

1. Introduction

The process industry ecosystem covers a broad range of sectors, which are characterised by a high energy and carbon intensity while serving as input to many value chains. This ecosystem transforms resources into materials that form the basis for the manufacturing industry to produce consumer products and other industrial/construction materials. They provide raw, processed, and intermediate materials. The process industry emits a large share of global Greenhouse Gas (GHG) emissions, as industrial processes employ high temperatures and depend on high energy densities to enable the processes involved. In fact, process emissions from industries should be fully recognised and prioritised, as they will inherently be emitted in several industrial sectors, regardless of the energy used. Currently, the process industry represents roughly 500,000 companies, contributes to 5% of the European GDP, creates 6.5 million direct jobs and supports 19.5 million indirect jobs. The process industry is responsible for the emission of 750 million tons of CO2 annually, which accounts for 13% of the European CO2 emissions.

In line with the European Green Deal Agenda, to reduce emissions, the industries mentioned previously industry sectors need to replace fossil fuel-based energy inputs with renewable electricity and other energy carriers, along with implementing improved resource and energy efficiency (including circular approaches and enabling infrastructures). They need to carry out activities ranging from taking advantage of new processes, up to the full deployment of new First-Of-A-Kind (FOAK) industrial plants to make their sectors competitive, resilient, and sustainable. Technology manufacturers, in particular Small and Medium-sized Enterprises (SMEs), as well as engineering companies can play a significant role in maximizing and spreading low-carbon technologies, both within the same sector and across sectors.

Several initiatives at EU level play a key role in moving towards implementation of low-carbon technologies. The proposed Net-Zero Industry Act targets domestic manufacturing of strategic net-zero technologies, which should cover at least 40% of the EU's annual deployment needs by 2030. It also covers elements that should ideally facilitate the transition towards large scale applications (e.g., faster permitting procedures for projects that contribute to the low carbon transition). Furthermore, the Critical Raw Materials Act sets ambitious goals such as having at least 40% of the strategic raw materials for net-zero technologies to be supplied from EU processing, 10% from mining, and 15% from recycling, all by 2030. Competing countries are deploying large investment plans targeting carbon neutrality, mainly in the United States[1] and China[2]. The process industry is still recovering from the COVID-19 pandemic and has been impacted, especially in relation to energy supply as a result of the Russian invasion of Ukraine. Resilience is further impacted by the conflicts in the Middle East, which continue to create global supply chain issues.

Within this international context, there is a need to continue to reduce the cost of decarbonisation and maintain the competitiveness of European industry throughout the net-zero transition. Currently, the deployment rate and the transfer of innovations to full industrial scale are still too slow in view of the challenges faced and overall targets in place. It is required to increase the speed of the implementation of new technologies and help overcome the barriers that currently hamper industry in making the necessary investments. As the

[1] https://home.treasury.gov/news/press-releases/jy1830#:~:text=The%20Inflation%20Reduction%20Act%20modifies,proportion%20of%20qualified%20apprentices%20from

[2] https://iea.blob.core.windows.net/assets/9448bd6e-670e-4cfd-953c-32e822a80f77/AnenergysectorroadmaptocarbonneutralityinChina.pdf

investments are high and based on an amortisation over long periods of time, medium to long-term stability of the regulatory conditions is a requirement.

All governments are required to provide their National Energy and Climate Plans (NECPs) for 2021-2030 under the 2018 EU Governance Regulation. They outline how EU countries intend to meet their 2030 energy and climate targets. EU countries were expected to submit their NECPs by June 2023 following key pieces of EU legislation having been updated as part of the 'Fit for 55' package, the European Green Deal, or through the REPowerEU plan. The plans now require an update to align with the increased ambition of the revised EU legislation.

Public and private stakeholders are willing to invest in order to share the risk, however both sides are under pressure to fund the right deployment that will create the right level of impact (economical, climatological, and environmental), which will also be taken up by society. This assumes that at all levels roadmaps, strategies, and policies need to be aligned and share a strategic common vision. To foster learning from one another, a Mutual Learning Exercise (MLE) was set up.

This MLE on Industrial Decarbonisation was launched in April 2023 as a platform for participating countries to discuss their specific needs and interests, exchange experiences and knowledge about success factors and lessons learned, and provide guidance to policymakers on how to develop or update their industrial technology roadmaps and sector-specific strategies for industrial decarbonisation. In addition, the MLE aimed at identifying best practices and models for mobilising private and public investments related to low-carbon technologies. As such, the aim was to help countries to effectively address the challenges of reducing carbon emissions in the industrial sector and move towards a more sustainable future. The MLE ends on 9-10 April 2024 with a series of dissemination activities, held under the Belgian Presidency in Brussels, *Liège,* and Genk.

The four topics of the MLE on industrial decarbonisation were:

- Topic 1: Introduction and overview of the national and region roadmaps

The first meeting introduced and discussed national roadmaps for low-carbon technologies in Energy-Intensive Industries (EIIs) and related sector-specific decarbonisation programs, along with the initial ERA industrial technology roadmap. Emphasis was also placed on technological developments, investments at different Technology Readiness Levels (TRLs), and how these factors are addressed in industrial decarbonisation strategies.

- Topic 2: Policies, design, and financing for R&I investments in development, uptake, and deployment of low-carbon technologies

The second topic and meeting focused on the design and potential impact of national support programs and initiatives as well as support for industrial decarbonisation and demonstration projects under the Recovery and Resilience Facility (RRF), state aid programs and regulatory framework, SME support programs, European Regional Development Fund (ERDF), and EIT Climate KIC. The meeting also focused on various financing instruments under the European Investment Bank (EIB), the European Investment Fund (EIF), as well as national promotional/development banks, among others. Finally, the mobilisation of public and private R&I investments for climate neutrality (e.g., investment pipelines, FOAKs, Important Projects of Common European Interest (IPCEI)) was discussed.

- Topic 3: Actor’s engagement

The third topic analysed best practices and insights obtained from interactions with national key stakeholders and government institutions from earlier MLE meetings. Additionally, the meeting focused on the experiences of several groups and partnerships, including the SET-Plan group, the High level group on EIIs, the dedicated European Research Area (ERA) Transition Forum subgroup for industrial technology roadmaps, and the Impact Panel of the Processes4Planet partnership, to further inform and improve future interactions.

- Topic 4: Framework conditions

In the fourth meeting, the MLE discussed the regulatory impact on the R&I and deployment cycle particularly at different stages of the Waste Framework Directive, the Industrial Emissions Directive, the Emissions Trading System Directive, and permits to FOAKs. In addition, the meeting focused on the role of technology infrastructures, open innovation test beds, and other platforms. Moreover, the meeting was concentrated on the knowledge and data aspects, including data valorisation, standardisation, monitoring of R&I data and key performance indicators, and green patenting, which is described within EU competition rules and the materials neutrality principle.

This final report is structured to first present the discussions and results of each meeting of the MLE on industrial decarbonisation, covering insights from thematic meetings on national strategies, research and innovation (R&I) investment policies, stakeholder engagement, and the framework conditions necessary for the adoption of low-carbon technologies. Following the summaries of each meeting, the report compiles key conclusions and policy recommendations drawn from all with MLE countries, underlining the essential need for updated roadmaps, better synergy between national and EU activities, inclusive stakeholder engagement, and addressing both regulatory and non-regulatory challenges to facilitate the industry's transition towards a greener future. Finally, the key policy recommendations are grouped thematically in the last chapter.

2. Insights from the MLE meetings

2.1. Overview of national strategies and roadmaps for industrial decarbonisation (April 2023, online)

The first meeting introduced and discussed national roadmaps for low-carbon technologies in Energy-Intensive Industries (EIIs) and related sector-specific decarbonisation programs, along with the initial ERA industrial technology roadmap. Emphasis was also placed on technological developments, investments at different Technology Readiness Levels (TRLs), and how these factors are addressed in industrial decarbonisation strategies.

For the analysis of the MLE countries' decarbonisation strategies and roadmaps 15 questions were addressed encompassing the sectoral coverage, methods, data and models used, involvement of different actors, alignment at regional and European level, and implications for policymaking.

2.1.1. Common analysis framework

The analysis revealed high ambition among MLE countries to systematically develop industrial technology roadmaps. The roadmaps address the process industries and particularly the EIIs such as chemicals, iron and steel, pulp and paper, and non-metallic mineral products. In addition, the majority of MLE countries cover other important sectors and areas and have developed specific roadmaps for them. Notably, energy supply (e.g., producing alternative fuels or hydrogen), the recycling sector, the transport sector, and/or agriculture can be mentioned as examples. Cross-sectoral collaboration is frequently addressed in the national roadmaps and strategies and was also highlighted as crucial during the workshop discussions. However, while some countries have developed separate roadmaps to address specific cross-sectoral themes, particularly the supply of energy and resources deserves more attention.

2.1.2. European alignment and stakeholder participation

Almost all roadmaps are aligned with activities on the European level. Policies and measures at the European level provide goals and a framework for the design of roadmaps at the national level. However, it should be noted that there is little collaboration among neighbouring countries outlined in the roadmaps.

The analysis of the country strategies and roadmaps showed that all countries adopted a highly participatory process engaging a wide range of stakeholders. At the kick-off and first workshop, MLE members also stressed the importance of an inclusive and collaborative strategy development process involving industry, academia, and policy experts. However, the analysis of the strategy documents and the discussions revealed that there is a lack of collaboration with non-governmental organisations (NGOs), labour unions, and citizens. The transformation EIIs is fundamental and can only be successfully achieved if all stakeholders are involved and jointly shape possible transformation paths. Institutions working in the interests of citizens, customers, and employees can ensure that measures relating to education, training, awareness raising, product labelling, energy use, consumption patterns, etc. are effective and that potential barriers are reduced.

In addition, during the workshops the role of science-industry relationships was discussed. In some countries there is still a lack of collaboration culture between academia and industry which hampers an effective development of roadmaps in an interactive way. In addition,

newly established research institutes are often faced with difficulties when trying to build up relationships with the industry. However, the road mapping process mediated by public authorities can be considered also as tool to establish science-industry relationships.

2.1.3. Challenges in collaboration and SME involvement

The role of SMEs for the industrial decarbonisation and their involvement in road mapping processes was also debated. Cluster organisations and other intermediaries can serve as enablers to address their needs and support SME mobilisation. Moreover, the analysis of current national strategies and roadmaps shows that several countries already have established specific funding programmes catered to SMEs.

2.1.4. Modelling and investment needs

Most countries use long-term modelling exercises to define different trajectories, pathways, and scenarios for the decarbonisation of processing industries. The result of this quantitative approach delivers an important building block for the identification of specific R&D and technological development needs and the definition of research, technology and innovation (RTI) policies.

While all roadmaps have defined the need for investments, there appears to be less effort put into defining specific investment needs, instruments and policies. In general, published figures on investment needs tend to be rough estimates calculated by experts building upon the application of simple forecasting rules and projections, with the use of modelling approaches being the exception. As a result, this aspect can therefore be seen as the main weakness of the roadmaps developed in the MLE countries.

There is rather weak evidence supporting the detailed impact pathways and mechanisms of how the results and recommendations of the roadmaps are incorporated into the definition and implementation of specific RTI policies and programmes at national level. The effective implementation of roadmaps, going beyond reports, was highlighted during the MLE meeting discussions, stressing the importance of translating strategies into tangible actions and measurable progress. The discussion revealed that the integration of R&D efforts with investment and industrial policies was identified as a critical factor for successful technological progress and sustainable industrial growth.

In general, policies and measures at the European level (European Green Deal, New Circular Economy Action Plan, Emissions Trading System (ETS), Industrial Emissions Directive, Renewable Energy Directive, etc.) provide goals and a framework for the design of roadmaps at the national level. Although national policymaking and roadmap development is aligned with activities at the European level, there is demand for joint learning and knowledge exchange particularly concerning the diverse funding opportunities offered by the European Commission. This is especially the case for investments in demonstration and First of a kind (FOAK) facilities and higher TRLs. Instruments such as the Recovery and Resilience Facility (RRF), Innovation Fund, ETS, State Aid, and General Block Exemption Regulation (GBER) can be mentioned in this context.

With respect to the size of the investment requirements, participants also stressed that it is important to map the demonstration projects and communicate the infrastructures to a wider audience and public, which could also contribute to further awareness raising on a broader scale.

2.1.5. Storytelling in line with national, regional, and European policy

Finally, the analysis of the national roadmaps and strategies revealed the need for better communication and the need for narratives and illustrative best practices to support in convincing society to support the industrial transformation (e.g. changing consumer behaviour, developing skills and re-skilling, support investments in renewables).

2.2. Policy-mix for R&I investments in deployment and uptake of low-carbon technologies (June 2023, Vienna)

The second topic of this MLE was focused on analysing the concepts and challenges of designing a policy-mix for R&I investments to support in accelerating the deployment and uptake of low-carbon technologies. This section reflects the discussions and outcomes of the second meeting of the MLE, held on 29-30 June 2023 in Vienna, Austria. With respect to the policy-mix and its operationalisation, a major focus was put on the design and potential impact of national support programmes and initiatives as well as the support for industrial decarbonisation and demonstration projects under the RRF, state aid programs and the regulatory framework, SME support programmes, and the ERDF, among others. Another crucial objective of this topic was to explore and discuss various financing instruments, as well as the mobilisation of public and private R&I investments for climate neutrality (e.g., investment pipelines, FOAK installations, and IPCEI.

The elaboration of the policy-mix concepts and challenges emphasised the importance of an operational perspective to ensure an effective uptake and deployment of low-carbon technologies. The policy-mix was systematically approached by considering its building blocks (i.e. elements, processes and characteristics) and further analysed through a survey circulated to the MLE participating countries to capture more insights on national strategy/industrial technology roadmap design, financing mechanisms, and the mobilisation of R&I investments.

2.2.1. Operationalisation of policy strategies

The policy strategy was considered as a crucial element of the policy-mix. The key challenge was how policy strategies can be best developed to achieve an overall impact on policy making. Several aspects of the national policy strategy were discussed during the MLE such as:

- The role of academia and science-industry relationships,
- The participation of NGOs,
- The role of SMEs and platforms,
- Inter-ministerial collaboration,
- Energy supply and availability of resources,
- Collaboration between neighbouring countries and regions
- Public communications and visibility.

A crucial best practice for policy strategy development for industrial decarbonisation is ensuring commitment from the industry. While in several countries a high level of commitment from the side of the industry is a given, building on a long tradition of industry representatives engaging in consultation and public-private stakeholder processes, some countries faced challenges in convincing industry stakeholders to participate in the strategy/roadmap development process. The importance of engaging industry stakeholders from the onset of roadmap development was highlighted. This approach ensures that clear problems are identified as the starting point. These challenges are then systematically tackled within the roadmaps, with the objective of outlining short-, medium-, and long-term strategies for their resolution.

The interaction between the policy instruments has also been debated. A recent report on the Whole-of-Government Approach (WGA[3]) to policymaking[4] highlighted the importance of a joint approach across different policy units on specific programmes, funding decisions or by creating specific inter-ministerial units focusing on a particular topic. Discussions during the meeting in Vienna of MLE countries highlighted the importance of a holistic action addressing the ambition-level captured by the emission targets, the support-level captured by the magnitude of positive investments, and the flexibility-level capturing the extent to which policies will adapt to innovations.

The role of ex-ante conditions in setting priorities for policymaking was highlighted and found to be crucial in the development of decarbonisation strategies for several of the participating MLE countries. These include the assessment of existing resources, the analysis of decarbonisation challenges and targets, stakeholder consultation, the assessment of emerging technologies, economic analyses, and feasibility analyses.

2.2.2. Role of policy instruments and support for upskilling

The support for up-skilling has been considered insufficient for the uptake of technologies, and despite observing a general awareness and acknowledgment that resources and efforts invested in up-skilling will ensure final deployment of low-carbon technologies, a collective effort that includes both government and education institutions is still crucially needed.

2.2.3. Challenges in investment and financing

Another critical factor in driving successful technological advancements and sustainable industrial growth was the alignment of R&D efforts with investment priorities and industrial policies. While all policy strategies have defined the need for investments, there is less evidence of specific investment instruments, strategies, and policies that have been put in place. The participants stressed that de-risking measures, in terms of financial de-risking (i.e. debt, equity, and guarantees that will spread the risk between participating parties or will transfer the risk to a third party) and policy de-risking, are important to reduce uncertainties for industrial decision-making. While there is some experience in aligning national and European R&D policies, e.g., in setting priorities for the Framework Programmes (FP), there is less experience and a lack of established coordination processes for aligning national, transnational, and European investment strategies and interests. The discussions during the workshop made it clear that there is a need for further information exchange and coordination

[3] https://projects.research-and-innovation.ec.europa.eu/en/statistics/policy-support-facility/psf-challenge/mutual-learning-exercise-whole-government-approach-research-and-innovation

[4] European Commission, Directorate-General for Research and Innovation, *New policy designs and instruments for a whole of government approach in R&I – Second thematic report*, Publications Office of the European Union, 2023.

on (new) funding opportunities, especially for investments in demonstration and FOAK facilities, as well as for higher stage TRLs.

State aid and specific financing schemes supporting industrial decarbonisation are also crucial instruments in setting the basis for national governments to develop concrete and long-term funding programmes. Most of the participating countries are aware of state aid instruments such as the recently revised GBER or the 2023 Temporary Crisis and Transition Framework (TCTF) that facilitate the deployment of public funds. A continued and synergetic approach remains a challenge across the participating countries as well as a broader reach in terms of the number of schemes available for supporting industrial decarbonisation strategies.

The importance of targeted financing mechanisms for SMEs and start-ups was debated with regard to the relevant policy-mix. Several countries have schemes in place to support SMEs, mostly in the form of different financial instruments or in the form of a diagnosis instrument supporting the development of their transition to low-carbon technologies. To increase support to SMEs and be more inclusive with respect to financial instruments for de-risking of innovation, stronger engagement with industry associations rather than a single organisation would be advisable.

In conclusion, achieving industrial decarbonisation requires a long-term vision (roadmap) and a diverse and coordinated mix of policy instruments in order to support its implementation. An approach that combines carbon taxation and innovation support, based on a proportionate combination of demand-pull and technology-push factors in favour of demand-pull are necessary to overcome implementation barriers. In addition, policies that facilitate the provision of the necessary infrastructure, while preserving business dynamism are required to enable both industrial firms' decarbonisation investments and ensure economic growth and competitiveness. R&I measures are also competing with other priorities and are decided on the basis of continuing existing schemes or setting up individual schemes. There is no systematic orientation in R&I measures towards the bigger picture of industrial decarbonisation and climate neutrality. Priorities in R&I remain fragmented in that regard and there is no comprehensive approach to deal with this. Rather, a Whole-of-Government Approach is needed, which, through the institutional set up, takes control of the comprehensive design and implementation of R&I programmes and investments to support overarching policy strategies.

2.3. Actors' engagement (September 2023, online)

The Third Thematic Report on "Actors' Engagement[5]" delves into the diverse roles of stakeholders in contributing to industrial decarbonisation. It encapsulates insights from the third MLE meeting, emphasizing the synergies between different sectors and the crucial involvement of stakeholders as a catalyst for decarbonisation. The report discusses the importance of effective communication, education, skill-building, and practical viewpoints from various stakeholders, offering a comprehensive overview of the strategies and practices relevant for industrial decarbonisation.

[5] https://op.europa.eu/en/publication-detail/-/publication/b678ce03-ae9e-11ee-b164-01aa75ed71a1/language-en/format-PDF/source-301205356

2.3.1. Key areas and stakeholder roles

The report identifies the main areas of industrial decarbonisation impacted by stakeholder engagement, such as policy, technology development, infrastructure, supply chain transformation, operational efficiency, financing, and investment. Stakeholders, including governments, industries, NGOs, and communities, are instrumental in navigating the complexities of climate change and decarbonisation. Their involvement brings diverse expertise, enhances trust, and facilitates the adoption of innovative solutions.

2.3.2. Challenges and strategies for decarbonisation

Significant challenges in industrial decarbonisation include finding effective solutions, rethinking finance, adapting to changing demands and costs, and supporting affected communities. The report acknowledges the uneven distribution of challenges and costs, emphasizing the need for equitable treatment and collective action. It highlights specific areas where actor engagement can have the greatest impact, such as in policymaking, technology deployment, and enhancing operational efficiency.

2.3.3. Insights from Research and Technology Organisations (RTOs) and industry

The report shares insights from RTOs and industry representatives, showcasing exemplary practices and comparative analyses of strategies across various sectors and regions. It underscores the importance of regulatory stability, predictive regulation, awareness, communication, citizen and NGO engagement, and the role of engineering companies as well as the European Association of Research and Technology (EARTO) in industrial decarbonisation.

2.3.4. The role of communication and knowledge sharing

Effective communication is highlighted as a key element in facilitating industrial decarbonisation, ensuring stakeholder inclusivity and the creation of a united front in order to tackle challenges related to addressing climate change. The report also stresses the significance of addressing knowledge and competence gaps, emphasizing the need for holistic understanding and the application of knowledge across multiple domains.

2.3.5. Concluding synthesis

The report concludes by synthesising the discussed themes, presenting a comprehensive overview of the current landscape and future pathways to achieve impactful industrial decarbonisation through the engagement of stakeholders. It reaffirms the importance of a collaborative approach, integrating regulatory frameworks, innovative solutions, and global cooperation to address immediate challenges and pave the way for a sustainable and resilient industrial future.

2.4. Framework conditions for deployment and uptake of low-carbon technologies (November 2023, Lisbon)

In the fourth meeting, the MLE discussed the regulatory impact on the R&I and deployment cycle particularly at different stages of the Waste Framework Directive, the Industrial Emissions Directive, the Emissions Trading System Directive, and permits to FOAKs. In addition, the meeting focused on the role of technology infrastructures, open innovation test beds, and other platforms. Moreover, the meeting was concentrated on the knowledge and data aspects, including data valorisation, standardisation, monitoring of R&I data and key

performance indicators, and green patenting, which is described within EU competition rules and the materials neutrality principle.

The deployment rate and the transfer of innovations to full industrial scale at present are still too slow in view of the challenging goals related to industrial decarbonisation. It is necessary to increase the speed of the implementation of new technologies and help overcome the barriers that currently prevent process industries from securing the required investments. As the investment needs are high and based on an amortisation over long periods of time, medium to long-term stability of the underlying regulatory conditions is needed. Aside from non-regulatory conditions (including knowledge valorisation, standardisation, and green patenting), the role of technology infrastructures, open innovation test beds, other platforms, and data and knowledge, also play a vital role in the industrial transformation to net-zero industry policy.

All of these aspects were explored within the topic of framework conditions for deployment and uptake of low-carbon technologies during the two-day meeting which took place in Lisbon, Portugal on the 28th and 29th of November 2023. The aim of this meeting was two-fold, firstly to identify and address barriers and drivers in the context of the deployment and uptake of low-carbon technologies, and secondly, to advise on concrete actions, through the active contribution of MLE representatives and industrial participants, in an open and constructive dialogue.

2.4.1. Key barriers and drivers

The conclusions cover a wide range of collaborative activities. Overall, the need to develop a compelling narrative was unanimous, emphasising the need to urgently focus on climate neutrality and the reindustrialisation of Europe. To achieve this objective, it is crucial to engage all stakeholders, including regions and municipalities, across the entire value chain.

By nature, de-risking innovation at TRLs above seven requires large investments and implies a significant technical and economic risk. As such, co-financing and blended funding models are deemed necessary. Subsequently, the coordination and alignment of financial schemes at the EU, national, regional, and local levels are widely sought aiming at reducing both, Capital Expenditures (CAPEX) and Operating Expenses (OPEX). In this context, Carbon Contracts for Differences (CCfDs) are recognised as a useful national financial tool, leading to the commercialisation of low-carbon technologies and large-scale deployment. In addition, regulatory sandboxes are deployed successfully in different countries to define good practices in the development and implementation of regulatory environments, facilitating their application.

Resilience of the European process industries is a key aspect for the EU. In particular, the access to affordable and clean energy is instrumental for decarbonising the EIIs. There is the need to assess different types of energy (and sorting systems) and how to smoothly integrate them in decarbonisation strategies. Hence, the alignment with the energy sector, which heavily impacts the framework conditions of process industries, is crucial.

2.4.2. Talent and SME engagement

Access to talent is a major challenge facing the EIIs today. In a competitive environment, within the process industries but also with other vibrant sectors (e.g. energy sector), it is crucial to onboard and regularly train skilled and talented people. Furthermore, process industries need to retain talented workers and promote long-term career opportunities. In practice, a “Community of Practice on Skills and Talent” would be useful.

2.4.3. Market and productivity perspectives

From a market perspective, public awareness as regards to the climate transition has multiplied the demand for green products. However, there is still a lack of compelling narratives and storytelling about the importance and impact of green products from process industries in society . To this end, the support and commitment of the industry is crucial. In parallel, market pull measures, and especially green procurement and/or taxation should be further explored, which in turn require standards and relevant measurement methods.

In times of high uncertainty, the planning of supporting tools to decarbonise the industry requires flexibility and the possibility to assess different alternatives. Thus, those critical activities should incorporate updated Key Performance Indicators (KPIs) and adopt a continuous monitoring and evaluation cycle and a learning approach. That being said, data collection from companies poses still some challenges, which influences, for example, the effectiveness and adaptability of scenarios used in policy design. To improve this situation, the process of collecting data and identifying indicators should take place in a collaborative framework between industry and public authorities, as a mutually beneficial opportunity to align industry needs with future decarbonisation programmes. In addition, access to permitting is rapidly becoming a major obstacle for investments and requires long, uncertain, and complex procedures at national/regional level. In this sense, a fast-track procedure for obtaining permits is suggested, and in practice, a “Community of Practice on permitting” would be beneficial.

From a productivity perspective, new approaches towards sustainable business models are required. Symbiotic approaches towards multi-actor, cross-sectorial, and collaborative schemes, such as Hydrogen Valleys[6], Hubs for Circularity (H4C[7]), Carbon hubs[8], or Regional Innovation Valleys[9], play a pivotal role in facilitating the exchange of data, fostering co-development, encouraging co-creation, and enabling experimentation with new business models.

Large companies within the EIIs are key players in deploying low-carbon technologies. Nevertheless, SMEs, play a key role in these industries as well. As technology providers to support the decarbonisation of processes, SMEs require financial mechanisms adapted to their needs. Furthermore, SMEs are also expected to decarbonise their processes, despite their low participation in co-developing public policies in this domain. Therefore, their engagement as active contributors in the road mapping exercises on decarbonisation pathways is required.

3. Key Conclusions and policy recommendations

Based on the thematic reports, the presentations, and discussions during the four meetings, several recommendations are formulated. The policy recommendations show a strong alignment over the different thematic approaches of the respective meetings and will be presented related to a few topics that are of general importance and recurred in the discussions at each meeting.

[6] https://h2v.eu/
[7] https://op.europa.eu/en/publication-detail/-/publication/9bdc29df-e53f-11ec-a534-01aa75ed71a1
[8] https://energy.ec.europa.eu/topics/oil-gas-and-coal/carbon-capture-storage-and-utilisation_en
[9] https://ec.europa.eu/regional_policy/whats-new/newsroom/24-09-2023-regional-innovation-valley-matchmaking-map-now-available_en

To make the recommendations more tangible, they are divided into generic recommendations and specific action plans.

3.1. Methods and data for road mapping and strategy development

Each MLE country has created or is in the process of creating roadmaps as important instruments to design specific policies for the promotion of industrial decarbonisation. Recommendations related to the roadmaps are proposed, especially in light of their crucial role in forming the basis for national policymaking, developing NECPs (to be approved mid-2024) and their actions.

3.1.1. Regularly update roadmaps, strategies and list of technologies

Most of the countries involved in the MLE developed their roadmaps during the last five years. Some countries already started specific initiatives earlier which strongly supported them in defining the roadmap for the NECP:

- Austria: Energy efficiency roadmap (2014)
- Sweden: Fossil free Sweden (2015)
- Belgium (Flanders): Spearhead initiatives for the different sectors (2017)
- Portugal: First strategic papers (2015)

Some countries are in the process of updating their roadmaps, which can help to define the final additions to their NECP.

- Finland is currently updating its roadmap (2024)
- Belgium (Wallonia and Flanders) made an update in 2024.
- Ireland finished its National Hydrogen Strategy and its Energy Security Strategy in 2023.
- Türkiye has announced a Net-Zero Energy Plan (2024), which includes a Hydrogen Technology Roadmap and covers Carbon Capture, Use and Storage (CCUS) technologies
- Slovakia's Strategic decarbonising framework is set by the NECP (draft update 2023), as well as the Low-Carbon Development Strategy until 2030 with a View to 2050
- Portugal considers updating the national Roadmap to Carbon Neutrality 2050 in 2024-2025.(RNC)
- Georgia has drafted its first NECP, which was submitted to the national parliament for adoption in December 2023. Besides, Georgia's Long-Term Low Emission Development Strategy 2050 (Lt-LEDS) was officially adopted on 24 April 2023, setting the stage for the country's carbon-neutral future, and outlining a clear roadmap towards sustainable, low-emission growth.

Preparedness via early actions was revealed as very helpful to anticipate actions with different stakeholders in a more open manner which allowed sufficient time for the underlying

process. It is also recommended to exploit feedback and evaluation loops as part of planning processes. As the whole policy will need continuous adaptation to the existing situation, a continuous and iterative working with roadmaps (and taking into account various financial, fiscal, and other measures) will support a strong degree of preparedness. Such an exercise also supports in implementing a national industrial strategy in a more coordinated manner, while formulating specific recommendations. It also allows to assess if the existing roadmaps cover all necessary aspects to be sufficiently competitive.

The availability of novel technologies and needed infrastructures forms the basis for building adapted roadmaps. As this information is mostly lacking, an updated information system would be very helpful. There is a strong request by Member States to have an information system indicating at least promising technologies, the obtained yields, energy-/emission-reductions and costs. Alignment with other strategies is needed to realize a full integrated approach.

Countries and Member States that continuously adapt their roadmaps have as a result a stronger readiness and thus resilience that allows them to cope with changing economic and regulatory situations, even taking advantage of uncertainty. This adaptation needs to be done in strong alignment with the stakeholders and based on underlying data on the availability of technologies.

Based on these analyses the recommendations can be summarised as follows:

- Continuous updating of roadmaps (national/regional level) in an iterative way;
- Need for continuous updated list of available technologies which can support a forward-looking mechanism to upgrade the Best Available Technologies (BAT[10]) (at national EC level);
- Alignment with other strategies at the national/regional and European level.

3.1.2. Develop and use better methods and evidence for estimating the investment needs

The estimation of the investment needs in relation to the roadmap for decarbonisation of the industry is a challenging task. Most countries use long-term modelling exercises to define different trajectories, pathways, and scenarios for the decarbonisation of the industry. The results of this quantitative approach deliver an important building block for the identification of specific R&D and technological development needs, including the definition of RTI policies. Spain and Sweden, for instance, calculate investment needs referring to the modelling exercise they have conducted. However, for this exercise to be as accurate as possible it is critical to have a legislative and regulatory framework that provides legal certainty that allows for companies to plan their mid/long term investments and therefore also for the countries to have a more tangible oversight of the impact of such projects for national economy, competitiveness, growth, and jobs.

In general, the figures published in the roadmaps and strategy documents are rather rough estimations provided by experts that apply simple forecasting rules and extrapolations. Usually, they also do not consider the substitution of the end product (e.g., using alternative materials and construction and demolition waste for the production of low carbon clinker and

[10] https://eippcb.jrc.ec.europa.eu/reference

consequently low-carbon cement for some industries like the cement). Very often, changes toward more sustainable processes might lead to less residues that were up to that moment used as input in other applications. In this way public policies based on product neutrality and life cycle assessment are essential. For example, sandboxes are noted as having an important role is supporting the quantification of the necessary funding and investment, while avoiding extra regulatory-based costs. For example, brownfield sites seem to be good candidates for alternative energy (pilot) production. If the costs of cleaning up the site are added to the private investment costs, this will lead to extraordinary costs in case the project fails or is moved to a greenfield site.

As some countries played a pioneering role in the use of models and evaluation systems, it is strongly recommended to exchange information among the MLE participating countries on the use of models and the data required. Models need to be based on 'what if?' questions to make them more reliable. A 'What if?' question refers to a model in which numbers can be changed in a certain range indicating once a technology is e.g. economic viable. A changing oil-price can indicate from which level on an alternative can become beneficial. The final investment estimates need to be based on 'no-regret' flows of transition. Currently, two Horizon Europe funded projects (AMIGDALA[11] and TRANSIENCE[12]) started with the aim of partially answering these questions. In order to estimate investment costs, continuous updating is a prerequisite.

In order to optimise the investments and to avoid that investments are made that need to be discarded later on, it is advised to work as much as possible with so called 'no-regret' investments. E.g. An investment into a unique hydrogen-fired burner when there is no green hydrogen available is risky. An investment in a flexible burner (hydrogen, biogas, liquefied natural gas, …) carries much less risk and can cope with the available gases. The transition time to climate neutrality will finally be defined by the availability of the sustainable gases. The economy will be defined by the prices of the gases. Having the flexibility of switching between gases allows a company to remain competitive, derisking the investment.

Based on these analyses the recommendations can be summarised as follows:

- Need for modelling and data integration in 'no-regret' flows of transition, which will allow for estimation of investment costs.

3.1.3. Better alignment of the national strategies and plans with activities at European level

The identification of synergies between national and European R&I schemes has led most of the MLE participating countries to list the main EU programmes (i.e., Horizon Europe, Innovation Funds, European Innovation Council (EIC)). Almost all roadmaps are aligned with activities at the European level. Policies and measures at the European level (European Green Deal, New Circular Economy Action Plan, Emissions Trading System, Industrial Emissions Directive, Renewable Energy Directive, REPower EU, etc.) provide goals and a framework for the design of roadmaps at the national level. The alignment also helps the streamlining of financial plans. However, there is still a lack of comprehensive understanding of all of the possible synergies despite the national and European priorities being aligned with each other.

[11] Alliance for Modelling Industries towards the Green Deal's objectives And circularity, Grant agreement ID: 101138534

[12] TRANSItioning towards an Efficient, carbon-Neutral Circular European industry, Grant agreement ID: 101137606

In addition, the results from the national exercises are partly used to represent the national interests in the negotiation of funding programmes at the European level. Some examples from the participating MLE members include:

- Sweden coordinated its activities with other MS (neighbouring countries)
- The Lithuanian exercise of critical assessment and integration of industrial strategies resulted in an advanced manufacturing roadmap (2022), which combines the previous three roadmaps and links them with the national progress plan (main national strategy approved by government) and the EU strategies while providing a hierarchical tree of objectives.
- Belgium (Flanders) collaborates in the definition of a trilateral strategy with the Netherlands and North Rhine Westphalia.

It is important to expand the current mapping exercise for demonstrators and technology infrastructures and to make its efforts more visible[13]. National strategies require an individual policy-mix taking into account the national specificities and resources. At this moment there is a lack of integrated mapping of the European and national/regional funded projects, their outcome, and impact. This overview and alignment at the level of successful technologies will lead to more optimal use of European and national/regional funding in collaboration with private investments.

Based on these analyses the recommendations can be summarised as follows:

- There is a strong need for a framework action plan:
  - Based on the mapping and monitoring of ongoing research projects (TRL>5) and demo-plants and FOAKs at European as at national/regional level.
  - Which can lead to the promotion and synergetic use of national/regional and European funding.
  - Which can suggest market pull actions (see e.g. targeted procurement actions).
  - To create a Community of Practice at the level of permitting and case studies and taking into account the conclusions and recommendations of this exercise.

3.1.4. Energy & resources/waste use should be prioritised to achieve the highest impact taking into account local conditions

The analysis of the strategies and roadmaps on the national level has shown that natural and energy resources are considered during the roadmap exercise. In the discussion, the crucial role of energy supply was mentioned several times with hydrogen, biofuels, and biomass having been mentioned as important energy sources. National specificities (e.g., coastline/inland, climate conditions) are also used to exploit national/regional resources and advantages. The decarbonisation path will depend on the availability of some resources (funding, green and affordable energy, alternative raw materials and fuels, etc.) and will be constrained by the largest investments return. A large hydrogen production project could e.g.

[13] New interactive map on demonstrators for clean innovative technologies in energy-intensive industries - European Commission (europa.eu)

act as a catalyst for some of the initiatives in terms of CO2 emission reduction potential. In that way, a more decentralised production of hydrogen for several industrial solutions can lead to synergies of their respective solutions (e.g., Power-to-Gas solutions, Power-to-Fuel, Power-to-X; also, E-fuels all resulting from hydrogen combined with captured CO2) As such, these combinations can play a double role in energy supply and carbon circularity. An example is also the cooperation with third countries to develop access to CO2 storage infrastructure and networks.

The issue of energy and resource use is partly quantified in the national roadmaps and strategies. These topics were addressed in the following MLE countries:

- Austria: Fluctuations of renewables
- Portugal: Land use and livestock (pulp and paper industry)
- Latvia, Portugal, Belgium (Flanders): bioeconomy and circular economy
- Türkiye: Implicit resource constraints in the technological roadmap
- Lithuania: Lithuania prepared a study on the national secondary raw material market, which provides recommendations on how to stimulate the use of secondary raw materials. Lithuania also created a waste effectiveness indicator which will be used as a progress indicator for green industry transformation.

As mentioned previously, it is important to engage in the development of specific strategies and roadmaps touching upon energy supply and the provision of feedstock and resources and to align their use for maximum efficiency gains (e.g., including captured CO2 that can be used as feedstock to produce synthetic fuels and contribute to decarbonising other sectors such as shipping and aviation). In combination with this, the impact of intermittency in energy supply, storage facilities, and flexibility must be taken into account. Recently, Belgium (Flanders) launched a model-based comprehensive study Energy 2050+ (Paths 2050[14]) to investigate the realistic pathways to provide technology-neutral and cost-effective climate-friendly energy in the future.

At the level of waste use there is a lack of priority setting relating to energy and resources. Large amounts of waste still end up in landfills whereas there is strong need to transition to enhanced landfill mining (ELFM) practices, as was done in Belgium (Flanders) in 2011. Currently, decisions related to waste treatment are still typically based on the ladder of Mensink and on the recycling hierarchy (9Rs). This is an approach that can be taken as principle. However, it should be noted that more and more impact should be considered in an integrated way where deviations from these principles might prove beneficial, e.g. some waste can be pre-treated and used as energy source in EII without significant cost or energy losses, whereas the recycling of complex waste could require more energy leading to a negative life-cycle assessment (LCA) outcome.

[14] https://perspective2050.energyville.be/

Based on these analyses the recommendations can be summarised as follows:

- Set up a new Community of Practice on energy and resources, including pre-treatment and production infrastructure as well as logistics for exchange in a cross-border approach. Hereby:

  - Countries and regions need infrastructure to provide green electricity and green hydrogen to be connected via cross-border electric power, hydrogen piping and develop a local, sustainable ecosystem.

  - Waste reuse, recycling, coprocessing (combination of simultaneous material recycling and energy recovery from waste in a thermal process) and landfill mining need strong infrastructural investments. First, it can be done at national/regional level and later, it can expand via the European Community of Practice of the Hubs4Circularity (H4C) at international level (e.g., motivating the correct waste separation and treatment both to be allocated to alternative waste fuels and construction and demolition waste that will contribute to circular economy and obtaining decarbonisation targets).

3.1.5. Investment needs and alignment with activities at European level

Integrating R&D efforts with investment and industrial policies was highlighted as a critical factor in driving successful technological advancements and sustainable industrial growth. While all roadmaps have defined the need for investments, there are less efforts put into defining specific investment instrument strategies and policies. The participants stressed that all de-risking measures are important to reduce uncertainties for industrial decision-making.

While there is some tradition and experience in aligning national R&D policies with European ones, e.g., in setting priorities for the European Framework Programmes to fund research and development, there is less experience and a lack of established coordination processes for aligning national, transnational, and European investment strategies and interests. The discussion during the workshop made it clear that there is a need for information exchange and coordination on (new) funding opportunities, especially for investments in demonstration and FOAK facilities and higher TRLs. Instruments such as the RRF, Innovation Funds, ETS, State aid, General Block Exemption Regulation (GBER), or Important Projects of Common European Interest (IPCEI) can be mentioned in that context.

Based on these analyses the recommendations can be summarised as follows:

- Most of the participating countries are aware of state aid instruments such as the recently revised General Block Exemption Regulation[15] or the 2023 Temporary Crisis and Transition Framework, that will facilitate the deployment of public funds. However, it is critical that consistent criteria are applied throughout the various state aid guidelines. Specifically, the criteria for significant risk of relocation varies on indirect compensation of CO_2 emissions in the Climate, Energy and Environmental Aid Guidelines (CEEAG) Belgium (Wallonia) has highlighted the issue faced in budget capacity when distributing public funds in this context. In terms of country-specific state aid schemes, there is a significant gap between countries like Belgium, Austria, Spain, and the rest of the participating countries in the number of schemes available for supporting industrial decarbonisation strategies. Additionally, a limited number of European industrial sectors

[15] https://competitionpolicy.ec.europa.eu/stateaid/legislation/regulations_en#:~:text=General%20Block%20Exemption%20Regulation,Council%20Regulation%20No&text=With%20these%20regulations%2C%20the%20Commission,prior%20notification%20and%20Commission%20approval.

receive indirect cost compensation under the EU state aid rules, protecting them from the risk of carbon leakage on indirect emissions (e.g., this is not the case for the cement industry to date, as the European cement industry's indirect costs, which are already significant, will rise in the future as key decarbonisation technologies are introduced (e.g. the installation of carbon capture technology leads to a significantly higher electricity demand on a given cement plant).

- The MS suggest to make full use of GBER and to transfer this information to policies and authorities, under the condition of a uniform rollout.

- Similar to the former point, it is important to support the alignment and coordination process between the national level and funding opportunities on the European level: Information about aid scheme, use of RRF, CCfD etc.

- Draw attention to develop a conducive environment for private funding as efficiency in the funding process is of the utmost importance. Aside from strategic options, the implementation needs to be predictable and timely.

- Set up of a working group to prepare a uniform interpretation of state aid rules and especially to develop a full CCfD and stage-gate approach[16] in a stepwise target-oriented funding system leading to a conducive environment for private funding.

3.2. Engagement of all stakeholders and implementation-deployment of industrial sectors

In order to implement decarbonisation strategies and roadmaps, there is a need for a strong engagement of all industrial sectors, as well as synergies with European, national, regional, and private sector instruments. Energy and resource supply, a continuous and reliable flow of funding systems, followed by sandbox-based test systems leading to industrial deployment and FOAKs will strongly increase the speed and quality of the development and deployment.

This set of recommendations is divided into those related to the engagement of all the stakeholders and the implementation thereof. In order to develop industrial deployment, the planning of the FOAKs and in larger industrial settings Hubs4Circularity is key.

3.2.1. Engagement of all stakeholders

3.2.1.1. Public Private Partnerships (PPPs)

There is a need for stronger interaction with the Public Private Partnerships (PPPs). Enhancing the collaboration between the national authorities in charge of developing the roadmaps with the public-private initiatives at the European level will improve the roadmaps and strengthen the commitment of the industrial stakeholders. Interactive consulting of the mutual roadmaps, updates, and taking into account the local boundary conditions will also enhance the regional deployment. This can start already in the phase of TRL five or higher and should not wait until discussion of deployment of a FOAK.

[16] A 'stage-gate model' refer to an idea that has to pass through a set of predetermined goals. The gated funding model limits the risk by forcing ideas to meet predetermined standards. The standard stages are stage 0: discovery, stage 1: scoping, stage 2: business plan concept, stage 3: development, stage 4: testing and validation, and stage 5: launch and implementation.

Based on these analyses the recommendations can be summarised as follows:

- Set up national/regional cooperation with European partnerships including public-private initiatives to bring the national/regional dimension-needs.

3.2.1.2. Global cooperation

The quest for industrial decarbonisation is intricate and complex. It requires not just appropriate regulations and technologies but also global cooperation, leadership dynamism, and mediation. International initiatives such as Mission Innovation[17], CEM-IDDI[18](Clean Energy Ministerial Industrial Deep Decarbonisation Initiative), IRENA[19] (International Renewable Energy Agency) and IEA TCP[20] (International Energy Agency Technology Collaboration Program) can be mentioned in this context. The relevant actors must identify possible areas to promote partnerships striving for the creation and scaling-up of new business or operating models, new types of products and services, and even new markets. Alliances to reduce CO2 emissions will strengthen and enhance synergies for the joint development of circular projects that can contribute to carbon neutrality. The lessons and insights from industry leaders, regional organisations, and countries showcase the way forward. They collectively paint a picture of a world where challenges are met with collaboration, where shared experiences guide future steps, and where the pursuit of a decarbonised future is a collective responsibility. The essence of the journey lies in shared commitment, innovation, and the unparalleled power of collaboration.

In addition to global cooperation related to regulations and technologies, leadership dynamism and mediation are crucial to reach decarbonisation objectives. Open involvement serves as a prerequisite in these activities in function of the targeted impact and not only on the immediate personal benefit.

Based on these analyses the recommendations can be summarised as follows:

- Stakeholders need to sign a charter in the beginning of the innovation circle exercise as part of an open involvement in function of impact that relates to the previously mentioned stepwise target-oriented funding scheme. This agreement needs to contain a plan on building infrastructure (commitment by national/regional authorities) support first in order to avoid investments not leading to the envisaged impact. Often these plans are based on the roadmaps of the industrial sectors. It there would be an alignment with the roadmap of the sectors and the roadmaps of the national/regional government, an agreement can be made based on the stepwise target-oriented scheme with appropriate funding systems.

- At the European level, industrial symbiosis may unlock new possibilities such as carbon circularity, but also energy reduction and resource optimisation.

- At the global level recent topics of research on CO2, such as decarbonation, already recognised by the IPCC, shall be highlighted and encouraged. Global collaboration can help to reduce costs, implement globally new technologies, set global standards and create equity at the level of competitiveness.

[17] https://mission-innovation.net/
[18] https://www.cleanenergyministerial.org/initiatives-campaigns/industrial-deep-decarbonisation-initiative/
[19] https://www.irena.org/
[20] https://www.iea.org/programmes/technology-collaboration-programme

3.2.1.3. Science-industry relationships

The academic world is at least divided in scientists involved in fundamental or applied research to create impact. Fostering business-science cooperation requires a very concrete problem with a potential business case and specific scientific expertise matching the problem. This should be addressed at the level of the difference in former Eastern-European Countries and Western-European countries, but also at the level of universities versus research organisations. TRL interpretation and understanding requires further attention mainly in relation to business-science cooperation, which requires a very concrete problem with a potential business case if it is to be resolved as well as specific scientific expertise matching the problem. There is a need to study these interpretations in detail in order to define specific measures to involve the academic world in a broader and Europe-wide way in the development of decarbonisation applications.

An important driver can be the set-up of Open Innovation Test Beds (OITBs) spread throughout Europe. They can strongly increase their turnover via an integrated single-entry approach if they provide unique expertise, assets, and knowledge. OITBs will also contribute to creating synergies amongst European scientists and the mutual sharing of knowledge. Some examples of OITBs are:

- INL - International Iberian Nanotechnology Laboratory[21]
- IBISBA: European Research Infrastructure Organisation for bioeconomy[22]
- NEWSKIN: OITB on ceramics[23]

Specific actions towards the academic world regarding their involvement in the process will make their research standout as compared to high level academic research. In addition, it is important to recognise the specific role of RTOs in bridging academia and industry and learning from the front runners. As such, better methods, and evidence for estimating the investment needs are required. The academic world must be attractive for industry and proactively engage with it rather than passively awaiting industry initiatives.

Applied research in socio-economic calculations warrants further attention, including research that targets upscaling and demonstration problems. This can also be improved via the strong and long-term use of existing demonstration facilities which require different funding means (see OPEX recommendation).

A clear distribution between high level fundamental research and applied research also requires a good understanding of both boundary conditions and objectives and can serve as a basis for research infrastructures such as OITBs making use of large equipment resulting from previously funded projects.

Based on these analyses the recommendations can be summarised as follows:

- A large part of equipment and demonstration facilities established via national and European funding systems can be shared and utilised after finalisation of the funding project in OITB's. This will lead to longer, more efficient and sustainable use of research and demonstration investments, improve scientific involvement and create strong alignments related to real industrial needs.

[21] https://www.inl.int/
[22] https://ibisba.eu/
[23] https://www.newskin-oitb.eu/

3.2.1.4. SME involvement

The importance and challenges of involving SMEs was highlighted during all MLE meetings. Several countries mentioned their activities specifically targeting SMEs. The role of SMEs in the industrial ecosystem of EIIs is however not always very well identified and recognised. Spain mentioned the support to industry that provides equipment for renewable energy and decarbonisation of industry. Also, in the circular economy approach SMEs can play strong intermediate roles. Listening only to the big industry might hurt the SMEs aspirations. Some examples of strong involvement of SMEs are:

- Lithuania: Sustainability fair (event) for SMEs
- Türkiye: Strong link to smart cities and houses via SME's involved in construction and city development.

It is recommended to evaluate the special need for SME activities and the role they can play as intermediates. SME's can be involved in implementing innovations (e.g. from spin offs) and set up innovative engineering (e.g. via engineering SME's). For instance, it is suggested to upgrade waste into secondary resources ready to be used by the EIIs. SMEs can play an important role as equipment providers, in the logistics and the broad diffusion of technologies and solutions.

SMEs could further be involved in the strategy process and design via SME funding instruments. Platforms and roadmaps must incorporate every element of the global production and consumption networks and hence also SMEs from the different levels. The experience from the MLE countries revealed that clusters are often important levers for the involvement of SMEs. It is also recommended to have governments propose solutions via specific advisors. In a long value chain, every partner needs to perceive a benefit and most of the time only the one bringing the solution it to the market can perceive that benefit. This can lead to lack of certain optimised elements in the value chain. For instance, one weak element in the value chain can cause the entire value chain to fail, either technically or economically. A fair distribution and risk sharing between SME's and large industry among the whole value chain needs to be set up via innovative business models.

In many cases process industries do not have the ambition to develop technologies themselves to a state where they can be commercialized and/or taken up by others in the same or in other sectors. The impact remains limited unless a technology provider takes over and commercialises the development. Some of these are SMEs that play a significant role in maximizing and spreading the low-carbon technologies within the same sector or across sectors. The financial mechanisms should stimulate their active participation in large scale projects, in view of their integrative potential.

SMEs will play a crucial role in closing the gaps in the value chain towards a circular economy and by providing the right equipment, digital support, logistics, pre-treatments, etc. It is observed that often, large EIIs are themselves active in collection, sorting, or pre-treating waste. They also manage the intermittency of renewable energy systems, although these are typical SME activities. SMEs also play a crucial role in contributing specific engineering innovations to allow a full technical deployment.

Based on these analyses the recommendation can be summarised as follows:

- During the updating of roadmaps, an investigation of gaps to be closed in the value chains needs to be incorporated. This investigation needs to be done at national/regional level due to the tight regional character of SMEs. New EU rules on corporate sustainability reporting, with a value chain approach, may help identify opportunities in innovation paths.

3.2.1.5. Municipalities

Municipalities can play a role in the local industrial environment, for example by participating in regulatory sandboxes, by offering strong logistics, through involvement of citizens (e.g., Energie Borsele[24]).

It is recommended that municipalities should already be involved in R&D activities that can have an impact on the local situation. By doing so, it enables citizen involvement, local embedding, and helps to address local hurdles (e.g., logistics) in due time.

Municipalities have an important role in local innovation and alignment processes with the society via the citizens. For example, Belgium (Wallonia) has such a Delivery Unit (DU) relating to the Tihange Nuclear Power Plant (www.switchtihange.be); the Caterpillar closure in Charleroi most likely initiated the “District Cleantech” on “Porte Ouest”. These examples show that municipalities need to be involved in relevant local transitions to avoid entering sudden closures of non-competitive activities.

3.2.1.6. NGOs, CSOs, and citizens

Platforms and roadmaps must incorporate every element of the global production, consumption, and circularity networks. Socio-economic clusters are often important levers for their involvement. Lithuania, for instance, created a roadmap for its circular economy[25][26] as a grassroot driven project where 700 people participated in identifying national priorities. In all countries, diverse stakeholder groups were involved including companies, business associations, academia, public administration, social partners, environmental associations, etc. Participation of non-governmental organisations (NGOs), Civil Society Organisations (CSOs), and similar stakeholders is useful, and, in most cases, they were involved in the process. It was observed that citizen involvement is often not well elaborated. Typically, awareness raising is mentioned as a critical step. This leads to the perception that once plans are in place the citizens will be informed and need to be convinced that this is the right plan.

Citizen involvement needs strong attention and should not only be based on awareness raising or education. Starting the involvement of citizens in the middle of a road-mapping process seems to be challenging. However, it is perceived as extremely important. Therefore, it is proposed to create convincing storylines about the history of our industrial landscape, the wealth it has brought and the environmental/climatological problems it has created, as well as the ways in which the stakeholders are trying tackle these issues in an open interactive and iterative way with the citizens.

[24] Accessible here: https://www.borsele.nl/borselse-voorwaarden-groep
[25] Accessible here: https://eimin.lrv.lt/uploads/eimin/documents/files/Booklet.pdf
[26] OECD High Impact Action report with an in-depth assessment of the roadmap creation process. Accessible here: https://www.oecd.org/lithuania/RIT_HIA_Lithuania.pdf

As an example, some citizen science projects (e.g., at Antwerp University[27]) can be mentioned. Citizen science projects are projects where citizens (incl. children) are involved in a massive collection of data (e.g., counting, sampling, observing, etc.) and the data are processed into conclusions and policy recommendations by scientists.

In other cases, social science needs to be strongly involved in the communication activities related to citizen engagement, e.g., the nuclear research centre in Belgium has a large department dealing with social science to communicate about potential extreme situations, such as nuclear disasters.[28]

Based on these analyses the recommendations to involve citizens and NGOs can be summarised as follows:

- Authorities in collaboration with the academic world can create citizen science projects to educate about climate and environmental problems and invite them to find common acceptable solutions.

- In order to avoid single views from dedicated NGOs it is proposed to set up exercises to integrate the concerns of different NGO's leading to an integrated proposal.

3.2.1.7. All EIIs and other industries

Most countries produce or possess chemicals, refining, iron and steel, pulp and paper, and non-metallic mineral products. Depending on the country, agriculture and forestry, waste and recycling, transport, construction, and manufacturing are also present, alongside energy production. These specific integrations in the roadmap are linked to the local economic ecosystem, smart specialisation, and citizen needs.

The analysis revealed that all roadmaps at the national level have a good sectorial coverage and deal with cross-sectoral themes, which are considered as important horizontal topics, (e.g., use of hydrogen, waste management, heat recovery). Some countries have developed separate roadmaps to address specific cross-sectoral themes, particularly in relation to energy supply. This is fully linked to so-called Hubs4Circularity, Hydrogen Valleys, Carbon Hubs, Digital Innovation Hubs etc. (see Industrial Symbiosis). The participating countries presented the following examples:

- Spain: Hydrogen roadmap

- Lithuania: Circular economy roadmap

- Portugal: National Hydrogen Strategy (EN-H2), established in 2020[29]

- Georgia: plans to develop a Green Hydrogen Strategy, as well as Green Growth Strategy and action plan in 2024

[27] Accessible here: https://www.uantwerpen.be/nl/onderzoek/wetenschap-voor-iedereen/burgers-en-samenlevi/citizen-science/projecten/
[28] Accessible here: https://www.sckcen.be/en/expertises/social-sciences
[29] https://www.dgeg.gov.pt/pt/areas-transversais/relacoes-internacionais/politica-energetica/estrategia-nacional-para-o-hidrogenio-en-h2/

In addition, the topic of digitalisation (see also below) is frequently mentioned as a cross-cutting issue. The potential of digital technologies and solutions is an important part in almost all roadmaps developed by the participating MLE countries, with decarbonisation being at the core of Industry 4.0. Examples include:

- Spain: Digitalisation of electric grids
- Latvia: IoT
- Portugal: Digitalisation and green transition
- Lithuania: Industry digitisation roadmap

It is very important to cover all EIIs and align with other industries in function of national needs. Integration with the energy sector is seen as a must as this is the crucial factor in the further development of sustainable ecosystems (e.g., whilst a mix of technologies are needed to decarbonise industrial production, Carbon Capture Use and Storage (CCUS) is particularly critical in the cement industry that faces unavoidable process emissions, and the sector requires fair access and market access conditions mirroring those existing in the energy sector).

Based on these analyses the recommendations can be summarised as follows:

- EIIs need a supportive energy sector (including hydrogen supply), and this all embedded in a full industrial system including SMEs and digitalisation and an action of mutual learning via European Communities of Practice (ECOPs) This can be combined with the ECOP on waste and the relation with H4C (see earlier)
- Clear regulations for CO_2 infrastructure (both CO_2 storage and transportation networks) are needed. The issue is particularly urgent as the first carbon capture projects are rapidly becoming a reality.

3.2.2. Implementation and deployment

The process industry in Europe plays a crucial role in the economic prosperity of European citizens. The related industries generate numerous job opportunities and serve as the backbone for the manufacturing sector. As part of these industries, large companies are key players to deploy low-carbon technologies. Nonetheless, Small and Medium-sized Enterprises (SMEs), play a key role, both as companies with the need to decarbonise their processes and as technology providers to support the decarbonisation of other companies' processes. However, process industries in Europe face significant challenges from global competition, primarily attributed to high energy costs and limited resources. Balancing the imperatives of meeting climate and circularity targets while remaining economically viable poses a considerable challenge for process industries.

To comprehensively evaluate all the boundary conditions influencing investments in low-carbon technologies, six key factors have been considered:

- Policy
- Productivity

- Market for green products
- Financial
- Resources
- State aid
- FOAK and demonstrators

The establishment of FOAKs and demonstrators is a key milestone for industrial decarbonisation. One challenge is to promote shared learning between companies, industrial sectors, and countries. In a recent report by the European Commission, financially supported pilot and demonstration facilities as well as FOAKs are listed. As the report does not present national plants, it is difficult to build a strategy on such a partial view. There is no collaboration between national and European authorities at this level.

As mentioned earlier in the suggestion for an R&I Framework Action Plan, there is a need for an overview supported by more content and real impact data. The long list of demonstrators and FOAKs underpins the lack of planning and strategies (national/regional/European).

At the level of funding, it is observed that similar FOAKs are sometimes supported by IPCEI and in other cases by the Innovation Fund (IF) etc. No decrease in funding is foreseen, e.g., if five plants are already financially supported for a similar Carbon Capture and Storage (CCS) technology, the subsequent plant may necessitate a decreased percentage of funding to avoid the risk of over funding as mentioned by Austria.

It has been noted that alterations in legislation, following the release of companies' implementation plans, can significantly hinder or delay economic development. Additionally, it has been mentioned that after demonstrating an efficient pilot plant, an acceleration of investment is crucial to prevent the loss of talent. Without timely investment following the pilot plant phase, there is a risk of losing skilled individuals to other countries.

There is a strong demand for an overview of all demonstrators and FOAK at the level of gap analysis, full deployment plan, and value chain approach funded by national and European mechanisms. As mentioned earlier, an investment cycle starts with a robust research/innovation action. There is also a need for a framework to make ‘no regret decisions.

Industry is ready to invest, but wants to be sure to invest if there is a shared common purpose and a strategic vision to promote synergies between roadmaps, legislative packages and funding instruments. In order to do so, the following aspects must be taken into consideration:

- Stability of the regulatory environment
- Technical aspects
- Societal acceptance
- Longevity of partnerships
- Availability and reliability of local value chains and logistics

This leads to the following recommendations:

- It is necessary to create a framework action plan

- Logistics and infrastructure need to be in place before either a green electrons-based or a green hydrogen-based economy can be built. See e.g., the Hydrogen infrastructure map of the JU Clean Hydrogen[30]

3.2.2.1. Upscaling CAPEX and OPEX

In the upscaling approach, most attention is currently focused on CAPEX, whereas OPEX is increasing strongly in demo plants and FOAKs. This very often leads to pilots operating for periods of time that are too short due to lack of funding or due to excessive costs. It was observed that private partners withdrew from ambitious and well advanced projects even with major public funds, just before building because the OPEX figures were running too high even for a pilot.

Based on these analyses the recommendations can be summarised as follows:

- EU and national funding programs should aim to support both CAPEX and OPEX costs (e.g., the latter are critical given the importance of electricity costs when it comes to carbon capture - in this respect, exploring CCfD for CCUS covering CAPEX, OPEX, storage and transport costs is critical).

- In funding schemes of demonstration plants and FOAKs, also OPEX should be seriously considered. Longer operations of demonstration plants can support better methods and evidence for estimating the investment needs that are required. Of course, this type of funding is very complex and needs only to be put in place in case of major technology changes.

3.2.2.2. New forms of de-risking instruments

There is a strong need for de-risking instruments. CCfDs can ensure a strong and stable carbon price signal that reduces the financing costs and risks of zero-emission investments, leading to their commercialisation and large-scale use. CCfDs are complementary to existing supply-side policies, such as innovation funding, the EU ETS, the Industrial Emissions, Renewable Energy and Energy Efficiency Directives, while relying on consumption-oriented policies, such as the revised Ecodesign Directive, to move towards a circular economy.

Carbon contracts for difference (CCfD- and state gate approach are very interesting to make developments more target oriented. It means that all companies reducing CO2 emissions and converting their production to climate-friendly production will be eligible to benefit from such program and be able to receive grants independently from their production sizes, therefore including small and medium-sized companies. However, none of the countries involved in this study have experience in CCfD. Many of them are evaluating the legal framework to put CCfD in place rather soon.

The challenge remains how to correctly prepare budgets as the budget estimates are either too low (in case of high development successes), or too high in case of several failures. This

[30] Accessible here: https://www.clean-hydrogen.europa.eu/index_en

means that CCfD and the state gate approach need new systems of budget provision at the political level. This applies to the national/regional as well as the European level.

Carbon Contracts for Difference (CCfD) give the companies a reliable basis upon which to invest, coupled with incentives to attain the promised carbon reduction targets. They are therefore an important instrument to help climate-friendly industrial processes to reach market maturity and to break through on to the market.

De-risking of private investment strongly relyies on public funding, CCfD, regulation, sandboxes and other elements. It is suggested to start development in a stepwise approach based on low TRL (RIA), higher TRL (IA) and demo (IA) up to TRL9 via a FOAK. It is strongly suggested to increase the speed and funding via a financing per result (based on CCfD and state gate approach). To prepare the step to FOAK, regulatory and technological sandboxes are needed to evaluate the functionality under real conditions, but without major regulatory hurdles. Such an approach will also allow to make the right quantification of funding and investment needs avoiding big surprises at the end. This integrated stepwise approach is a fundamental change in the funding approach and should be considered.

Based on these analyses the recommendations can be summarised as follows:

- A stepwise, results-based approach should speed up innovation. Through a test phase in a regulatory sandbox it will find its way to FOAK and full deployment. A uniform funding instrument should be presented at European level in order to avoid a wide variety of instrument in the different MS with similar objectives. The effort required to develop such an instrument at national level is enormous and takes a lot of time. It is therefore proposed to establish this, for example, within the framework of the EU Innovation Fund and the “Auction as a Service for MS” model.

3.3. Monitoring and data

3.3.1. Prioritisation and smart specialisation based on ex-ante monitoring and adjustments

Industry and innovation policy aims to promote a smart specialisation, taking into account the specific strengths of a region or country, which also applies to industrial decarbonisation. Lithuania, for instance, presented how they identify priorities for smart specialisation which was otherwise not often mentioned during the MLE. During such a process, ex-ante conditions in setting priorities need to be controlled and verified during the development and final deployment.

It is recommended to integrate feedback and evaluation loops in engagement processes. Based on this, Smart Specialisation Strategies (S3)need to be aligned with the planning of demonstration plants and FOAKs, especially in recognizing the role of regions in the value chain thinking. Following the development and finally deployment, ex ante conditions need to be adjusted and monitored.

Based on these analyses the recommendations can be summarised as follows:

- ‘Prioritisation and smart specialisation should be based on ex-ante monitoring and adjustments (at regional and interregional level).

3.3.2. Impact of investment policy

While all roadmaps have defined the need for investment and give, as described above, only rough estimations, less effort is put into defining specific investment instruments and policies. None of the countries take a more systematic approach on this matter. Therefore, this issue can be seen as the main weakness of the roadmaps developed in the MLE countries. Some examples:

- Sweden: Banking industry collaboration
- Slovenia: Tax policy should be aligned with the climate neutrality goal
- Austria: Closer collaboration between R&D funding agency and public investment bank via an impact measurement system

To further encourage the adoption of low-carbon products, public and private funding should prioritize projects, products and their use, durability, and potential for circularity in various industries that have a low climate impact, which implies much more than just CO2 emissions reductions, as a key condition for financing. Life cycle assessments are critical and must be kept in mind because so-called green products, whose evaluation only considers the production phase, may have significant unquantified externalities before and after the production. It is important that public authorities convey the message to the public that issues are complex, and several answers are needed to tackle decarbonisation and climate change mitigation and adaptation. Public policies based on product neutrality and life cycle assessment are essential.

In addition, standards for low-carbon products could differentiate between incremental emissions reductions and truly low-carbon processes, ensuring that products meet specific criteria for sustainability, including environmental, economic and social aspects going beyond mere CO2 measures. Although it is important to fund the deployment and transition of industrial performance, looking at the past and present performance of production facilities as evidence and as a frame of reference remains vital to seek improvements. Standardisation is a complex process which is undergoing an impressive revision at European level with the involvement of the European Commission, MS, European Committee of Standardization (CEN), industry representatives, NGOs, etc. It is however not the aim of this report to detail specific recommendations on standards.

The impact on investment policy needs to be aligned with banking and investors and the mapping of demonstration and FOAK facilities. This can be supported by impact monitoring systems, whereby a holistic approach implies that this should be part of the road mapping exercise from the onset.

Based on these analyses the recommendation can be summarised as follows:

- Impact monitoring systems, including Environmental-Social-Governance (ESG) reporting criteria, should align investment policy with banking and investors to define the right needs for demonstration and FOAK facilities (at national/regional level).

3.3.3. Use and improve methods and approaches to assess the impacts of policies

It can be interesting to consider the RT&I framework action plans in a synergetic use between European and national policies and to create, as mentioned by Slovakia, a so-called With Existing Measures (WEM) and With Adapted Measures (WAM) strategy. It makes it possible

to move on to the same target but by upgrading the measures without contradicting the past messages.

Impact calculation is still a weak point and can be linked to the modelling exercises at MS and European level. These impact calculations argue for a strong knowledge about resource availability (see next point), and differentiation among uses, e.g., How to use hydrogen or other energy sources and for which application (modelling)?

Most of the participating countries are in the process of evaluating how to apply a regulatory sandbox environment for the decarbonisation of the process industry. Austria, for instance, through the Research Promotion Agency (FFG) “Energy.Free.Space” program, launched already three calls for proposals (third call concluded in Q2 2023), and Belgium (Flanders) is also operating one regulatory sandbox in Genk.

Most countries are paving the way to implement actions in the field in the near future. Spain is currently drafting a new industry law (“Ley de Industria”), and Slovakia is aiming to expand and increase the use of renewable energy sources. To this end, they are both defining the legal framework to welcome those initiatives. Lastly, there are other relevant initiatives such as those in Portugal worth mentioning, where the Technological Free Zones[31] (ZLT – Zonas Livres Tecnológicas) have been established, corresponding to the concept of regulatory sandboxes.

Although data sharing is difficult for industries, in some cases industry is less reluctant to do it with public authorities when incentives such as subsidies are offered. Thus, in times of crisis, this need from the industries might become an opportunity for more public-private collaboration actions. However, it is generally agreed that it is not efficient to keep changing targets as it conveys uncertainty to the industry. As acknowledged by the industries, R&D investment is the first step towards decarbonisation, and it is an important part of the entire cycle. However, the different financial schemes for scaling up projects at low TRL up to higher TRLs remain important.

Based on these analyses the recommendations can be summarised as follows:

- Impact modelling should be, together with efficiency estimations, integrated in the final RT&I policy by creating knowledge from data and evidence for decision-making and tested in practice via regulatory sandboxes.

3.4. Coordination and collaboration

3.4.1. Smart specialisation and interconnectedness

Most roadmaps consider specific regional conditions and needs and pay specific attention to cities and municipalities (Latvia) and S3 (Belgium, Wallonia). Portugal’s Smart Specialisation

[31] The Technological Free Zones are demonstration and testing areas or spaces for new technologies that need specific and adapted regulatory regimes. They are a "safe space" in which companies can test innovative products, services, business models, and delivery mechanisms without immediately incurring all the normal regulatory consequences related to the activity in question. They are intended to allow testing and experimentation in a real or near real way, with direct and permanent control by the competent regulatory authorities, particularly in terms of testing, provision of information, guidelines, and recommendations, corresponding to the concept of regulatory sandboxes.
Until now, Portugal have established 2 ZLT’s: ZLT Infante D. Henrique, in Troia, aiming at testing unmanned security and defense systems and other technologies in subsurface, surface (land and wet) and air environments; ZLT Matosinhos aims at promoting experimentation and testing of innovative solutions of mobility geared towards carbon neutrality in cities.

Strategy[32] also considers decarbonised cities and territories in the policy-mix. Especially for small countries or regions, smart specialisation will help to focus the activities and initiatives of the quadruple helix and support them in securing their place in the value chains where they can provide the most value.

The MLE emphasised the importance of fostering interconnectedness between roadmaps across countries, as well as enabling valuable knowledge exchange and mutual learning in the industrial decarbonisation and roadmap development process.

Interconnection and smart specialisation need to be installed based on impact modelling with supporting data and not just on local estimated advantages or emotional principles.

Based on these analyses the recommendations can be summarised as follows:

- There is a need for models that can investigate the best European value chains, based on innovation, existing logistics, and existing assets, while at the same time exploring new assets. This smart specialisation should also be based on fair sharing of profits and burden at the same level.

3.4.2. Inter-ministerial alignment

It was observed that road mapping is often set up by one dedicated ministry which differs across the MS. However, strong tensions and problems arise due to the lack of inter-ministerial alignment. Lithuania mentioned translating roadmaps into ministerial language to produce action plans as a crucial step.

Based on these analyses the recommendations can be summarised as follows:

- Find ways to smoothly enable and coordinate inter-ministerial collaboration on the national level via the appointment of ministerial contact points (national/regional level). (e.g., for the purpose of this MLE Portugal organized an inter-ministerial group to further debate and prepare the MLE contributions and to involve other government areas. Austria implemented a transformation policy including inter-ministerial collaboration and coordination through whole of a government approach)[33].

3.4.3. Collaboration among countries

Collaboration among countries is very important for smaller countries or regions as well as border regions and was frequently discussed in the MLE.

Sweden, for instance, has explicitly coordinated its activities with other MS, in particular with other neighbouring countries. Another case is Belgium (Flanders) which collaborates in the definition of a trilateral strategy with the Netherlands and North Rhine Westphalia in the fields of energy, logistics, and R&I.

In general, smart specialisation needs to be aligned with the planning of demonstration facilities and FOAKs especially in recognizing the role of regions in the value chain thinking.

[32] Accessible here: https://www.ani.pt/media/7248/enei-2030-estrat%C3%A9gia-nacional-de-investiga%C3%A7%C3%A3o-e-inova%C3%A7%C3%A3o-para-uma-especializa%C3%A7%C3%A3o-inteligente-2030.pdf

[33] Reference to the MLE on the Whole of Government Approach in Research and Innovation. Accessible here: https://projects.research-and-innovation.ec.europa.eu/en/statistics/policy-support-facility/psf-challenge/mutual-learning-exercise-whole-government-approach-research-and-innovation

There is also a strong need by small countries or regions to enhance the collaboration between (neighbouring) countries and regions at the level of logistics and assets planning.

Based on these analyses the recommendations can be summarised as follows:

- Initiate and expand collaboration among countries integrating the different stakeholders and using the previously mentioned modelling to decide about optimal win-win innovations across the borders and creating the right logistic connections (national/regional level). Such activities must benefit all participating countries/regions.

3.4.4. Strengthen industrial symbiosis

In almost all national roadmaps industrial symbiosis and sectoral coupling (e.g., using waste heat through the collaboration between the manufacturing sector and energy sector) or synergies, are addressed[34]. The circular economy is explicitly used as a concept and strategy in Slovenia. The seaports in Belgium (Flanders) are investing in specific zones for circular economy such as the NextGen district in Antwerp, as part of their strategy to be a climate-neutral port by 2050. Lithuania also stresses industrial symbiosis in the specific circular economy roadmap. Several different forms of industrial symbiosis and initiatives are mentioned by other countries as well(e.g., the Portuguese chemical sector has an industrial symbiosis project in the Estarreja Chemical Complex joining Bondalti, Dow Chemicals, and Air Liquide).

At this moment, Hydrogen Valleys and Hubs4 Circularity are set up as single initiatives. The alignment of it can lead to the integrated use of carbon, water, resources and digital tools. National and local authorities can play a decisive role in the sustainable development and economic attractiveness of such future industrial sites. It can be done via:

- Local logistics
- Upskilling and job attraction
- Local citizen involvement

Based on these analyses the recommendations can be summarised as follows:

- Set up of integrated industrial hubs (H4C), based on supportive logistics, energy storage systems (control of intermittency) and focus on refurbishing existing or creating new industrial parks with an own agenda and common vote.

3.5. Regulatory and non-regulatory issues

During the discussion it became clear that regulation is a strong driver for decarbonisation. However, continuous changes in regulation seem to block decisions on full deployment. As such, long-term targets prepared by regulatory sandboxes and supported by public procurement could go a long way in supporting the desired regulatory stability that industry seeks. Regulatory and non-regulators issued cover amongst others standardisation, public procurement and the use of regulatory sandboxes.

[34] https://op.europa.eu/en/publication-detail/-/publication/f26dfd11-6288-11ea-b735-01aa75ed71a1

3.5.1. Standardisation as a common tool to promote high level climate neutral industries

Standardisation activities are important for promoting industrial decarbonisation. In one MLE workshop Portugal explained the important role of standards as a tool to assist in industrial decarbonisation, as well as of a stable legislative and regulatory framework that provide legal certainty also for companies to operate and contribute to European competitiveness. Technical committees were presented as a pathway to discuss and shape the future standards and how they operate. Beyond industrial decarbonisation, standardisation was positioned as an integral component of broader efforts to address Sustainable Development Goal (SDG) 13, Climate Action, with direct relevance to the process industry. Furthermore, a key search tool to identify interesting activities in the field is presented[35], as well as several related activities as open sources[36] [37]. Lastly, in several ongoing technical committees related topics to industrial decarbonisation[38] [39] [40] were introduced.

The use of different energy sources based on availability needs to be adapted to the processes and technologies in order to see if they can be applied in this way or if it is necessary to set priorities.

Based on these analyses the recommendations can be summarised as follows:

- Countries need to contribute strongly to the technical committees on standardisation of industrial decarbonisation to make standards applicable and to gain a competitive advantage.

3.5.2. Establishment of long-term targets for companies in a stable environment

Companies need long term climate targets to deploy the innovation strategies in the right way without derogations of the targets, changing boundary conditions, etc.

Based on these analyses the recommendations can be summarised as follows:

- There is a need for the establishment of long-term targets for companies in a stable environment with prior indications of possible exemptions.

- Access to data for monitoring purposes can support the way to the target and feed the standards for competitiveness reasons.

3.5.3. Establish regulatory sandboxes

Regulatory sandboxes serve a broader purpose beyond just evaluating technology; they significantly aid in refining the regulations that underpin long-term goals. By testing them in a real-life environment, potential inconsistencies in the regulations can be identified before becoming European regulations. Real life sandboxes can help to support brownfield

[35] https://www.iso.org/advanced-search/x/title/status/P,U,W,D/docNumber/docPartNo/docType/0/langCode/ics/currentStage/true/searchAbstract/false/stage/stageDateStart/stageDateEnd/committee/sdg/06
[36] https://www.iso.org/files/live/sites/isoorg/files/store/en/PUB100271.pdf
[37] https://www.iso.org/publication/PUB100067.html
[38] https://standards.cencenelec.eu/dyn/www/f?p=205:7:0::::FSP_ORG_ID:3356655&cs=1843926F8FC09BB963D5EA641A207A887
[39] https://www.iso.org/committee/648607.html
[40] https://www.iso.org/committee/54560.html

rejuvenation by avoiding going to greenfield development. Regulatory sandboxes can be seen as the preparatory real-life tests before the big step to becoming FOAKs.

Based on these analyses the recommendations can be summarised as follows:

- Integrating sandboxes and phased implementation, supported by innovative financing models that focus on results rather than processes, is crucial for successful and comprehensive deployment. This approach will prevent protracted permitting disputes.

3.5.4. Use public procurement more systematically

Growing demand for green products is crucial. To this end, it is required to stimulate the changing customer requirements towards high quality green products, along the value chain, where the process industries operate. Brand owners act as drivers for green materials made with less CO2, less hazardous compounds and based on high recycled material content or bio (i.e. no fossil) content. Such tendencies will result in growing investor and public interest in sustainability and low-carbon technologies. To this end, governments can take action to support low carbon manufacturers by creating demand and developing the market for low-carbon industrial products.

In order to support de-risking at the level of market creation, public procurement (e.g., green steel, renewable plastics, green concrete, etc.) can strongly help the initial steps in finding and creating a market for the new products or products made by more sustainable processes. There is the so-called attitude/behaviour gap in the market - meaning that the acceptance of new greener products is not necessarily matched by an effective purchase, due to several factors including higher price and lack of trust. Green Public Procurement (GPP[41]), Sustainable Public Procurement[42] and Strategic Public Procurement[43] must be in place and to help instil confidence in the market on the performance and durability of green, low carbon products and solutions. In order to explain these three similar terms the following definitions are formulated.

Green Public Procurement is a process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be procured."

Sustainable Public Procurement is the making products sustainable by default in the internal market is the best way to support sustainable public procurement".

Strategic Public Procurement for innovation is defined as any kind of public procurement practice that is intended to stimulate innovation through research and development and the market uptake of innovative products and services.

[41] https://green-business.ec.europa.eu/green-public-procurement_en
[42] https://sustainable-procurement.org/news?c=search&uid=oe4K2FiG
[43] https://www.oecd-ilibrary.org/docserver/gov_glance-2017-60en.pdf?expires=1711020447&id=id&accname=guest&checksum=1BD9FCEF9DB9DF7EF3981CA578496E9C

Based on these analyses the recommendations can be summarised as follows:

- Green Public Procurement (GPP) can be the first step in bringing products made via more sustainable processes to the market.

- Aside from GPP, consider Strategic Public Procurement, which can leverage technological improvements and disruptive technologies, leading the way to sustainable solutions, resilient value chains, and energy independence.

3.6. Communication

Communication and roadmap information is seen as lacking in the broad social landscape leading to a lack of trust and the feeling that insufficient activities are being carried out by the national/regional governments. This communication is missing or not very well functioning at the level of citizens as well as at the level of industrial stakeholders, frequently resulting in negative perceptions that hinder interaction, understanding, and trust.

3.6.1. Public communication, awareness raising and visibility

A compelling narrative is required, emphasising the need to urgently focus on climate neutrality and the reindustrialisation of Europe. The positive outcomes for citizens, such as the creation of new skilled jobs or the improvement of the environmental ecosystems (e.g. reduced pollution) must be highlighted as well. This approach is essential to foster a positive public perception. To achieve this objective, it is crucial to engage all stakeholders, including regions and municipalities. A comprehensive approach must be adopted, considering the entire value chain. In line with this need, under the Belgian presidency, the process industries have published a joint declaration to express their full support for a European Industrial Deal to complement the European Green Deal and keep high quality jobs for European workers in Europe. It also it includes 10 actions to restore competitiveness. Additionally, as part of the active communication actions in describing the benefits of the process industry to the society, results arising from publicly funded research, development, and innovation (R&D&I) projects should be used to enhance visibility and effectively communicate the impact to society at large, via the use of incentives (e.g., bonus). To this end, a strong involvement and commitment of regional authorities is required.

The MLE experts welcomed the initiative by the EC to build up a database on demonstration projects across Europe, which could facilitate further alignment of investments and policies between different countries. Participants also stressed that it is possible to communicate on the existence and the mapping of these demonstration projects to a wider audience and public, which could also contribute to further awareness raising on a broader scale. Publicly available information was raised several times during the MLE as an issue that requires attention and that overall the narrative around industrial decarbonisation also requires illustrative best practices to convince society. This is also linked to the overall visibility of national roadmaps. Roadmaps are not at all known by the public or society as a whole. In addition, figures alone are not convincing, but there is a need for storytelling and examples.

Thus, roadmaps should be brought to the broader public via storytelling based on clear narratives. Communication must be clear, consistent, and transparent. Communication must unify varied stakeholders, allowing them to move towards the shared objectives of carbon neutrality.

To prevent carbon leakage and foster re-industrialisation, it is essential to translate these goals into tangible actions and clear communication. Highlighting compelling examples can effectively demonstrate the benefits:

- New sustainable mines not only generate employment opportunities but also supply critical raw materials (CRMs) with minimal environmental impact.
- The wind energy sector in Europe is a significant source of employment.
- The battery industry is anticipated to create millions of jobs.
- Employment opportunities for engineering companies, though specific data is not yet available, are expected to rise.
- The establishment of new plants is projected to generate numerous jobs, with precise figures still to be determined.

These examples underscore the potential for sustainable practices and innovations to drive job creation and economic growth.

Based on these analyses the recommendations can be summarised as follows:

- Tell your story and show a bright and inclusive future' (National/regional and EC level) in an open and comprehensive way.

3.6.2. Turn lobbying activities into involvement activities and using industrial frontrunners as well as industrial federations

The MLE discussions came to the conclusion that lobbying efforts at times create resistance, hamper changes and create a loss of momentum. Instead, commitment via early involvement of industry and other stakeholders would help stakeholders and engaged actors find their ambition. Many roadmaps are set up in collaboration with industrial stakeholders. Often times these industrial stakeholders are the same, limited in number, and not per definition representing the whole sector. Alternatively, the sector federations could play a role if they are willing to enter into a commitment with a long-term constructive contribution.

The recommendation is hence to turn lobbying activities into involvement activities and use industrial frontrunners as well as industrial federations to make this turn. Be prepared and anticipate how problems and obstacles can be solved due to possible trade-offs, inertia, problematic lobbying, etc. In such a participatory process it is important to ensure regular opportunities for the involvement and exchange with federations and stakeholders to get input on how to put ideas into practice.

Based on these analyses the recommendations can be summarised as follows:

- Moving from lobbying into involvement will create a more constructive spirit in the common development of a new green future (national/regional and EC level)

3.7. Knowledge, competence, and talent

Member states and industry are very concerned about the lack of competence, talent and workforce for several innovation actions in the future. Several MS are conducting studies

about the future lack of workforce and skills. It is suggested to create overviews of needed European talents and to solve the problem by creating attractive educational curricula.

3.7.1. Raise the needed European talents and retain them via attractive educational curricula

The European industry is confronted with ensuring the availability of sufficient and appropriate talent and skills to fill in the jobs for the future activities. There is also a need for reskilling and upskilling in function of the future technologies. Recently, Belgium (Flanders) published a report on their green skills needs. The report indicated the gaps of skilled people, but also the additional needs in some sectors, strongly including the EIIs, for skilled employees. The Portuguese industries mentioned the urgent need for talent.in view of the continuation of production and especially in view of the transition toward sustainable production. This emphasises the need for skilled people to manage the technological tasks on the one hand, and the need for talent to create the technological innovations needed on the other.

The success of industrial decarbonisation hinges on knowledge and competence. The nuances of this transition expand beyond mere technology; they encompass social, economic, and cultural facets. As industries pivot, it becomes clear that the journey towards carbon neutrality isn't just about innovation but also about deep-rooted understanding and expertise. Knowledge-sharing becomes paramount. Stakeholders, from local communities to global experts, bring a diverse pool of knowledge, ensuring that the challenges of decarbonisation are met with a holistic approach. Governments and educational institutions solidify this foundation by fostering an environment that values environmental awareness and continuous learning.

Engagement and motivation of different actors must be built on knowledge and competence by the educational system in revising curricula toward the future skills needs to deploy and sustain a sustainable industry (national/regional level). As an example, the, Skills Alliance for Industrial Symbiosis (SPIRE-SAIS[44]), can be mentioned.

There is a general awareness, and it is acknowledged, that resources and effort invested in up-skilling will accelerate the uptake of new low-carbon technologies. However, only four participating countries are actively moving towards specific plans to implement this activity. Belgium (Flanders) has already put in place training for more mature technologies (such as heat pumps) and plans more training as it recognises the transition is technology-driven. Slovenia highlighted the importance of a collective effort that includes government and institutions to educate skilled people of the future. The Georgian Ministry of Economy and Sustainable Development is actively working on the implementation of the renewable energy law, with a focus on green skills. Four short-term educational programs for renewable energy installers were launched in 2022 by Georgian Technical University with close cooperation with the Ministry of Economy and Sustainable Development (MoESD). Besides that, MoESD is preparing the vocational programs for energy efficiency auditors in industry, buildings, and transport, building energy efficiency certification specialist, inspector of heating and cooling of buildings.

[44] https://www.aspire2050.eu/sais

Based on these analyses the recommendations can be summarised as follows:

- Each country/region can make a kind of green skills need study to develop and adapt educational programmes and actions (National/regional level) in order to foster a stronger cooperation between academia and industry; making curricula and qualification better fit the development of future skills in the context of both the digital and decarbonisation transitions:
  - Investigation of the future needs of technical, professional, and transversal skills (needed workforce) in collaboration with the industrial associations. See also Pact of Skills of P4P.
  - Investigation of expansion demands in certain sectors.
  - Promote the needed skilling (ex-ante)
  - Set up programs for upskilling (ex post) by raising educational programs for upskilling industrial employees.

4. Summary of recommendations

4.1. Generic recommendations

- Roadmaps need to be continuously updated at the national and regional level in alignment with the European roadmaps and ambitions as well as the industrial roadmaps and commitments. Specifically, some supportive actions are needed:
  - The MS are strongly asking for a continuous updated list of available technologies. This list can support a forward-looking mechanism to upgrade the BAT over a longer term.
  - Alignment with the roadmaps of the European sector federations and partnerships.
  - Modelling and data integration in 'no-regret' flows of transition to estimate investment cost [to be developed at the levels of the EC and the European Committee for Standardisation (CEN) and used at national/regional level].
  - Recent topics of research decarbonation, already recognised by international stakeholders such as the IPCC, should be highlighted, and encouraged.
  - Investigation of gaps that need to be closed in the value chains (to be done at national/regional level due to the tight regional character of SMEs).
  - New EU rules on corporate sustainability reporting, with a value chain approach, may help identify opportunities in innovation paths.
  - Prioritisation and smart specialisation should be based on *ex-ante* monitoring and adjustments (at regional and interregional level).

- Impact modelling should be, together with efficiency estimations, integrated in the final RT&I policy by creating knowledge from data and evidence for decision-making and tested in practice via regulatory sandboxes.

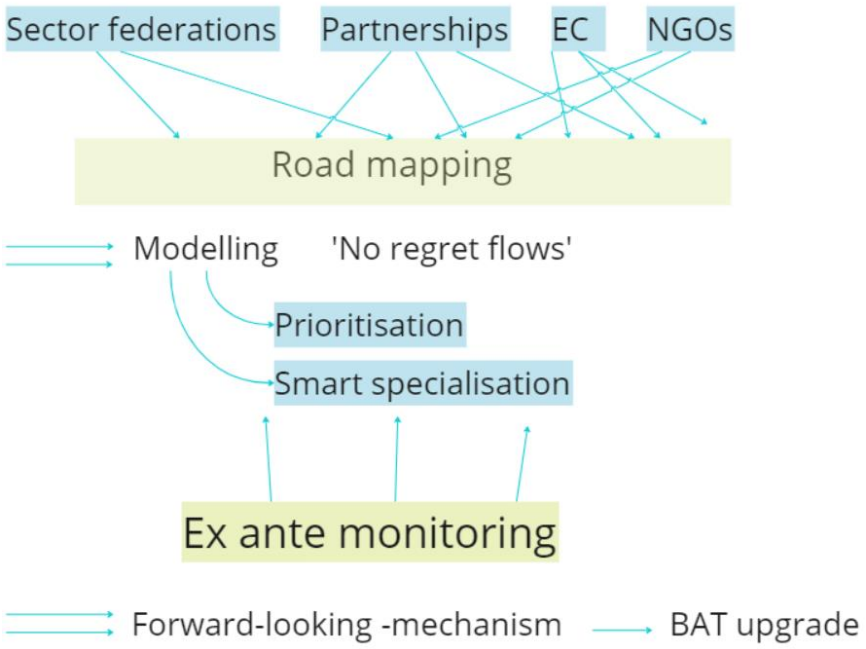

Figure 1: Roadmaps
Source: Ludo Diels, 2024

- All stakeholders need to be involved. This supposes the following actions:
  - Stakeholders should sign Memorandums of Understanding (MOUs) in the beginning of the innovation circle exercise as part of an open mind involvement in function of impact and related to the further proposal of a stepwise target-oriented funding scheme.
  - This agreement should contain a plan on building infrastructure support (commitment by national/regional authorities) in order to avoid investments not leading to the envisaged impact.
  - Implement industrial symbiosis to unlock new possibilities such as carbon circularity, resource efficiency, energy efficiency and water efficiency.
  - Find ways to smoothly enable and coordinate inter-ministerial collaboration on the national level via the appointment of ministerial contact points (national/regional level).
  - Citizen science projects should be encouraged and incentivised as they can help stakeholders understand the problems, inviting them to find common acceptable solutions.
  - Exercises to integrate the concerns of different NGOs leading to an integrated proposal.

- Cross-border collaborations can be set up by public bodies integrating the different stakeholders and using the earlier mentioned modelling to decide about optimal win-win innovations across the borders and creating the right logistic connections (national/regional level). Such activities must be at the benefit of both border regions.

- EIIs needs supportive measures to deploy R&I into full scale facilities, such as:

  - A supportive energy sector (including hydrogen supply) embedded in a full industrial ecosystem including SMEs and digitalisation and an action of mutual learning via European Communities of Practice (ECOPs)

  - Clear regulations for CO_2 infrastructure (both CO_2 storage and transportation networks) are needed. The issue is particularly urgent as the first carbon capture projects are rapidly becoming a reality.

  - Logistics and infrastructure perspective. Logistics and infrastructure need to be in place before either a green electrons-based or a green hydrogen-based economy can be built.

  - Establishment of integrated industrial hubs (H4C[45]), based on supportive logistics, energy storage systems (control of intermittency) and focus on refurbishing existing or creating new industrial parks with a specific agenda and common vote. This can be combined with the ECOP on waste and the relation with H4C.

  - Models that can investigate the most promising European value chains, based on innovation, existing logistics, and existing assets, and explore new assets. It should also be based on fair sharing of profits and burden at the same level.

  - Moving from lobbying into involvement, which will create a more constructive spirit in the common development of a new green future (national/regional and European level) in collaboration with industry

[45] Accessible here: https://www.h4c-community.eu/

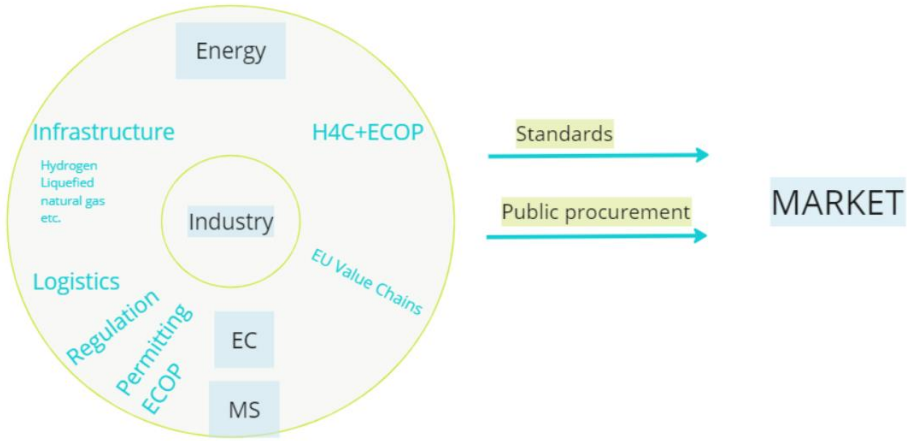

Figure 2: Supportive measures to EIIs
Source: Ludo Diels, 2024

With regard to funding and derisking the following actions are strongly recommended:

- A big part of large equipment and demonstration facilities established via national and European funding systems should be shared with other researchers after finalisation of the funding project in OITB's which will lead to much longer, more efficient and sustainable use of research and demonstration investments. This set up would strongly improve the scientific involvement and integration.

- Funding schemes of demo plants and FOAKs should aim to support both CAPEX and OPEX costs (e.g., the latter are critical given the importance of electricity costs when it comes to carbon capture - in this respect, exploring CCfD for CCUS covering CAPEX, OPEX, storage, and transport costs is critical). Lengthier operations of demo plants can support better methods and evidence for estimating the investment needs that are required. This type of funding is very complex and needs only to be put in place in case of major technology changes.

- Impact monitoring systems (aligned with ESG-reporting) should align investment policy with banking and investors to define the right needs for demo- and FOAK-plants (at national/regional level).

- Several regulatory and non-regulatory issues need to support the actions:

  - Set up a Community of Practice on Permitting.

  - Countries need to strongly contribute to the technical committees on standardisation of industrial decarbonisation.

  - There is a need for establishment of long-term targets for companies in a stable environment with prior indications of possible exemptions.

- Integrating sandboxes and phased implementation, supported by innovative financing models that focus on results rather than processes, is crucial for successful and comprehensive deployment. This approach will prevent protracted permitting disputes.

- Green and Sustainable Public procurement can be the first step in bringing products made via more sustainable processes to the market. Aside from Green Public Procurement, Strategic Public Procurement should also be considered, which can leverage technological improvements and disruptive technologies, leading the way to sustainable solutions, resilient value chains, and energy independency.

- Build compelling and concise storylines that show a bright and inclusive future

4.2. Dedicated action plans

- There is a strong need for a framework action plan based on:

  - Mapping and monitoring of ongoing research projects (TRL>5), demonstration facilities, and FOAKs at European and at national/regional level.

  - This can lead to the promotion of the synergetic use of national and European funding.

  - Suggest market pull actions (see targeted procurement actions).

  - Create a Community of Practice at the level of permitting, as well as case studies and taking into account the conclusions and recommendations of this exercise.

Figure 3: Framework action plan
Source: Ludo Diels, 2024

- A stepwise, target-oriented approach should speed up innovation and, via a test phase in a regulatory sandbox, find its way to FOAK and full deployment. A uniform funding instrument should be presented here at European level in order to avoid a wide variety of instrument variants in the different MS. The effort required to develop and notify such an

instrument at national level is enormous and takes a lot of time. It is therefore proposed to establish this, for example, within the framework of the EU Innovation Fund or as an auction model (e.g. European Hydrogen Bank Pilot Auction[46]). The system should be based on:

- The clear definition of targets, setting the direction and goals for innovation funding,
- A stepwise approach from RIA to IA, demonstration, and FOAK without time losses in between,
- Support from both regulatory and practical sandboxes, offering a controlled environment for testing innovation,
- The realisation of FOAKs through uniform financing, ensuring that funding decisions are made with a 'no-regret' policy, minimising risks for all stakeholders,
- Integration into both local and international logistics systems to secure the necessary sustainable resources, extending support to smaller stakeholders,
- A strong emphasis on global competitiveness, incorporating considerations for operational expenses (OPEX) funding, Carbon Contracts for Difference (CCfD), stage gate, and auction-based funding systems, ensuring that the financial structures support sustained innovation and competitiveness.

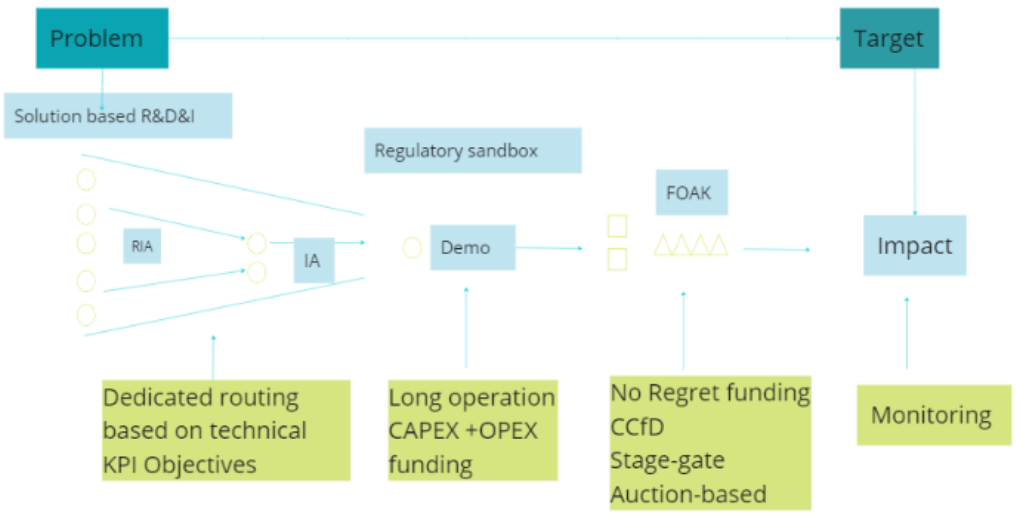

Figure 4: Stepwise, target-oriented approach
Source: Ludo Diels, 2024

[46] https://climate.ec.europa.eu/news-your-voice/news/european-hydrogen-bank-pilot-auction-132-bids-received-17-european-countries-2024-02-19_en

- Set up a new Community of Practice on energy and resources which should include considerations on:

  - Countries and regions need infrastructure to provide green electricity and green hydrogen production and be connected via cross-border electric power, hydrogen piping, etc. to develop the local sustainable ecosystem.

  - Waste reuse, recycling, coprocessing (combination of simultaneous material recycling and energy recovery from waste in a thermal process), and landfill mining need strong infrastructural investments. Initially this can be done at national/regional level and later, it can expand via the ECOP of the H4C to an international level.

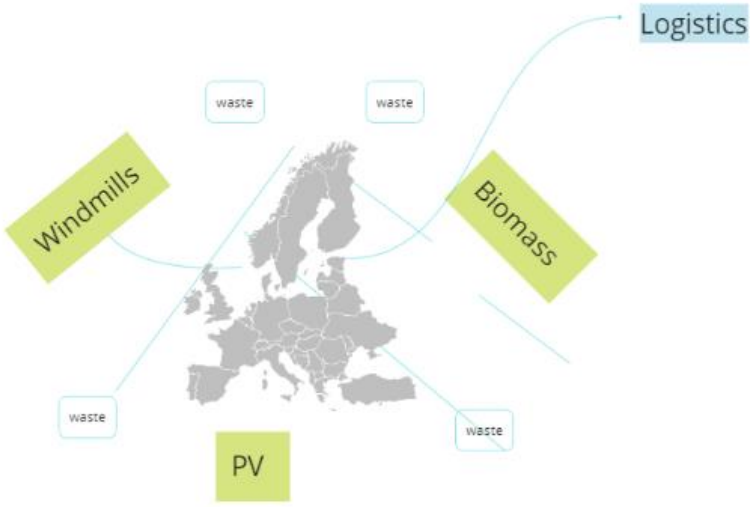

Figure 5: Community of Practice on energy and resources
Source: Ludo Diels, 2024

- Each country/region can develop a green skills needs study to develop and adapt educational programmes and actions (national/regional level) in order to foster a stronger cooperation between academia and industry, thus supporting curricula and qualifications to better fit the development of future skills in the context of both the digital and decarbonisation transitions. Aspects to include are:

  - Investigation of the future needs of technical, professional, and transversal skills (required workforce) in collaboration with the sectors.

  - Investigation of expansion demands in certain sectors.

  - Promote the necessary skilling (ex-ante)

  - Set up programmes for upskilling (ex-post) by raising educational programmes for upskilling industrial employees.

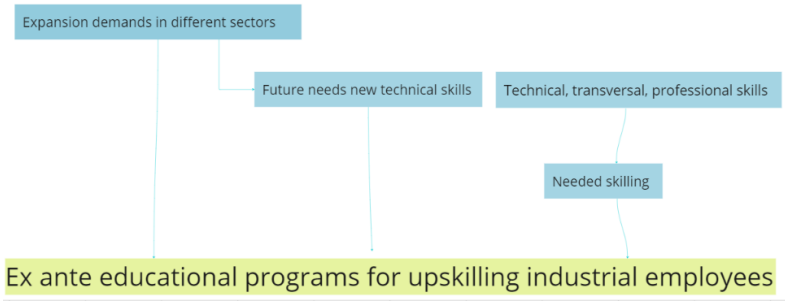

Figure 6: Green skills deployment
Source: Ludo Diels, 2024

4.3. Impact on participating countries: Recommendations according to priority level

All participating countries support the recommendations in this report. 10 out of 12 countries indicated which ones they would wish to start implementing immediately, as priorities. This is illustrated in the bullet-based overview below.

- Austria:
  - Whole-of-government approach and inter-ministerial coordination.
  - Support from the EU funds regarding CAPEX and OPEX funding area, especially simplified and accelerated notification procedures.
  - Information on financing (options) for different types of demonstrations.
  - Financing of systems without historical CO_2.
  - Look into area of “creating demand” through (innovative) public procurement, learning from others.
  - CCfD.
  - Close connection to hydrogen and carbon management activities (strategies, IPCEI, among others).
  - Involvement of SME’s.
  - International partnerships / cooperation.
  - Improvement of mechanism of IF regarding submissions and support to facilitating the transfer of decarbonisation technologies to market.

- Belgium (Flanders):
  - Uniform modelling and monitoring.
  - Derisking investment system.
  - R&I framework action plan: synergetic use national/EC.
  - Alignment of roadmaps between countries/regions.
  - Financing models that lower initial operating costs.
  - Role of SMEs.
- Belgium (Wallonia):
  - Inter-ministerial alignment.
  - Stakeholder involvement from the onset.
  - NGO's and linking with citizen science projects.
  - Interregional collaboration to align activities at all levels.
- Spain:
  - Regulatory sandboxes.
  - Industrial policy framework.
  - Alignment with PPPs.
  - Recommendations for the design of aid schemes supporting industrial decarbonisation and efficient use of the GBER.
  - Recommendations for CCfD design, as well as for schemes centred on CAPEX.
  - Recommendations on how to link better energy and industrial policy, as well as R&I and industrial policy to accelerate the uptake of new decarbonisation technologies.
  - Taking into account OPEX cost in large demonstration plants.
- Finland:
  - Stepwise result-driven approach for innovation and deployment funding.
  - Considering that some recommendations take longer to implement because of budget cuts and structural changes that affect stakeholder interests.

- Georgia:
  - Involve all stakeholders from the beginning, raise awareness and apply compelling storytelling.
  - Alignment at all levels to create appropriate framework conditions.
  - Derisking investment system for low-carbon technologies in the form of grants and soft loans.
- Lithuania:
  - Awareness raising.
  - List of available technologies.
- Portugal:
  - The R&I Framework Action Plan should include a skills & talent dimension.
  - Derisking investment system.
  - Integrated Step-Wise funding mechanism.
  - Uniform monitoring and modelling system.
  - Collaboration with other regions.
  - Faster and streamlined permitting processes for green technologies: simplification, coordination, and bureaucratic reduction. Even though there is common EU legislation, the capacity of its application in the countries and the time to grant the permits may vary.
  - Need for a coherent and stable legislative and regulatory framework providing legal certainty when industrial players are planning their mid/long term investments.
- Slovakia:
  - Alignment at all levels of the roadmap with the different stakeholders.
  - Inter-ministerial alignment.
  - Making monitoring more uniform.
  - Better collaboration between government and industry.
- Türkiye:
  - Involvement of all stakeholders from the beginning.
  - Alignment at all levels of the roadmap with the different stakeholders.

- Inter-ministerial alignment.
- Making monitoring more uniform.
- Urgent implementation of the roadmap including regulatory aspects.
- NGOs involvement and linking to citizen science projects.

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This Final Report synthesises the outcomes and insights from the Mutual Learning Exercise on Industrial Decarbonisation. It presents a comprehensive analysis of the challenges and opportunities in decarbonising the European process industry, characterised by its high energy and carbon intensity. Drawing on the collaboration of twelve participating countries, it identifies key drivers for the adoption of low-carbon technologies and underscores the urgent need for coordinated efforts to address energy supply challenges. The Report advocates for accelerating the pace of innovation transfer to industrial scale, emphasising the importance of stable regulatory conditions for securing investments. The report calls for a harmonised approach between national and EU-level initiatives, underscoring the necessity of aligning roadmaps, strategies, and policies to achieve a sustainable, low-carbon industrial future.

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