



Mutual Learning Exercise Industrial Decarbonisation:

Overview of national strategies and roadmaps for
industrial decarbonization

First thematic report

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Mutual Learning Exercise: Industrial decarbonisation, Overview of national strategies and roadmaps for industrial decarbonization, First Thematic Report

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Mutual Learning Exercise: Industrial decarbonisation

**National strategies and roadmaps for industrial
decarbonization**

First Thematic Report

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1. Introduction

This Mutual learning exercise (MLE) serves as a platform for 12 participating countries to discuss their specific needs and interests, exchange experiences and knowledge about success factors and lessons learned and provide guidance to policy makers on how to develop or update their industrial technology roadmaps and sector-specific strategies for industrial decarbonisation¹.

A1 – European Semester and Country Intelligence’ of the ERA & Innovation Directorate at DG Research and Innovation is the Policy Support Facility Team for this MLE, while E.1 - Industrial Research, Innovation and Investment Agendas oversees the work, with the support of E3 - Industrial Transformation of the Prosperity Directorate, DG Research and Innovation.

The first thematic report has been prepared as a result of the kick-off meeting of this MLE, held virtually on 28 April 2023.

1.1. Background

The industrial technology roadmaps are a crucial component of the new European Research Area (ERA) strategy. They are designed to accelerate the transfer of research and innovation (R&I) results into the market in order to drive the green and digital transformation of industries across the European Union (EU). The roadmaps outline the way forward to better utilise industrial R&I results at the European and national levels. The European Commission, 21 Member States², 3 Associated Countries³, and 7 key stakeholders⁴ have committed to supporting this effort, which also involves activities related to technology infrastructure, policy framework to support industrial R&I, and social adaptation to the green and digital transitions.

The first ERA industrial technology roadmap, published in April 2022, focuses on low-carbon technologies in energy-intensive industries. It evaluates the current state of technology and support instruments in the EU. The roadmap shows a gap in R&I investments compared to the emissions targets of the European Green Deal. The transition to a climate-neutral economy by 2050 requires transformation in all sectors and reducing emissions in energy-intensive industries, which accounted for 17% of the EU's total emissions in 2019. This is crucial to meet the EU climate goals. The roadmap also indicates that some EU Member States have already created decarbonisation strategies for energy-intensive industries in partnership with relevant stakeholders. These strategies are important tools for designing a detailed process with milestones towards commonly agreed emission reduction targets. The European Commission is also investing in partnerships with industry to address gaps and promote circular business models. These partnerships, like Clean Steel and Processes4Planet (P4P), include initiatives like the P4P Impact Panel and Hubs4Circularity to drive innovation and engage regions with heavy industrial presence in the transition to carbon neutrality.

¹ Factsheet: [Industrial decarbonisation - Publications Office of the EU \(europa.eu\)](#)

² Austria, Belgium, Bulgaria, Cyprus, Czechia, Denmark, Estonia, France, Finland, Germany, Ireland, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, and Sweden.

³ Georgia, Israel and Norway.

⁴ All European Academies (ALLEA), Committee of the Regions (CoR), European Association of Research and Technology (EARTO), European University Association (EUA), Science Europe, the Guild of European Research-Intensive Universities (the GUILD), and Universities of Applied Sciences for Europe (UAS4 Europe).

In response to the challenges posed by the war of Russia in Ukraine and disruptions in the global energy market, the European Commission has introduced the REPowerEU Plan in May 2022. Under this plan, the Recovery and Resilience Facility will support Member States in introducing critical reforms and investments to phase out EU's dependence on Russian fossil fuels and foster zero-carbon sources and energy resilience. The Commission also proposed a Net-Zero Industry Act on 16 March 2023 with clean tech objectives for 2030, focused on strategic projects and simplified permitting for new clean tech production sites. Furthermore, a new REPowerEU chapter of the Recovery and Resilience Plan was proposed on 27 February 2023 as an amendment to the Recovery and Resilience Facility (RRF) Regulation 2021/241. An additional EUR 20 billion in grants will be made available to finance investments and reforms. Member States are encouraged to include measures with a cross-border dimension and representing minimum 30% of their REPowerEU chapter. They will have to consult relevant stakeholders and are encouraged to submit their modified plans with REPowerEU chapters as soon as possible and in any case by August 2023. In this way, the assessment and adoption process can be finalised for signing the financing and/or loan agreements still in 2023. Payments under the RRF regulation cannot be made after December 2026.

1.2. Objectives

The Mutual Learning Exercise (MLE) is an established instrument of the EU to promote the exchange of best practices among the participating countries and to allow countries to learn from each other and from the experts. As emphasised by DG Research and Innovation, during the virtual kick-off meeting of the Industrial Decarbonisation MLE on 28 April 2023, the success of this exercise lies on the openness and trust among participants in sharing their experiences and on the involvement of Associated Countries. The Commission expert also highlighted the importance of interaction among the several MLEs and the need to reflect on the implementation of the MLE.

In this context, the MLE on Industrial Decarbonisation⁵ is expected to contribute to achieving the Green Deal objectives and to follow-up on one of the actions of the first ERA industrial technology roadmap, namely, to facilitate specific national sectoral and cross-sectoral strategies or programmes with key stakeholders as part of the ERA policy agenda 2022-2024. This includes the preparation of a roadmap with key information on the state of play and what needs to be done to deploy the roadmap, as well as the sharing of EU policies and EU best practices. In his intervention during the MLE kick-off meeting, DG Research and Innovation emphasised that the objectives of this MLE should include linking research and innovation policy and the industrial ecosystem within the new ERA.

After a call for interest to participate in the Industrial Decarbonisation MLE, 12 European countries have committed in early 2023 to participate in the specific MLE. These countries are Austria, Belgium, Finland, Georgia, Latvia, Lithuania, Portugal, Slovakia, Slovenia, Spain, Sweden, and Türkiye.

The MLE on Industrial Decarbonisation, which will run between April 2023 and March 2024, will serve 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 policy makers on how to develop or update their industrial technology roadmaps and sector-specific strategies for industrial decarbonisation. In addition, the MLE will provide best practices and models for mobilising private and public investments in low-carbon technologies in energy-intensive industries and their deployment, taking into account also framework conditions, with the objective of supporting the green transition and achieving

⁵ [Factsheet of the Industrial Decarbonisation MLE](#)

net-zero emissions. This will help countries to effectively address the challenges of reducing carbon emissions in the industrial sector and move towards a more sustainable future. The MLE will help to effectively address the challenges of reducing carbon emissions and link R&I on industrial decarbonisation to National Climate and Energy Plans and the new REPowerEU chapter in the Recovery and Resilience Plans of Member States. DG Research and Innovation stated during the kick-off meeting that the ultimate goal of this MLE is faster deployment of new technology, business solutions, and models to facilitate the transition to a climate-neutral continent, while also strengthening Europe's industrial sector.

1.3. Process and topics

The MLE will be structured in five rounds of meetings on specific topics proposed by the European Commission in the ERA Forum in October 2022 and refined after a consultation process with the participating countries during a scoping online workshop, held on 12 December 2022. The kick-off meeting (online, topic 1) was held on 28 April 2023. Another meeting was organised on 29-30 June 2023 (physical, in Vienna – topic 2), whereas there are three other meetings under the MLE, namely in September (online, topic 3), in November (physical, location to be confirmed, topic 4) and in January 2024 (online, conclusions). A final dissemination event is envisaged to take place in March 2024 (hybrid meeting, Brussels).

The four topics of the MLE on industrial decarbonisation are:

Topic 1: Introduction and overview of national strategies

The meeting introduced and discussed national roadmaps for low-carbon technologies in energy-intensive industries and related sector-specific decarbonisation programs, along with the initial ERA industrial technology roadmap for low-carbon technologies in energy-intensive industries. Emphasis was also put on technological developments, on investments at different TRLs, and on 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, such as under the Recovery and Resilience Facility, state aid programs and the regulatory framework, SME support programmes, European Regional Development Fund, or Climate KIC EIT. The meeting also focused on various financing instruments under the European Investment Bank, the European Investment Fund, National Promotion/Development Banks, among other. Finally, the mobilisation of public and private R&I investments for climate neutrality (e.g., investment pipelines, first-of-a-kind installations, Important Projects of Common European Interest) was discussed.

Topic 3: Actors' engagement

The third topic will deliver best practices and insights gained from interactions with national key stakeholders and government institutions from earlier MLE meetings. Additionally, the meeting will focus on the experiences of several groups and partnerships, including the European Strategic Energy Technology (SET)-Plan group, the High-level group on energy-intensive industries, the group of ERA Action 12 contact points, 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 will discuss 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 first-of-a-kind installations. In addition, the meeting will focus on the role of technology infrastructures, open innovation test beds, and other platforms. The topic will further include the knowledge and data aspects (i.e., data valorisation, standardisation, monitoring of R&I data and key performance indicators) as well as green patenting.

1.4. Structure of this report

This first thematic report gives an overview of industrial decarbonisation roadmaps and strategies at national level, along with the initial ERA industrial technology roadmap. After presenting selected key findings of the ERA industrial technology roadmap, an overview of lessons learned from past roadmapping exercises is given. Based on an analytical grid, the state-of-play in the different countries is presented. Finally, the report gives an outlook for the next phase and the meeting, held on 29-30 June 2023 in Vienna. The thematic report, hence, delivers input for a further reflection about the lessons in developing roadmaps and national strategies as a foundation for the next MLE meeting.

2. The ERA industrial technology roadmap for low-carbon technologies

The ERA industrial technology roadmap for low-carbon technologies in energy-efficient industries was published in April 2022 by the European Commission⁶. It provides the analysis of the status quo and integrates findings from various analyses of primary and secondary data and consultations with various experts from Member States, industry and other stakeholder groups.

The report:

- 1) Offers a list of key emerging low-carbon technologies for energy-intensive industries and their level of maturity.
- 2) Outlines scenarios for the transition of energy-intensive industries to climate neutrality and tools for leveraging R&I investments to accelerate development and uptake of low-carbon technologies.
- 3) Elaborates on R&I needs, including public and private R&I investments.
- 4) Considers the relevant European partnerships, green patenting activity and R&I investments as a starting point and maps the state of play of European and national public support instruments as well as enabling conditions, including regulatory framework, valorisation and standardisation aspects.
- 5) Concludes with key findings and related actions.

⁶ The report can be found here: [ERA industrial technology roadmap for low-carbon technologies in energy-intensive industries \(europa.eu\)](https://era.europa.eu/era-industrial-technology-roadmap-for-low-carbon-technologies-in-energy-intensive-industries)

The following figure shows the key findings and barriers as identified in the industrial tech roadmap and the corresponding key actions to address those barriers, as presented during the kick-off meeting of this MLE on 28 April 2023.

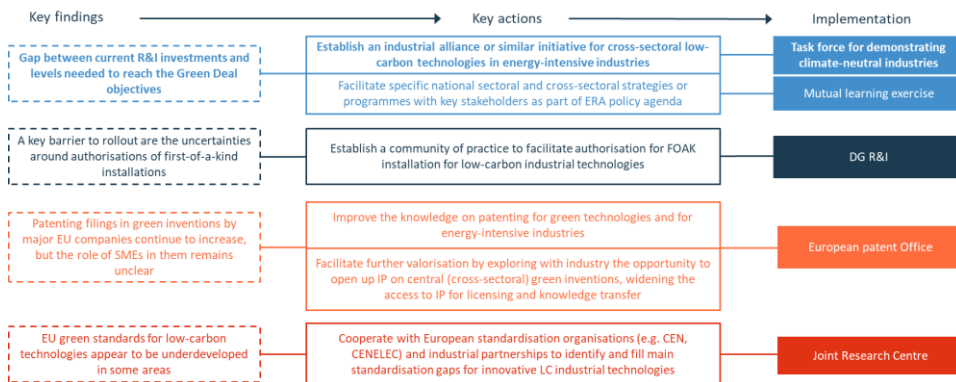


Figure 1: Key findings of the ERA roadmap and key actions to overcome the barriers.

Source: DG Research and Innovation.

Another related workstream is the EC Task Force for demonstrating climate-neutral industries. This task force functioned as a Commission internal cooperation led by DG Research and Innovation, DG Internal Market, Industry, Entrepreneurship and SMEs and DG Climate Action between January and May 2023. The objective of this Task Force was to identify R&I investment gaps for demonstration and bringing to the market of new technologies. The Task force had the following tasks:

- Mapping relevant innovation demonstration projects supported at EU-level.
- Assessing potential gaps.
- Preparing the grounds for discussion with Member States, industry and other stakeholders towards a commitment to address gaps before 2030 and to further develop viable technologies.

The Task force has identified relevant industrial demonstrators with information about the location, sector and technology group. During the kick-off meeting, DG Research and Innovation presented this overview of 184 identified demonstrators. The presentation revealed a clear innovation pipeline from TRL 6 to TRL 9, with the Horizon Framework Programme and Innovation Fund playing critical roles for projects with respectively lower and higher maturity. Some findings from the analysis include that the decarbonisation pathways of green hydrogen, circularity and energy efficiency are most represented; that steel, chemicals, and cement are the prominent sectors; and, finally, that the distribution of demonstrators across Member States is not strictly based on industrial significance. The analysis also shows that the integration needs for renewable energy sources (hydrogen, electricity) are to be considered. In the meantime, this analysis resulted in the publication of a report in June 2023⁷.

The Commission experts emphasised the link between this exercise and the industrial decarbonisation MLE in the sense that the MLE can help contributing to decarbonisation

⁷ The report can be found here: [Innovative clean technologies can make energy-intensive industries climate neutral \(europa.eu\)](https://www.europa.eu/innovation/clean-tech)

investments and to quickly bring demonstrators for climate-neutral industries to the market in view of the approaching deadline of 2030 and the need for independence from fossil fuels.

3. Designing Roadmaps that matter

The need for roadmaps

Industrial technology roadmaps have become widely used in the past for the management of complex technologies implying the involvement of a number of different actors who only jointly can master specific challenges. Roadmaps align the activities in an industry and are particularly helpful to reduce uncertainty for and give orientation to different organisations.

Roadmaps are strategic plans with a clear timeline, showing the paths or routes for reaching specific goals. Roadmapping is a goal-oriented approach supporting the development of complex solutions, technologies, products or processes. Different types of roadmaps can be identified for different applications and actors: literature has described for instance science roadmaps, technology roadmaps, industry technology roadmaps, product technology roadmaps and product-portfolio roadmaps⁸. While the former three types of roadmaps cover the development of a specific scientific field, technology or industry, the latter two specify in more detail the long-term strategy of companies for development of products grounded on different technologies.

A roadmap can help to align the activities of different actors and is also crucial for research, technology and innovation policy to base their decisions on a commonly agreed plan. Thus, decision makers in firms, business associations, research actors, funding agencies and investors, as well as ministries are, amongst others, the target groups addressed by a roadmap.

Industry associations, industrial interest groups and policy have initiated and supported the generation of roadmaps for different technologies and industries. The development of new technologies for the industrial decarbonisation is a major challenge. Due to its complex nature, it is necessary to involve actors along the entire value chain. Also due to long development cycles, such industrial technology roadmaps are needed to harmonise the development efforts and to reduce uncertainty among the relevant actors.

EU-level roadmaps for industrial decarbonisation

Public institutions and interest groups, both at the international and national levels, have started to prepare roadmaps for the decarbonisation of the industry. The roadmaps of the International Energy Agency, Material Economics, the Mission Innovation Initiative and the Processes4Planet Partnership can be mentioned as important documents aiming to define specific pathways, technologies and needs for the development and deployment of low-carbon technologies for the manufacturing industry in Europe.

In the context of long-term planning of research, technological development and innovation, the Clean Steel Partnership and the Processes4Planet Partnership (European public-private partnerships) both aim at the decarbonisation of the energy-intensive process industries.

⁸ Kostoff, R.N., Schaller, R.R. (2001): Science and Technology Roadmaps, IEEE Transactions on Engineering Management, Vol. 48, No. 2, pp.132-143; de Alcantara, D.P, Martens, M.L: (2019): Technology Roadmapping (TRM): a systematic review of the literature focusing on models, Technological Forecasting and Social Change, 138, 127-138.

Both have developed roadmaps referred to as Strategic Research and Innovation Agendas (SRIA).

The ERA Industrial technology roadmap for low-carbon technologies in energy-intensive industries, published by the European Commission in April 2022, is the most recent key document at the European level, which also builds upon previously published roadmaps and studies.

Guidelines for the development of roadmaps

One objective of the MLE on industrial decarbonisation is to learn how to define roadmaps and strategic plans at national level in a way that mobilises stakeholders and impacts policy making at national level, but also help to align activities between different countries and with the European level.

Some studies have been published in the past to give advice on how to effectively develop roadmaps (Guidelines). The results of this are briefly described in the following paragraphs. These studies provide a first departure point for further discussion.

The International Energy Agency (IEA) has promoted the development of roadmaps to support the transformation of the energy and industrial sector and has also published a series of global roadmaps devoted to low-carbon energy technologies. The IEA argues that roadmaps allow achieving consensus for the development of energy technologies, help to priorities technology development but also point at policy and regulatory frameworks, investment needs and public engagement.

The IEA Energy Technology Roadmaps Guideline often serves as a point of departure for the design of the roadmap at the national and international levels.⁹ IEA suggests four steps for the development of roadmaps encompassing:

- Planning and preparation
- Visioning
- Roadmap development
- Roadmap implementation and revision

Planning and preparation include the selection of methodologies used in the workshops as well as data analysis and research for already existing strategies and projects.

The visioning phase is a crucial and important step when developing roadmaps. It was decided to formulate a generic vision valid for all industry sectors and to define more specific sectoral visions addressing specifics of each industry. Goals defined by policy, such as the EU's 2050 targets and the Paris Agreement, usually serve as important orientation for developing the roadmaps.

Based on the vision, specific R&D themes and topics with a timeline for the short-, medium, and long-term development can be defined in a participatory process with different

⁹ IEA (2014): Energy Technology Roadmaps a guide to development and implementation, International Energy Agency, Paris.

stakeholder groups and technical experts. Based on a back casting approach the participants are asked to define those R&D projects that are required to reach the vision.

Besides the definition of R&D priorities and projects, specific policy measures and framework conditions can be considered as important complementary activities to be realised to achieve the vision. Thus, a roadmap defines how and over which timeline to develop the processes and technologies including also supporting activities as logistics, awareness, legislation, i.e., framework conditions.

The **Science, Technology and Innovation Policy Roadmap Guideline** for the Sustainable Development Goals (SDGs), published by the inno4s network in 2019, is another framework that proposes the following six steps for developing roadmaps:

1. Scope and ambition
2. Baseline analysis
3. Vision and goals
4. Innovation pathways
5. Policy action plan
6. Implementation and policy learning

Before starting with the development of the roadmap, the scope of the roadmap and the strategic context needs to be defined in a pre-stage. The time horizon, the boundaries, purpose, the target groups and the governance approach (e.g., Steering Committee) are to be fixed. Specific sectors (e.g., for decarbonisation) or value chains (e.g., for circular economy) need to be defined in collaboration with the contracting authorities of a roadmap. The entire process is a highly participatory process and involves the engagement of various experts from different areas and countries, and from industry, academia, intermediaries, interest groups and policy.

In the case of the first **ERA Industrial Technology Roadmap on Low-carbon technologies in Energy-intensive industries of the European Commission**, the development process built on a baseline analysis in which data was collected on the potential industrial technologies that contribute to achieving the targets, but also on the relevant market and institutional factors that are most likely to determine future development or define the targets to be achieved (e.g., climate targets). For this purpose, a number of in-depth analyses were conducted by different organisations involved in the process. The analyses covered the identification of relevant technologies (e.g., by means of R&D spending, patents, start-ups) and innovation ecosystem. In addition, the current political goals (e.g., EU industrial policy, EU climate goals) and goals defined by the industry (e.g., within existing industry technology roadmaps) were synthesised.

This work delivered an important pillar for the roadmap development process and particularly the development of the vision. The baseline analysis delivered evidence and the starting point for the discussion with the experts in a workshop. Consultation processes, results from a survey and further analyses allowed to describe the technology pathways and finally to define recommendations and measures to reach the goals. Along the way of preparation of the ERA Industrial Technology Roadmap, government experts, nominated by Member States and Associated Countries, participated in a dedicated group under the ERA Transition Forum in

2021-2022 to provide feedback and insights to findings of the draft report, as well as contributed to national and regional practices.

In the course of this MLE, **further analysis has been conducted by Petri Vasara** (Sr. Advisor to the MLE), aiming to deliver inputs for the discussion on how to develop and implement roadmaps that matter¹⁰. The paper is based on the practical experience of the author in conducting roadmap work across the globe and across sectors, and of ideas that have been created during that work.

The discussion paper formulates the following **questions** as fundamental to a significant step forward¹¹:

1. **Synergy:** Do sectors in industrial technology roadmaps (later on ‘roadmaps’ for simplicity) have synergetic elements - do we now “multiple-count efforts” instead of using these synergies?
2. **Real World Installations:** What will, as opposed to just lists of technologies, actually be operational and fulfilling goals at different times?
3. **Value Chains:** Especially considering all the follow-on impacts on the global supply chain from changes at the site of action - will technology, implementation capabilities or raw materials be available?
4. **Resilience:** Living in the post-2020 disruption: will the roadmaps withstand unpredictable events and other shocks?

Based on reflecting on these questions the discussion paper defines some **key strategic lessons**:

5. **Synergetic technologies:** Do not conduct separate roadmaps without the linkages and iterations to make the match, unless the sectors roadmapped are extremely different. Heavy industries with heavy climate impact are related – but bringing in synergies, many lighter industries and the digital sector act in many roles together with the heavy industries.
6. **Connected value chains:** Do not assume that technologies are independent and doable unless their value chain of other technologies, even basic computer chips, and materials is organised. The strategic autonomy needs in practice, at least for many key parts, procurement roadmaps. Companies are responsible for their own procurement, but public/private-funded technologies should think strategically on a broader scale from the beginning.
7. **Functional installations:** There is a great difference between a (necessary) list of promising technologies and their readiness levels and installed producing volumes at key times.
8. **Resilient roadmaps:** If the roadmap collapses fairly easily in case of disruption, it becomes only an experience and not a real-world policy instrument.

¹⁰ Vasara, Petri (2023), Mutual Learning Exercise: Industrial decarbonisation - Discussion paper (to be published)

¹¹ For further detail, see the discussion paper “Towards resilient industrial technology roadmaps”.

The discussion paper also addresses the key issue of data, which has recently gained importance due to advancements in artificial intelligence (AI). At the core of all roadmaps is data: data on the alternatives, on impacts, costs, properties, connections and uncertainties, etc. Data is needed for monitoring purposes, as progress or failure over time impacts a policy choice. The paper states that the analysis of existing data with AI is a key asset, so far underutilised in roadmapping and technology analysis.

The paper concludes: *“All-in-all, it is the best of times, it is the worst of times for doing industrial technology roadmaps. The best, because we have the tools, technologies and need; the worst, because all changes so fast and resilience is of the absolute essence.”*

4. National roadmaps and strategies in participating countries

4.1. Key observations by the participating countries at the kick-off meeting

At the online kick-off MLE meeting that took place on 28 April 2023, participating countries were invited to react to the presentations, present national roadmaps and strategies, and engage in discussions on relevant areas (instrument, approach, challenge).

The representative of the Belgian region **Wallonia** praised the exercise as an interesting approach and a way to connect the several national or regional policies at the EU level. His intervention also highlighted the importance of focusing on the demonstrators and how to link the several policies at the national and regional levels, including the Smart Specialisation Strategies, and giving the example of hydrogen valleys. Both Flanders and Wallonia, have started with the implementation of their roadmap, especially by considering the needs of companies. Therefore, learning from other countries, sharing experiences, and mapping the several initiatives at the EU level are very important for Belgium.

In the case of **Georgia**, the representative also considered these actions to be very important. Georgia has been promoting energy efficiency and intends to have more collaboration between industry and academia. Since they are in the early stage of the exercise, sharing experiences from other European countries, including at the legislative level, to motivate industry to act is very important. Currently, Georgia has been promoting smart technology and services and intends to make more links with the energy and climate plan. So far, there has been a strong interest in investing in renewable energy.

The representation of **Austria** welcomed the solutions and collaborations. The speaker mentioned that several Ministries are involved in the process in Austria and one of the most important aspects of this exercise is to understand what is happening at the national level in other European countries, including legislation and new types of instruments for stakeholders.

Spain also highlighted the importance of doing a mapping of other European initiatives, especially in terms of opportunities, uptake and support from public administrations, and with the expectation of learning how to effectively design the schemes and policies. In addition, Spain referred to sectorial eligibility and the differences among the several types of industries, such as low temperature (e.g., food industry) vs. high temperature industries (e.g., steel industry).

In its intervention, **Lithuania** mentioned that the current three roadmaps in Lithuania will be integrated into one single roadmap for industrial decarbonisation, with actions to be

implemented by 2030. Lithuania also mentioned internationalisation of R&I and the interaction between academia and industry. One additional aspect brought up by Lithuania was the importance of digitalisation and advanced materials.

Slovenia stated that their roadmap for decarbonisation was developed few years ago, in collaboration with the Climate KIC. However, the roadmap needs to be updated, and thus, Slovenia would like to know more about the technologies being used at the EU level.

The representatives from **Portugal** referred to the current implementation of their decarbonisation roadmap for the chemicals and cement sectors, with the financial help of the National Recovery and Resilience Plan. Portugal underlined the relationship between the roadmaps (for example, cement industry should have an impact on chemicals when producing CO₂), as well as the need for a paradigm shift, more efficiency measures and carbon storage projects. Investments and reforms should accelerate the decarbonisation. A final aspect raised by Portugal was the link between industries and R&D institutions and between SMEs and large companies.

In the case of **Türkiye**, the representative communicated that they have started developing the national decarbonisation programme by creating plans for several energy-intensive industries and other critical sectors for the economy. They referred to the green growth technology roadmap, which involved public and private institutions, sectorial focus groups and umbrella organisations to define the most relevant industries and technologies. Türkiye also organised the first Climate Council meeting in 2022 to discuss studies and technology missions with the involvement of academia and researchers. The meeting also served to discuss outputs and inputs for and from each sector, to set targets and TRLs, to discuss horizontal topics like energy and enabling technologies and to estimate investment needs. They also underlined the importance of R&D, digital technologies and incentives.

Slovakia mentioned that decarbonisation is included in their National Recovery and Resilience Plan, and it hopes to get more inspiration from the MLE.

In its intervention, **Latvia** emphasised the challenge of decarbonisation and that they are at the beginning of the process, including changing the legislation, finding financing and developing R&D and infrastructure, especially in hydrogen, with a link to the RIS3 Smart Energy.

As one of the most advanced countries in this process, **Sweden** highlighted in its presentation during the kick-off meeting the importance of carbon pricing, the change of mindset, storytelling (including the acceptance and trust to speed up the process), and the pressure from industry for public authorities to reduce barriers. Sweden also mentioned that their legislation is answering some expectations and forward looking. Sweden raised the importance of consultation with industry and stakeholders before legislation is adopted. Among the crucial aspects mentioned was the value chain and competitiveness, and the importance of reducing risks for small producers to sell in open market.

4.2. Cross-countries analysis of available national strategies

For the purpose of analysing practices and lessons regarding developing and implementing roadmaps and strategies on the national level, some key criteria and questions have been answered by the experts and members of the participating countries. After identification of the relevant documents and corresponding literature review, a "reading grid" of 15 key questions was applied to analyse in a coherent way some key dimensions of the national strategies. These 15 questions were:

1. **Timing:** When has the (first) roadmap/national programme/strategy been developed?
2. **Sectoral coverage:** Which sectors does the roadmap/national programme/strategy cover? Are there links to other sectors (e.g., transport, energy, building)
3. **Link to the National Energy and Climate Plan (NECP):** What are the connections to the NECP? (input, recommendations, same stakeholders etc.)
4. **Vision and milestones:** Does the roadmap/national programme/strategy reveal explicit goals and milestones? (on the sectoral level? specific technologies? etc.)
5. **Scenarios, modelling and simulations:** Does the roadmap/national programme/strategy use findings from quantitative modelling exercises?
6. **Smart Specialisation:** To what extent does the roadmap/national programme/strategy take into account regional specifics and strategies?
7. **Availability of resources:** To what extent does the roadmap/national programme/strategy take into account the availability of resources (feedstock, energy, water, etc.)?
8. **Cross-sectoral themes:** How important are cross-sectoral themes?
9. **Quantification of funding and investment needs:** How were public and private investment needs quantified and defined? To what extent does the roadmap take into account business plans and financial parameters (e.g., Total cost of ownership, Return on investment)?
10. **Industrial symbiosis:** In which way does the roadmap/national programme/strategy consider industrial symbiosis?
11. **Participation:** Which stakeholder (industry, research, policy, etc.) were involved in the development of the roadmap/national programme/strategy and how were they mobilised?
12. **Digitalisation:** To what extent does the roadmap/national programme/strategy take into account support digital technologies, i.e., twin transition?
13. **Impact on R&D policy:** What were the effects of the roadmap/national programme/strategy on R&D policy making on the national level? What were the effects to promote national priorities on the international level (e.g., alignment with EC programs)?
14. **Impact on investment policy:** What were the effects of the roadmap/national programme/strategy on investment policy?
15. **Alignment at international level:** To what extent have roadmaps been aligned with roadmaps in other countries or at EU/international level?

In what follows we present a first cross-country analysis of the national strategies and roadmaps. The detailed answers to the questions, country-by-country, can be found in the

annex. The analysis covers all twelve participating countries (AT, BE, ES, FI, Georgia, LV, LT, PT, SE, SI, SK, Türkiye).

4.2.1. Timing - Date of first development of the roadmap/strategy addressing the needs of industry

Most countries started to develop roadmaps for the decarbonisation of the industry in the **last four years**, with roadmaps published in 2019 (Latvia, Portugal and Slovakia), 2020 (Finland, Slovenia and Spain) and 2021 (Lithuania, Türkiye). Georgia has not developed a specific roadmap, but strategic documents related to climate change contain industry decarbonisation chapters where planned actions are described.

Austria took an early initiative by developing an "Energy efficiency roadmap" already in 2014, focusing on four energy-intensive sectors.

Sweden has set up 'Fossil Free Sweden' in 2015, which led to the development of roadmap in the subsequent years. Portugal developed first strategic papers in 2015, which, however, were not yet fully elaborated roadmaps.

Finally, Flanders also has a long experience in the matter, based on its "spearhead clusters" (strategic clusters, comparable to the so-called 'pôles de compétitivité') that were set up in 2017 and allowed the industry to develop their roadmaps, to develop specific R&D and to have access to investment programs.

4.2.2. Coverage of sectors

Almost all roadmaps of the participating MLE countries address the process industries and the **energy-intensive industries** in particular, such as chemicals, iron&steel, paper&pulp and non-metallic mineral products. Austria and Türkiye, for instance, focus their roadmaps on such industries. In the Flanders roadmap especially chemistry, refining and steel are strongly covered. Lithuania developed three roadmaps covering industry digitisation, value chain, and transformation to circular economy. Slovakia, in contrast, has no specific focus on energy-intensive industries.

However, most countries also cover the **energy production sector** (e.g., production of renewables) in their roadmaps (e.g., Spain, Slovenia, Latvia and Portugal).

Some MLE countries cover other sectors as well. Slovenia and Portugal address agriculture, land use and forestry in their roadmaps. In Belgium, the recycling sector plays an important role. Latvia, Portugal, Finland and Slovenia cover the building and construction sector, and the transport sector is addressed in Slovenia and Finland. Georgia covers besides the manufacturing industry also the energy generation, transport, agriculture, waste management and forestry sector.

Sweden even covers 22 sectors also encompassing the construction, retail, forest, agriculture, ski resort, maritime, heavy road haulage and digitalisation consultancy industry. In an ongoing roadmapping project in Austria, a larger number of industries is addressed as well.

4.2.3. Link to the National Energy and Climate Plan (NECP)

The NECPs are developed in accordance with Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action.

The roadmaps at the national level are aligned to a different extent and in different ways with the NECP. All countries refer to the same strategic objectives, as for instance defined by the Paris Agreement or the EU Green Deal. Both, the NECPs and the roadmaps, hence, contribute to the achievement of the common goals, and they define measures and instruments for the decarbonisation of the industry. In Lithuania, for instance, the roadmaps are expected to fulfil the objectives, policies and measures which are defined in the NECP. In general, the NECP is broader and covers also other sectors such as transport, building or agriculture.

In Belgium, the division of competence (sharing of decision-making power between the regions and communities) is reflected in the draft NECP.

In Portugal, the roadmap was carried out **in parallel** with the preparatory work for the NECP. Both activities benefited from the involvement of the same stakeholder group and the same simulation models for the national energy systems were used. In Slovakia, both, the NECP and the roadmap are similar in relation to the covered sectors, methodology and involved stakeholder groups.

In Finland, the link to the NECP is **more indirect**, as the roadmap was strongly driven by industry to outline a way to reach the target set by the government.

In Türkiye, there is only a **weak alignment**, and it is argued that both plans are compatible in the sense of having the same assumption about the use of hydrogen and renewable energy and that the roadmap and the NECP contribute to the achievement of the goals of the Paris Agreement.

The NECP usually covers also strategies and measures for climate change mitigation and adaption. Some countries such as Lithuania have published also separate National Climate Change Mitigation and Adaptation (NCCMA) plan.

4.2.4. Vision and milestones

All roadmaps explicitly define visions or strategic objectives, referring also to the political goals (e.g., Paris Agreement). The time horizon varies **between 2030 and 2050**. Most national roadmaps also define milestones for the achievement of medium-term goals.

The roadmaps not only formulate goals concerning the reduction of GHG emissions, but also for the production, use and sharing of renewable energy resources and the use of specific technologies and solutions.

Most countries (Austria, Belgium, Finland, Georgia, Portugal, Spain, Türkiye and Sweden) also define **specific goals on the sectoral level**, usually as part at the sectoral roadmaps. In Finland, for instance, the government objective of a carbon-neutral Finland by 2035 is the main vision, and the individual roadmaps provided sectoral responses to this goal. In addition, several sectors have targets they have defined themselves. Technology-neutrality is strongly present in Finland as well, i.e., reaching the goals is key, the means are left to the industry.

4.2.5. Scenarios, modelling and simulations

Most countries (Austria, Portugal, Slovenia, Spain and Sweden) use **long-term modelling exercises** to define different trajectories, pathways and scenarios for the decarbonisation of the industry. Latvia uses **statistical information** but has not employed a larger modelling

exercise. Some countries (e.g., Finland, Georgia) also explicitly deal with the different **sectors** and hence each sectoral roadmap contain their own scenarios and models.

The countries use different modelling approaches and tools: Spain, for instance, uses the POTEnCIA approach developed by the JRC, Portugal employs the GEM-E3-Modell. In most countries, the modelling exercises were developed for the first time for such a long-time horizon. Slovakia deploys the PRIMES model scenarios, i.e., the EU energy system model.

The national roadmap in Portugal (RNBC 2050), for instance, is based on three alternative macroeconomic scenarios for development of the Portuguese economy and on two sets of objectives for each scenario. The roadmap presents in more detail two scenarios, the Peloton and Yellow Jersey scenarios (PL|YJ) for the carbon neutrality trajectories. Lithuania calculated a FIT55 and the ETS2 scenario and hence dealing with the different EU goals.

As mentioned above, some countries (e.g., Spain) employ the same models for both the roadmaps and the NECP.

4.2.6. Smart Specialisation

Most roadmaps take into account **specific regional conditions and needs**. In contrast, Finland explicitly did not address regional and location policy as key principle and focused on the different sectors.

However, not all countries have explicitly developed smart specialisation strategies in the past, although regional factors are usually taken into account in any definition of RTI policies at the national level.

Slovenia refers to its smart specialisation strategy as a relevant framework for developing the roadmap. Latvia develops its Climate Neutrality Strategy for cities and municipalities. In Wallonia, the smart specialisation strategy is tightly linked to the region's Circular strategy. Wallonia has launched a process to define its own industrial decarbonisation strategy, which will be linked to its S3 (although not exclusively).

4.2.7. Availability of resources

In the majority of countries (Austria, Finland, Georgia, Latvia, Lithuania, Portugal, Slovenia, Slovakia, Türkiye, Wallonia and Sweden), **natural and energy resources** are considered in the course of the roadmapping exercise. Topic such as biomass, biofuels, hydrogen and electric energy are of crucial importance. They are discussed and partly quantified.

In Austria, for instance, a specific modelling exercise was done during the development of roadmap, focussing on the goal to use fluctuating renewable energies. Portugal addresses topics such as land use and livestock in the context of the agriculture and forestry sector.

The Green Growth Technology Roadmap of Türkiye does not explicitly consider the availability of resources. However, the feasibility of technological solutions within the country has been taken into account **implicitly** because the technological solutions in various sectors are developed by experts from academia and industry having in mind the resource constrains.

In some national roadmaps (e.g., Latvia, Portugal and Flanders region of Belgium), the concept of the **bioeconomy and circular economy** are adopted explicitly as well.

4.2.8. Cross-sectoral themes

All roadmaps at the national level deal with **cross-sectoral themes**, which are considered as important horizontal topics, (e.g., use of hydrogen, waste management, heat recovery). Slovakia stresses that the roadmap is a cross-cutting document across all sectors of the economy which must implement individual policies to complement each other towards the fulfilment of the common goal. In Finland, cross-sectoral themes appear in the roadmaps whenever relevant, however, sectors developed their own roadmaps and did not consider cross-sectoral themes, although coordination meetings were held.

Some countries have also developed **separate roadmaps** to address specific cross-sectoral themes, particular in relation to energy supply. Spain, for instance, has published a Hydrogen Roadmap. Roadmaps focussing on the circular economy can be mentioned as well (e.g., Lithuania). In addition, the topic of digitalisation (see also below) is also frequently mentioned as a cross-cutting issue.

4.2.9. Quantification of funding and investment needs

The estimation of the investment needs in relation to the decarbonisation of the industry is a challenging task.

Portugal, Slovenia, Spain, Türkiye and Sweden have provided figures for the investments necessary to achieve the goal of climate neutrality. Latvia has not yet provided such data. In Austria, estimations will be made available in the new roadmap to be published in July of this year.

Spain and Sweden calculate the investment needs **referring to the modelling exercise** they have conducted. In Slovakia, decarbonisation needs were modelled in the scenario with additional measures (WAM) from the World Bank. However, in the other countries the approach and method to calculate the investment figures are not described in more depth or in a transparent way.

In general, the figures published are rather **rough estimations** provided by experts and applying simple forecasting rules and extrapolations. They also do usually not take into account the substitution of the end product, e.g., using alternative materials and constructions instead of using cement.

4.2.10. 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), are addressed. In Spain and Georgia, industrial symbiosis is not considered as a concept as such. Nevertheless, **synergies** between industrial sectors are mentioned.

The **circular economy** is explicitly used as concept and strategy in Slovenia. Flanders mentions Industrial parks. Lithuania also stresses industrial symbiosis in the specific circular economy roadmap.

4.2.11. Participation

As mentioned already in the previous chapters, **participation of diverse stakeholder groups** is considered as an important success factor for a road mapping exercise.

In all countries, diverse stakeholder groups were involved encompassing companies, business associations, academia, public administration, social partners, environmental associations, etc.

In Georgia, the roadmap was developed with a strong involvement of the relevant ministries. Although representatives from the public and private sectors were involved, there is no tradition for close collaboration between industry and academia.

4.2.12. Digitalisation

The **potential of digital technologies and solutions** is an important part in almost all roadmaps developed by the participating MLE countries. Finland, for instance, addresses energy consumption in relation to mobile communication (5G/6G), cloud computing and artificial intelligence.

While in the past, digitalisation was not a strong point of attention in Flanders, it changed completely in recent years and now full attention is paid to digitalisation and the green transition.

While some countries treat it rather **broad** and as cross-sectoral issue (e.g., Türkiye defines digital technologies as enabling technology) some focus on **specific** technologies and sectors, e.g., IoT is mentioned in Latvia, digitalisation of electric grids is an important element of the Spain roadmap, and specific efforts in the transport sector are described in Portugal. As mentioned above, Lithuania developed an industry digitisation roadmap.

4.2.13. Impact on Research, Technology and Innovation policy (RTI)

The technologies and RTI themes identified in the roadmaps form an important **basis for the definition of specific RTI programs and instruments**. In general, there is no direct, automatic link to governmental funding.

In Austria, Spain, Slovakia, Sweden, Türkiye the results have been or will be adopted in the RTI support programs.

However, there is rather weak evidence about 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.

4.2.14. Impact on investment policy

While all roadmaps have defined the need for investment and reveal, as described above, rough estimations, less effort is put to defining specific investment instrument and policies.

In Sweden, the policy and the banking industry association have collaborated to examine the various incentive mechanisms necessary for achieving the climate targets. Slovenia states that tax policy should be aligned with the climate neutrality goal. In Austria, as a result of the discussion on the design of the new energy research programme and the flagship region programme, closer cooperation between the R&D funding agency (KLIEN) and the public investment bank was agreed upon. Additional funds for investments will be made available by the public investment bank.

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.

4.2.15. Alignment at the European level

Almost all roadmaps are aligned with activities at the European level. Policies and measures at the European level (European Green Deal, EU new circular economy action plan, Emissions Trading System, Industrial Emissions Directive, Renewable Energy Directive) provide goals and a framework for the design of roadmaps at the national level. 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.

Sweden has explicitly coordinated its activities with other Member States, in particular with other neighbouring countries. Flanders collaborates in the definition of a trilateral strategy with the Netherlands and North Rhine Westphalia.

5. Conclusion

The first MLE meeting focused on the objective of developing a joint understanding and establishing common expectations, aiming to accelerate the deployment of low-carbon technologies in energy-intensive industries. Expectations from participating countries included leveraging synergies between existing European Union tools, designing effective state aid schemes, and encouraging active engagement between industry, academia, and policy stakeholders. The MLE meeting 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.

The analysis of the decarbonisation strategies and roadmaps of the MLE countries (based on a common analytical grid) revealed high ambitions to systematically develop roadmaps. The roadmaps in the MLE countries address the energy-intensive process industries (such as chemicals, iron&steel, paper&pulp and non-metallic mineral products). In addition, the majority of countries cover also other important sectors and areas or have even developed sector-specific roadmaps. Energy supply (e.g., renewable electricity or producing alternative fuels or hydrogen), the recycling sector, the transport sector or agriculture can be mentioned as well. In general, cross-sectoral collaboration is frequently addressed with the national roadmaps and strategies and was also highlighted as crucial during the workshop discussions.

Almost all roadmaps are aligned with activities at the European level. Policies and measures at the European level provide goals and a framework for the design of roadmaps on the national level. However, collaboration with other neighbouring countries is less common.

The analysis of the country strategies and roadmaps revealed that all countries adopted a highly participatory process, engaging a wide range of stakeholders. In the kick-off workshop the importance of inclusive and collaborative processes involving industries, academia, and policy experts, was stressed.

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 and the definition of RTI policies. The example of Sweden, which is one of the countries with the longest experience in developing roadmaps, shows however that roadmaps also need to convey a narrative in order to mobilise the different stakeholders.

There is rather weak evidence about 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 discussion in the MLE meeting, where the importance of translating strategies into tangible actions and measurable progress was stressed.

While all roadmaps have defined the need for investments, less effort is put to defining specific investment instrument and policies. In general, published figures on investment needs are rather rough estimates by experts and the application of simple forecasting rules and projections using modelling approaches is the exception. This issue can, therefore, be seen as the main weakness of the roadmaps developed in the MLE countries.

These results are in line with the European Commission's call and the findings of the ERA industrial technology roadmap for low-carbon technologies in energy-intensive industries, which points to the existing investment gap in R&D, industrial demonstration and deployment. In this context, integrating R&D efforts with industrial policies was pointed out as a critical factor in driving successful technological advancements and sustainable industrial growth.

Annex: Profile of MLE Countries

Austria

<p>Date of first development of the roadmap/national programme/strategy addressing the need of industry</p>	<p>When has the (first) roadmap/national programme/strategy been developed?</p>
<p>In 2013 the Climate and Energy Fund (KLIEN) started to address more specifically the needs to promote R&D for the manufacturing industry. Up to this date specific R&D projects or programmes covering the needs for decarbonisation of the industry received not much attention.</p> <p>In order to design a specific R&D programme addressing the needs of the Austrian industry, a project was funded aiming to develop an “Energy efficiency roadmap”. The project ran from 02/2014 to 10/2104 and a report was published.</p> <p>Developments on the European and international level (e.g., COP 21 in Paris in 2015) to promote the decarbonisation of the industry triggered the development of the roadmap in Austria. By developing a national roadmap Austria was able to represent the interest of Austrian on the European level.</p> <p>The first roadmap focused on the four sectors (chemicals, iron&steel, paper&pulp, non-metallic mineral products), in a second roadmapping process organised in 2015 the sectors textiles and food&beverages were addressed.</p> <p>At the moment, a project is running on the national level aiming to update the roadmap. The roadmap (Strategic Research and Innovation Agenda) will be published in July 2023.</p>	
<p>Coverage of sectors</p>	<p>Which sectors does the roadmap/national programme/strategy cover? Are links to other sectors (e.g. transport, energy, building)</p>
<p>The roadmap published in 2014 and 2015 covered chemicals, iron&steel, paper&pulp, non-metallic mineral products, textiles and food&beverages.</p> <p>Within the roadmapping process stakeholder from the energy sector were involved.</p> <p>In 2018 a further technology roadmap focusing on energy storage systems was developed in collaboration with the industry. This cross-sectoral roadmap covers the energy sector, transport sector and manufacturing sector (e-mobility).</p>	
<p>Link to the National Energy and Climate Plan (NECP)</p>	<p>What are the connections to the NECP? (input, recommendations, same stakeholders etc.)</p>
<p>The above-mentioned roadmaps were heavily used to design R&D programs realised by the KLIEN (e.g., FTI initiative Flagship Region Energy). These measures are described in the NECP.</p>	
<p>Vision and milestones</p>	<p>Does the roadmap/national programme/strategy reveal explicit goals and milestones? (on the sectoral level? specific technologies? Etc.</p>
<p>The roadmaps defined both, industry wide as well as sectoral visions and goals. For the definition of the specific R&D themes, a time planning is done and TRL are defined to a large extent.</p>	
<p>Scenarios, modelling and simulations</p>	<p>Does the roadmap/national programme/strategy use findings from quantitative modelling exercises?</p>
<p>The first three roadmaps mentioned above did not use results from modelling exercises.</p> <p>In another roadmap developed in 2017, a modelling exercise was conducted to assess the need for energy supply and storage technologies due to the use of fluctuating renewable energy.</p> <p>In another study, scenarios for the development need of energy infrastructures for the industry were done in 2021.</p> <p>In the new roadmap (transform industry) currently developed and to be published in July of this year</p>	

a specific modelling exercise (scenarios) is done for 13 industrial sectors until 2040. The results will feed into the development of the new roadmap (SRIA transform industry).

Smart Specialisation	To what extent does the roadmap/national programme/strategy take into account regional specifics and strategies?
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Regional factors were also taken into account when determining the potential of industrial symbiosis. But more specific regional factors have been considered in the course the NEFI industrial flagship programme and the funded R&D projects.

Availability of resources	To what extent does the roadmap/national programme/strategy take in account the availability of resources (feedstock, energy, water, etc.)?
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In the first three roadmaps, energy and material resources were considered on a more generic level, but specific quantitative data was used.

The above-mentioned roadmap entitled "Renewables4Industry" was carried out to assess the impact on R&D and RTI policies due to the use of fluctuating renewable energies.

In addition, estimates of energy demand (by different energy sources) were made in some other studies and R&D projects recently finalised (e.g. energy infrastructures for industry).

Cross-sectoral themes	How important are cross-sectoral themes?
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The energy storage system roadmap had a strong cross-sectoral focus addressing the energy, manufacturing and transport sector and dealing with topic such as using waste heat.

Quantification of funding and investment needs	How were public and private investment needs quantified and defined? To what extent does the roadmap take into account business plans and financial parameters (e.g., Total cost of ownership, Return on investment)?
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The roadmaps published so far have not included estimates of the R&D and capital investment required.

However, in the roadmap currently being developed, future estimates about the development of OPEX and CAPEX will be made.

Industrial symbiosis	In which way does the roadmap/national programme/strategy consider industrial symbiosis?
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In all the roadmaps, industrial symbiosis and sectoral coupling, e.g., using waste heat or collaboration between the manufacturing sector and energy sector were addressed.

In a number of R&D projects currently conducted in Austria (e.g., within the NEFI flagship programme) industrial symbiosis is exploited.

Participation	Which stakeholder (industry, research, policy, etc.) were involved in the development of the roadmap/national programme/strategy and how were they mobilised?
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In all roadmapping processes, representatives from industry, academia and interest groups participated. The roadmaps development process was funded by the public. The funding agency signalled the importance to co-shape the development agenda.

The broad involvement from various sectors also enabled the cross-sectoral learning.

For the preparation of the roadmap background papers were drafted by individual experts and institutions for each sector summarising the current technological challenges and solutions. The involved experts further broadened the knowledge base.

Digitalisation	To what extent does the roadmap/national programme/strategy take into account support digital technologies, i.e., twin transition?
Digital technologies, e.g., DSM, digital platforms, played an important role in all roadmaps. Projects which have been funded by the KLIEN, e.g., within the NEFI flagship programme exploit most frequently digital technologies.	
Impact on R&D policy	What were the effects of the roadmap/national programme/strategy on R&D policy making on the national level? What were the effects to promote national priorities on the international level (e.g., alignment with EC programs)?
The roadmaps had a strong impact for policy making, particularly to define the specific programs and calls by the KLIEN. The most important outcome was the establishment of the FTI initiative Flagship Region Energy with a large 7-year programme (NEFI) focusing on Industry. The themes and topics as defined in the roadmaps have been taken up by the KLIEN funding agency for the specific design of programmes and calls. Some companies also stated that they gained valuable insights for the development of their own strategies and roadmaps by participating in the roadmapping process. Currently the successor programme “Transformation of economy” is developed. For specific calls in the future findings from the new roadmap currently developed will be used.	
Impact on investment policy	What were the effects of the roadmap/national programme/strategy on investment policy?
As a result of the discussion on the design of the new energy research programme and the flagship region programme, closer cooperation between KLEIN and KPC (Kommunalkredit Förderbank) was agreed. Additional funds for investments will be made available by KPC.	
Alignment on the international level	To what extent have roadmap been aligned with roadmaps in other countries or at EU/international level?
The roadmaps were used by KLIEN and the BMK to represent Austria’s interests in the negotiation of funding programmes at European level.	

Table 1: Profile of MLE Country – Austria

Belgium (Flanders)

Date of first development of the roadmap/national programme/strategy addressing the need of industry	When has the (first) roadmap/national programme/strategy been developed?
Belgium is a Federal State, where the decision-making power is shared between a Federal government, three Regions (Wallonia, Flanders and the Brussels Capital Region) and three Communities (the Flemish, the French and the German-speaking Community). This division of competences is reflected in the Belgian draft integrated National Energy and Climate Plan (NECP), to which additional plans from the federated entities were annexed for further information. Flanders has a long experience via it spearheads clusters that started in 2017. These spearhead clusters allowed the industry to set up their roadmaps, to develop specific R&D and to have access to investment programs. It was an opening at the regional level, supporting the national ambitions and aligning with the Europeans ambitions of ‘A Clean Planet for all’ and the ‘Green Deal’. The clusters are:	

- Catalisti: sustainable chemistry;
- Blue Cluster: maritime developments;
- Flanders Food: food and food processing;
- Medvia: at the level of medical developments;
- Flux50: energy production and logistics;
- SIM: sustainable materials development;
- VIL: logistics.

Further, Flanders adapted a commitment by decree on 23 March 2022 that every new Flemish Government must make an adapted Flemish Industrial Climate Transition Program in a maximum delay of 1 year after the installation of the new government. It must be in line with the European and Belgian agreements, in line with the Paris Agreement and supported by the different independent Flemish advisory bodies.

Coverage of sectors	Which sectors does the roadmap/national programme/strategy cover? Are links to other sectors (e.g. transport, energy, building)
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The spearhead clusters are mentioned in the paragraph above. Besides that, recycling is strongly under development via 'Vlaanderen Circulair, Circular Flanders' and the construction business is supported by demonstration living labs as 'Living Tomorrow' and 'KampC'.

Link to the National Energy and Climate Plan (NECP)	What are the connections to the NECP? (input, recommendations, same stakeholders etc.)
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Belgium's 2030 target for greenhouse gas (GHG) emissions not covered by the EU Emissions trading System (non-ETS), is -35% compared to 2005, as set in the Effort Sharing Regulation (ESR)¹. Adopted policies would lead to 13% reductions and the draft NECP aims at achieving the -35% target domestically. In order to define the connection, it is always difficult as it is a kind of sum between the regions.

The NECP does not yet contain an impact assessment of planned policies and measures.

Vision and milestones	Does the roadmap/national programme/strategy reveal explicit goals and milestones? (on the sectoral level? specific technologies? Etc.
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Belgium proposes an 18.3% share of energy from renewable sources in gross final consumption of energy in 2030 as contribution to the EU renewable energy target for 2030. This level of ambition is significantly below the share of 25% by 2030 that results from the formula in Annex II of the Governance.

Scenarios, modelling and simulations	Does the roadmap/national programme/strategy use findings from quantitative modelling exercises?
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The literature review pointed to the use of data from existing resources in Flanders, but no quantitative modelling exercise is used.

Smart Specialisation	To what extent does the roadmap/national programme/strategy take into account regional specifics and strategies?
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At the level of Flanders, the regional roadmap, especially for the Energy intensive industry, is strongly developed and inspires the national program.

Availability of resources	To what extent does the roadmap/national programme/strategy take in account the availability of resources (feedstock, energy, water, etc.)?
The availability of resources is taken into account at the level of the regions.	
Cross-sectoral themes	How important are cross-sectoral themes?
The energy storage system roadmap had a strong cross-sectoral focus addressing the energy, manufacturing and transport sector and dealing with topic such as using waste heat.	
Quantification of funding and investment needs	How were public and private investment needs quantified and defined? To what extent does the roadmap take into account business plans and financial parameters (e.g., Total cost of ownership, Return on investment)?
<p>The NECP does not yet contain a list of energy subsidies and actions undertaken and planned to phase them out, in particular for fossil fuels.</p> <p>Public and private investments are listed in the Flemish approach. But no plan exists on future investment needs. Up to now the roadmap is not explicitly taking into account business plans and financial parameters. Flanders has a strong plan via its Moonshot program (providing every year 20 million €) at the level of R&D.</p>	
Industrial symbiosis	In which way does the roadmap/national programme/strategy consider industrial symbiosis?
<p>Industrial symbiosis is not elaborated in the national program, yet in practice it is being developed. There is a lack of communication of this symbiosis to the public and society. The two largest clusters focusing on Industrial Symbiosis are the port of Ghent (Sustainable Delta Resources initiative) in collaboration with the Netherlands (port of Terneuzen) and the Port of Antwerp@C and NextGen District (88 ha available for circularity activities).</p> <p>On top of that, Flanders is strongly embedded in the international clustering of the Trilateral activity between the Netherlands, North-Rhine-Westphalia and Flanders for chemical collaboration in the broad sense. This Trilateral region is the largest chemical cluster in the world and focusing strongly on H₂, energy, CO₂, process intensification, bio-economy and recycling in order to become the biggest sustainability cluster. The region fully develops the ideas of Hubs4Circularity, not only at the regional level, but also via the cross-border collaboration.</p>	
Participation	Which stakeholder (industry, research, policy, etc.) were involved in the development of the roadmap/national programme/strategy and how were they mobilised?
The regional roadmap is fully supported by the energy intensive industry which means for Flanders chemistry and steel production.	
Digitalisation	To what extent does the roadmap/national programme/strategy take into account support digital technologies, i.e., twin transition?
In the past digitalisation was not a strong point of attention, which changed completely the last period. Now full attention is going to digitalisation and twin transition.	

Impact on R&D policy	<p>What were the effects of the roadmap/national programme/strategy on R&D policy making on the national level? What were the effects to promote national priorities on the international level (e.g., alignment with EC programs)?</p>
<p>As mentioned earlier, the effects of the roadmap on the R&D policy are fully aligned via the Moonshot program that is coordinated via Catalisti, the spearhead for sustainable chemistry in Flanders, and with the support of the manufacturing industry and the power providers. The Moonshot program has defined 4 programs: Mot 01: Biobased; Mot02: Circularity of C & Materials; Mot 03: Electrification & Process Transformation; Mot04: Energy Innovation.</p> <p>The whole system is based on 4 transition pathways: 1) use of biomass, 2) recycling and maximal valorisation of carbon, 3) energy and 4) CO2 capture (CCS/CCU).</p> <p>9 'Must haves' and 8 'Boundary conditions' are defined for each scenario.</p>	
Impact on investment policy	<p>What were the effects of the roadmap/national programme/strategy on investment policy?</p>
<p>Especially the cluster activities and industrial symbiosis are leading and driving systems for investments in the large industrial sites. This is based on interaction between private investments, support by regional and European investments, but also strong investments by the region and port authorities in the logistics support. This all is combined with strong energy investments in order to provide renewable energy at the right places in Flanders via strong high voltage lines transporting electron from offshore at the seaside to the inland industrial clusters.</p> <p>The Moonshot-based Flemish strategy foresees the demonstrations between 2030 and 2040 and full deployment between 2040 and 2050.</p> <p>At the level of policy 6 pillars are defined:</p> <ul style="list-style-type: none"> • Pillar 1: Stable, reachable & coherent policy • Pillar 2: Develop and industrial transition program • Pillar 3: Financial plan • Pillar 4: Basis infrastructure, future-oriented & non-discriminator • Pillar 5: Industrial support program for innovation and implementation • Pillar 6: Consistent a realistic framework 	
Alignment on the international level	<p>To what extent have roadmap been aligned with roadmaps in other countries or at EU/international level?</p>
<p>The regional roadmap is certainly in line with the roadmaps at the EU or international level. But no real alignment (e.g., based on smart specialisation) is done and no strong embedding in the EU-strategy is put forward.</p>	

Table 2: Profile of MLE Country – Belgium (Flanders)

Belgium (Wallonia)

Date of first development of the roadmap/national programme/strategy addressing the need of industry

When has the (first) roadmap/national programme/strategy been developed?

Belgium is a federal state, where the decision-making power is shared between a Federal government, three Regions (Wallonia, Flanders and the Brussels Capital Region) and three Communities (the Flemish, the French and the German-speaking Community). This division of competences is reflected in the Belgian draft integrated National Energy and Climate Plan (NECP), to which additional plans from the federated entities were annexed for further information.

The Walloon (regional) NECP is approved on 21 March 2023 and regional contribution to the NECP and its objectives per sector can be summarised as:

- Phase out of coal and oil;
- Plan for exiting natural gas;
- Development of an H2-cluster;
- Development of Carbon capture technologies;
- Stop the public support to fossil energy.

At the level of renewable energy, the following actions are defined:

- Remove barriers for renewable electricity;
- Remove barriers for renewable heat;
- Framework for sustainable use of biomass;
- Develop biogas, mine gas and e-gas;
- Develop 2-, 3-G biofuels.

Coverage of sectors

Which sectors does the roadmap/national programme/strategy cover? Are links to other sectors (e.g. transport, energy, building)

Some new sector agreements are under development:

- Set up a plan and follow the transition for low-carbon companies;
- Develop a roadmap including monitoring of impact of measures;
- Support SME's via voluntary agreements;
- Enforce the legislative framework for energy consumption a GHG emission reduction;
- Support a circular economy.
- A public procurement for development of a roadmap for decarbonisation of industry is currently on-going. A industrial decarbonisation roadmap is expected early 2024. underway.

Link to the National Energy and Climate Plan (NECP)	What are the connections to the NECP? (Input, recommendations, same stakeholders etc.)
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Belgium's 2030 target for greenhouse gas (GHG) emissions not covered by the EU Emissions trading System (non-ETS), is -35% compared to 2005, as set in the Effort Sharing Regulation (ESR)¹. Adopted policies would lead to 13% reductions and the draft NECP aims at achieving the -35% target domestically. Direct and unambiguous connection between the national plan and the regional policies is difficult to identify.

The NECP does not yet contain an impact assessment of planned policies and measures.

Vision and milestones	Does the roadmap/national programme/strategy reveal explicit goals and milestones? (On the sectoral level? specific technologies, etc.?)
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Belgium proposes an 18.3% share of energy from renewable sources in gross final consumption of energy in 2030 as contribution to the EU renewable energy target for 2030. This level of ambition is significantly below the share of 25% by 2030 that results from the formula in Annex II of the Governance.

Wallonia wants to become a region with economic and industrial ecosystems engaged in circular economy, to pioneer in circular innovation and to manage natural resources in a circular way (e.g. water, wood, biomass, etc.).

Wallonia will focus on priority value chains: construction, water, metallurgy, textiles, plastics, food & feed industry.

Scenarios, modelling and simulations	Does the roadmap/national programme/strategy use findings from quantitative modelling exercises?
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Not yet a very strong mentioning of findings from quantitative modelling exercises.

Smart Specialisation	To what extent does the roadmap/national programme/strategy take into account regional specifics and strategies?
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In its further actions Wallonia focuses on the Smart specialisation of Wallonia with 4 strategic initiatives:

- Green hydrogen;
- Energy communities;
- Renovation of buildings;

Decarbonisation of mobility and energy systems.

Availability of resources	To what extent does the roadmap/national programme/strategy take in account the availability of resources (feedstock, energy, water, etc.)?
Wallonia pays more attention to water and biomass as feedstock in its strategy, yet this is not yet fully valorised in a roadmap.	
Cross-sectoral themes	How important are cross-sectoral themes?
As there is no roadmap yet, cross-sectoral themes are lacking although we see strong potential at the level of the Walloon industrial ecosystem.	
Quantification of funding and investment needs	How were public and private investment needs quantified and defined? To what extent does the roadmap take into account business plans and financial parameters (e.g., Total cost of ownership, Return on investment)?
The NECP does not yet contain a list of energy subsidies and actions undertaken and planned to phase them out, in particular for fossil fuels.	
Examples exist of investment support through IPCEI. These examples are also an indication toward potential of industrial symbiosis.	
Industrial symbiosis	In which way does the roadmap/national programme/strategy consider industrial symbiosis?
Industrial symbiosis is not yet mentioned, although potential exists in the energy intensive industry clusters (especially with a link to the mineral and cement industry).	
Participation	Which stakeholder (industry, research, policy, etc.) were involved in the development of the roadmap/national programme/strategy and how were they mobilised?
Roadmap development still needs to be started. From the procurement phase, it is clear that the Walloon policy wants to involve all its important industrial sectors, with strong attention also to its SME's.	
Digitalisation	To what extent does the roadmap/national programme/strategy take into account support digital technologies, i.e., twin transition?
There is not yet a strong mentioning of digitalisation.	

Impact on R&D policy	What were the effects of the roadmap/national programme/strategy on R&D policy making on the national level? What were the effects to promote national priorities on the international level (e.g., alignment with EC programs)?
The link between the future roadmap and R&D policy still needs to be set up.	
Impact on investment policy	What were the effects of the roadmap/national programme/strategy on investment policy?
Also, here a strong roadmap will support the investment policy.	
Alignment on the international level	To what extent have roadmap been aligned with roadmaps in other countries or at EU/international level?
The regional strategy is certainly in line with the roadmaps at the EU or international level. But no real alignment (e.g., based on smart specialisation) is done and no strong embedding in the EU-strategy is put forward.	

Table 3: Profile of MLE Country – Belgium (Wallonia)

Spain

Date of first development of the roadmap/national programme/strategy addressing the need of industry	When has the (first) roadmap/national programme/strategy been developed?
November 2020	
<ul style="list-style-type: none"> • Renewable energy sector • Sustainable and competitive industry <ul style="list-style-type: none"> - The use of alternative raw materials and the promotion of the circular economy - Moving from current processes to ones that use decarbonised technologies - Use of electrical systems for heat generation (low temperature, e.g., heat pumps) - For high-temperature heat generation, use of renewable hydrogen as an energy vector. - Carbon capture, utilisation and storage (CCUS) - Renewable and very high-efficiency cogeneration - Implement energy efficiency measures. - F-gases (fluorinated gases) 	
Coverage of sectors	Which sectors does the roadmap/national programme/strategy cover? Are links to other sectors (e.g. transport, energy, building)
This roadmap (ELP 2050) is based on the fulfilment of the objectives, policies and measures included in the updated draft of the NECP.	

The measures included in the NEPC aim at removing one out of every 3 tons of CO2 before 2030. The NECP, in conjunction with ELP and other programs, has contributed to promoting and implementing the changes targeted by these roadmaps.

- Royal Decree-Law 23/2020, of June 23, 2010 (energy and other measures for economic recovery)
- Hydrogen Roadmap
- Draft of Energy Storage Strategy
- Project of royal decree: regulation of the Economic Regime of Renewable Energies for Electricity Production Facilities
- Self-consumption strategy (under development)
- Offshore wind energy and marine energy in Spain Roadmap (under development)
- Biogas Roadmap (under revision)

Targets set in the EU - specific NECP for Spain:

- 23% reduction in greenhouse gas (GHG) emissions with respect to 1990
- 42% of renewable energies over total final energy consumption.
- 39.5% improvement in energy efficiency.
- 74% of renewable energies in electricity generation.

An integrated governance system will be implemented for the NECP and ELP based on indicators and aligned with the monitoring reports to be developed under the NECP 2021-2030 Governance Regulation.

[Link to the National Energy and Climate Plan \(NECP\)](#)

[What are the connections to the NECP? \(input, recommendations, same stakeholders etc.\)](#)

This roadmap (ELP 2050) is based on the fulfilment of the objectives, policies and measures included in the updated draft of the NECP. The measures included in the NEPC aim at removing one out of every 3 tons of CO2 eq within 2030. The NECP, in conjunction with ELP and other programs, have contributed to promoting and implementing the changes targeted by these roadmaps.

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- Self-consumption strategy (under development)

- Offshore wind energy and marine energy in Spain Roadmap (under development)
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Vision and milestones

Does the roadmap/national programme/strategy reveal explicit goals and milestones? (on the sectoral level? specific technologies, etc.?)

Objectives:

1. To meet the commitments of the Paris Agreement;
2. Anticipating and planning the transition to a climate-neutral economy;
3. Provide a clear long-term objective as a reference to set up lines of action.

Reduction of primary energy consumption by about 50%.

Implementation of energy efficiency measures:

- Energy consumption: primary energy consumption will be significantly reduced over the period 2021-2050. This is due to both, the deployment of renewable energies and energy efficiency policies, as well as the promotion of the circular economy and behavioural change and changing habits.
- Foreign energy dependence: As a result of declining imports of fossil fuels (coal, oil and gas) between 2021 and 2050, largely replaced by renewable (produced locally) energy, foreign energy dependence is projected to drop from 74% in 2018 to approximately 13% in 2050.

Share of renewable energies:

- Electricity generation in 2050: close to 100%
- Heating and cooling sector up to 97%

The industry will significantly reduce its emissions from 72 MTCO₂ in 2020 to 7 MTCO₂ in 2050. The F-Gas sector will lessen its GHG emissions up to 94% by 2050 compared to current levels.

Scenarios, modelling and simulations

Does the roadmap/national programme/strategy use findings from quantitative modelling exercises?

Both ELP and the PNIEC have been routed on the same models in the development of their respective data analysis. The ELP includes two scenarios: Trend and Target. The trend scenario from 2030 onwards is a continuation of the PNIEC target scenario, since it is assumed that it will be met. **Hypothesis:** macroeconomic variables that have been considered in the analysed scenarios

- GDP
- Population (Source: The 2018 Ageing Report: Economic and Budgetary Projections for the EU Member States (2016-2070) https://ec.europa.eu/info/sites/info/files/economy-finance/ip065_en.pdf)
- Fuel prices: Modelling tool developed by the JRC for the EU (POTEnCIA - Policy Oriented Tool for Energy and Climate Change Impact Assessment)
- CO2 prices: scenarios established by the European Commission up to the year 2040. From that year on, the growth scenario contained in the EU Reference Scenario 2016 has been used (https://ec.europa.eu/energy/sites/ener/files/documents/20160713%20draft_publication_REF2016_v13.pdf).
- Evolution of technology costs: data provided by the JRC of the European Commission in the POTEnCIA model.

Technological development for decarbonisation: The analysis covers the technologies (assumptions), which are needed to fulfil the expected goals by 2050. Also, the exercise includes some technological routes are still not fully developed (low TRL), but they are assumed to contribute positively to the overall goal. In those cases, complementary literature review has been undertaken to enrich and complement those calculations in the following areas:

- Decarbonised steel production: change in the manufacturing process.
- Other emitting industrial sectors: Carbon capture, utilisation and storage (CCUS) of CO2
- Production, storage and use of renewable hydrogen.

Smart Specialisation

To what extent does the roadmap/national programme/strategy take into account regional specifics and strategies?

Aligned with the regional strategies.
(More information should be collected to confirm alignment and coordination from national to regional level)

Availability of resources

To what extent does the roadmap/national programme/strategy take in account the availability of resources (feedstock, energy, water, etc.)?

The ELP strategy considers:

- Consumption in Spain of different fuels by energy-intensive industrial sectors (2018)
- Future evolution of basic materials production in Spain (Instituto de Investigación Tecnológica, Comillas, 2019)

Cross-sectoral themes	How important are cross-sectoral themes?
<ul style="list-style-type: none"> Hydrogen Roadmap (under revision). The first document was published in 2020. Biogas Roadmap (under revision). The first document was published in 2021. 	
Quantification of funding and investment needs	<p>How were public and private investment needs quantified and defined? To what extent does the roadmap take into account business plans and financial parameters (e.g., Total cost of ownership, Return on investment)?</p>
<p>It is estimated that total cumulative investments over the period 2031-2050 will reach 500.000 million euros. 300.000 million of them will feed into the implementation phase of the Long-term Decarbonisation Strategy (ELP 2050). Additional annual investments are around 1% of GDP, in line with the figures presented by the ELP.</p> <p>Model to assess the impact of the policies on a series of socioeconomic variables: DENIO is a dynamic New-Keynesian econometric model designed to evaluate the economic impact of scenarios and policies in Spain, especially those related to energy and climate change (deployment of renewable energies and clean technologies, electrification, energy efficiency, rehabilitation, environmental taxes, etc.). The model analyses the impact of these policies on a series of socioeconomic variables such as employment, gross domestic product (GDP), trade balance, household income/expenditure/wealth and its distribution, savings, general government accounts, private and public debt, inflation, etc.</p>	
Industrial symbiosis	In which way does the roadmap/national programme/strategy consider industrial symbiosis?
<p>Industrial symbiosis is not considered as such. Nevertheless, synergies between industrial sectors are mentioned: "The transformation of the industrial sector will have a comprehensive approach, taking into account the synergies derived from sectors' coupling activities".</p>	
Participation	Which stakeholder (industry, research, policy, etc.) were involved in the development of the roadmap/national programme/strategy and how were they mobilised?
<p>78 entities participated in the public consultation process of the draft of the ELP Roadmap:</p> <ul style="list-style-type: none"> 20 companies 25 business associations 10 environmental associations 6 confederations 6 Public administrations 3 professional associations 3 individuals' persons 2 foundations <p>Most of the entities are linked to the energy and environmental sectors.</p>	

Digitalisation	To what extent does the roadmap/national programme/strategy take into account support digital technologies, i.e., twin transition?
<p>Digitalisation of electric grids:</p> <p>Challenges to be experienced on the demand side of digitisation are:</p> <ul style="list-style-type: none"> • Big Data, artificial intelligence and the development of algorithms will transform homes into intelligent centers (to make instantaneous decisions about their consumption) • The industrial sector will be able to achieve significant savings through monitoring, improved safety and better control of their production processes. <p>On the supply side, the growing share of unmanageable renewable generation poses new challenges for the management of production and its integration into the system.</p>	
Impact on R&D policy	What were the effects of the roadmap/national programme/strategy on R&D policy making on the national level? What were the effects to promote national priorities on the international level (e.g., alignment with EC programs)?
<p>The Spanish Strategy for Science, Technology and Innovation 2021-2027 (EECTI 2021-2027) is the basic instrument to consolidate and reinforce the Spanish Science, Technology and Innovation System. Also, it is specifically designed to facilitate the deployment of the ELP, aligned with the European R&D policies.</p>	
Impact on investment policy	What were the effects of the roadmap/national programme/strategy on investment policy?
<p>Increase in interconnection capacity interconnection of electric power (Further investigation in this part is required)</p>	
Alignment on the international level	To what extent have roadmap been aligned with roadmaps in other countries or at EU/international level?
<ul style="list-style-type: none"> • The Paris Agreement • The European Green Deal • InvestEU • Plan Next Generation EU <p>The roadmap is aligned with the Sustainable Development Goals:</p> <ul style="list-style-type: none"> • SDG 1. No poverty • SDG 3. Good health and well-being • SDG 5. Gender equality • SDG 7. Affordable and clean energy 	

- SDG 8. Decent work and economic growth
- SDG 9. Industry, innovation, and infrastructure
- SDG 10. Reduced inequalities
- SDG 11. Sustainable cities and communities
- SDG 13. Climate action
- SDG 15. Life on land

Table 4: Profile of MLE Country Spain

Finland

Date of first development of the roadmap/national programme/strategy addressing the need of industry	When has the (first) roadmap/national programme/strategy been developed?
The first national roadmap was developed as part of the Marin government's climate neutrality goal 2035 for Finland and executed in 2019-2020.	
Coverage of sectors	Which sectors does the roadmap/national programme/strategy cover? Are links to other sectors (e.g. transport, energy, building)
The roadmap focuses on the emission intensive and strong exporting sectors: chemicals, energy, forest and technology form the core. In addition, around this core, sectors such as construction, fashion, lighting and traffic conducted their own roadmaps.	
Link to the National Energy and Climate Plan (NECP)	What are the connections to the NECP? (Input, recommendations, same stakeholders etc.)
The connections to the NECP are indirect, i.e., the focus was on a private/public roadmap driven by industry to outline a road to reach the government-set goal.	
Vision and milestones	Does the roadmap/national programme/strategy reveal explicit goals and milestones? (on the sectoral level? specific technologies? Etc.
The government objective of a carbon-neutral Finland by 2035 is the main vision, and the individual roadmaps provided sectoral responses to this goal. In addition, several sectors have targets they have defined themselves. Technology-neutrality is strongly present, i.e. reaching the goals is key, the means are left to the industry.	
Scenarios, modelling and simulations	Does the roadmap/national programme/strategy use findings from quantitative modelling exercises?
Each of the core sectoral roadmaps contain their own scenarios and models. Since the same consultant and core team was responsible for all these roadmaps (N.B. the choice was not done for all at the same time – this happened in a snowball effect), there is compatibility in the calculations.	
Smart Specialisation	To what extent does the roadmap/national programme/strategy take into account regional specifics and strategies?
The division is by sector of industry, not by geographical region. Actually, not going into regional and location policy was a key principle.	

Availability of resources	To what extent does the roadmap/national programme/strategy take in account the availability of resources (feedstock, energy, water, etc.)?
Thanks to the unified execution of the core roadmaps, the availability of resources is taken into account – care was taken to prevent sectors using the same resources several times.	
Cross-sectoral themes	How important are cross-sectoral themes?
Cross-sectoral themes appear in the roadmaps, whenever relevant. However, sectors did their own roadmaps without considering cross-sectoral connections, although coordination meetings were held.	
Quantification of funding and investment needs	How were public and private investment needs quantified and defined? To what extent does the roadmap take into account business plans and financial parameters (e.g., Total cost of ownership, Return on investment)?
Private investment needs were quantified and defined for each scenario in each core roadmap. Some indications of needed e.g., infrastructure investments were given, but the focus was on needed sectoral investments. Business plans of individual companies are a very sensitive subject with roadmaps done by competitors sitting at the same table. Thus, no investments were identified by name, unless they had been made public and the company agreed to have them included. The investments in green steel are an example of this – publicly announced plans and agreement from investing company to have the investment named. Financials were in the same category as business plans, i.e. companies do not and cannot reveal the profitability of their investments to competitors.	
Industrial symbiosis	In which way does the roadmap/national programme/strategy consider industrial symbiosis?
With related resources and “converging” products e.g., in the borderlands between process industries, symbiosis thinking existed. In e.g., processing of waste to value, a similar example of symbiosis took place. However, no plans for symbiosis were made – and since the exercise was lead by the industries, symbiosis would actually have been a large-scale strategic decision.	
Participation	Which stakeholder (industry, research, policy, etc.) were involved in the development of the roadmap/national programme/strategy and how were they mobilised?
Policy-makers (at the level of government programme and goals) introduced and put in motion a coordinated set of sectoral roadmaps by industry, with the input of specialised consultants.	
Digitalisation	To what extent does the roadmap/national programme/strategy take into account support digital technologies, i.e., twin transition?
Digital technologies were taken into account also in detail. As an example, one of the core roadmaps goes into e.g., 5G/6G in mobile and the energy use development of artificial intelligence and cloud services, and specific strategies to reduce the energy consumption of algorithms.	

Impact on R&D policy	What were the effects of the roadmap/national programme/strategy on R&D policy making on the national level? What were the effects to promote national priorities on the international level (e.g., alignment with EC programs)?
It is hard to quantify the exact effects of the roadmaps on R&D policy – the roadmaps became well known and were also presented, e.g., at COP, but there was no direct, automatic link to governmental funding. Finnish authorities and industry sectors also communicated the results to different instances in Brussels.	
Impact on investment policy	What were the effects of the roadmap/national programme/strategy on investment policy?
As the goal year is 2035, and the roadmaps were ready during the pandemic period in 2020, the starting circumstances have been exceptional, and it is too early to assess the effects. The impact on investment policy can only be evaluated closer to 2035.	
Alignment on the international level	To what extent have roadmap been aligned with roadmaps in other countries or at EU/international level?
The fact that the consultant and team that did the core roadmaps had also worked in other countries on roadmaps and also on these issues for e.g., industry associations in Brussels, means that there was a possibility to start from a further-along position and come up with solutions to questions that experience had shown to be difficult. The ambition level was to go further rather than align with previous work. The EU ambitions and targets played an important role.	

Table 5: Profile of MLE Country Finland

Georgia

Date of first development of the roadmap/national programme/strategy addressing the need of industry	When has the (first) roadmap/national programme/strategy been developed?
At the moment, there is not any specific roadmap/national programme/strategy regarding the industrial decarbonization in place. However, industrial decarbonization issues are included in climate change related strategic documents. More specifically, Georgia's NDC (adopted in 2021) states that "NDC supports the low carbon development of the industry sector through encouraging the climate-friendly innovative technologies and services, in order to be achieved [5%] of emission limitations comparing to emissions projected the reference scenario".	
Besides, in order to achieve NDC targets, Georgia developed National Climate Change Strategy for 2021-2030 and Climate change action plan 2021-2023 – the Strategy sets approaches how to achieve NDC targets by 2030 and action plan lists specific activities planned in 2021-2023. Both these documents contain industry decarbonisation chapters.	
And lastly, in 2023 Georgia adopted Long-term Low Emissions Development concept (LT LED) that describes different scenarios for Georgia's development up to mid-century – each scenario includes approaches and activities that should be implemented in order to achieve the scenario goals. The mentioned list of approaches and activities also include what changes should be implemented in industry sector.	

Coverage of sectors	Which sectors does the roadmap/national programme/strategy cover? Are links to other sectors (e.g. transport, energy, building)
For example, Climate Strategy and Action Plan covers:	
<ul style="list-style-type: none"> • Energy Generation and Transmission • Energy Consumption in Transport • Energy Consumption in Buildings • Energy Consumption in Industry and Industrial Processes • Agriculture • Waste Management • Forestry 	
As for LT-LEDS concept it covers energy, industry, agriculture and waste.	
Link to the National Energy and Climate Plan (NECP)	What are the connections to the NECP? (input, recommendations, same stakeholders etc.)
There are interlinkages between draft NECP, CAP and LT-LEDS . Such as stakeholders, measures or some inputs.	
Vision and milestones	Does the roadmap/national programme/strategy reveal explicit goals and milestones? (on the sectoral level? specific technologies? Etc.
There are specific targets and measures to be achieved and implemented. For example, climate strategy has its detailed action plan to be implemented.	
Just for example, NDC states the specific target – NDC supports the low carbon development of the industry sector through encouraging the climate-friendly innovative technologies and services, in order to be achieved [5%] of emission limitations comparing to emissions projected the reference scenario.	
Scenarios, modelling and simulations	Does the roadmap/national programme/strategy use findings from quantitative modelling exercises?
Indeed, for example in NECP and LT-LEDS.	
For example, LT LED contains different scenarios of Georgia’s development, and these scenarios includes different approaches and activities that should be implemented in industry sector.	
Smart Specialisation	To what extent does the roadmap/national programme/strategy take into account regional specifics and strategies?
In case of Georgia, regional specificities are taken into account when developing relevant policy documents	
For example, NDC, National Climate Change Strategy for 2021-2030 and LT LED – these documents are in line with UNFCCC obligations.	

Availability of resources	To what extent does the roadmap/national programme/strategy take in account the availability of resources (feedstock, energy, water, etc.)?
Strategic documents are taking into account availability of resources. For preparation of some policy documents modelling tools were used where availability of resources plays important role.	
Cross-sectoral themes	How important are cross-sectoral themes?
Cross-sectoral themes are very important relevant attention is insured while development strategies such as NECP, LT-LEDS, CSAP.	
Quantification of funding and investment needs	How were public and private investment needs quantified and defined? To what extent does the roadmap take into account business plans and financial parameters (e.g., Total cost of ownership, Return on investment)?
As for the NECP there is special table where all public and private investments are reflected and clarified the type of funding. (in-kind of financial etc.) as for LEDS it shows total investments in sectors.	
Industrial symbiosis	In which way does the roadmap/national programme/strategy consider industrial symbiosis?
So far, they are not considered in the documents	
Participation	Which stakeholder (industry, research, policy, etc.) were involved in the development of the roadmap/national programme/strategy and how were they mobilised?
During the development of NDC, National Climate Change Strategy for 2021-2030 and LT LED a wide range of stakeholders - state institutions, industry representatives, non-governmental organizations, research and educational organizations and so on – were involved. The named stakeholders were consulted during the development of these documents, draft versions were sent to them and received comments reflected in the documents and lastly, public hearings were held after the development of these documents.	
Digitalisation	To what extent does the roadmap/national programme/strategy take into account support digital technologies, i.e., twin transition?
In SME strategy of Georgia there is measure covering digital services, namely Towards Industry 4.0 the digital transformation of SMEs is essential to help them use digital technologies and build stronger digital capabilities to seize growth opportunities in the digital economy. To this end, on the one hand, it is necessary further to develop the relevant physical infrastructure and to improve the legal framework of the policy to promote the development of broadband networks and services. On the other hand, it is crucial to offer relevant trainings targeted at the development of digital skills of entrepreneurs.	
Impact on R&D policy	What were the effects of the roadmap/national programme/strategy on R&D policy making on the national level? What were the effects to promote national priorities on the international level (e.g., alignment with EC programs)?
There is no immediate effect yet, but development of these policy documents has increased cooperation with Ministry of Education and other relevant entities and attention for example to the	

R&D of energy sector will be increased.	
Impact on investment policy	What were the effects of the roadmap/national programme/strategy on investment policy?
We will have to determine this in the upcoming period to see the effect on the investment policy.	
Alignment on the international level	To what extent have roadmap been aligned with roadmaps in other countries or at EU/international level?
Yes, these documents, for example NECP and LT-LEDS are developed taking into account best international/EU experience with involvement of relevant international experts.	

Table 6: Profile of MLE Country Georgia

Lithuania

Date of first development of the roadmap/national programme/strategy addressing the need of industry	When has the (first) roadmap/national programme/strategy been developed?
Lithuania's original NECP, submitted to the EU in 2019, incorporates several domestic policy initiatives such as the National Energy Independence Strategy (adopted in 2018), the National Strategy for Climate Change Policy (adopted in 2012 and updated in 2019), and the National Air Pollution Plan (adopted in 2019). It was developed alongside the National Progress Plan (NPP), which outlines key priorities for social, economic, environmental, and security policies. In 2021, Lithuania updated its overarching climate policy targets in the National Climate Change Mitigation and Adaptation (NCCMA). Additionally, three roadmaps for the industry were developed and accepted in 2021: Industry Digitalization, Value Chain, and Transformation to Circular Economy.	
Coverage of sectors	Which sectors does the roadmap/national programme/strategy cover? Are links to other sectors (e.g. transport, energy, building)
The policies detailed in Lithuania's NECP are differentiated by economic sector, encompassing transport, energy, industry, waste, and agriculture and forestry. Within the industry sector, special attention is given to cement production, oil processing, food, construction industries, and others that contribute the largest shares of CO2 emissions or hold significant potential for circular economy initiatives.	
Link to the National Energy and Climate Plan (NECP)	What are the connections to the NECP? (input, recommendations, same stakeholders etc.)
The Decarbonisation Working Groups and the developed roadmaps are expected to fulfil the objectives, policies and measures included in the NECP.	
Vision and milestones	Does the roadmap/national programme/strategy reveal explicit goals and milestones? (on the sectoral level? specific technologies? Etc.
The Decarbonisation Working Groups and the developed roadmaps possesses joint objectives:	
<ul style="list-style-type: none"> • Anticipating and planning the transition to a climate-neutral economy • Provide a clear long-term objectives in Climate change mitigation and Climate neutrality. • To reduce emissions by 30% by 2030 compared with 2005 levels, targeting a 50% reduction the EU ETS sectors further 25% reduction in non-ETS sectors 	

Scenarios, modelling and simulations

Does the roadmap/national programme/strategy use findings from quantitative modelling exercises?

- Two policy scenarios for the period up to 2030 have been presented by the OECD. These scenarios are based on planned policies in Lithuania and the European Union (EU) that have not yet been implemented, assuming other countries maintain their current levels of climate policy ambition (reference scenario). The scenarios are as follows:
- FIT55 scenario: In this scenario, Lithuania implements the proposed excise duty amendment, which includes the introduction of a carbon tax component for certain fuels and sectors. At the EU level, member states adopt measures to achieve the EU's 55% emissions reduction target by 2030. This includes proposed reforms to the EU Emissions Trading System (ETS) and the European Tax Directive (ETD) outlined in the Fit for 55 package. Additionally, a carbon price is implemented in non-ETS sectors in order to meet the proposed targets, excluding Lithuania.
- ETS2 scenario: In this scenario, the reforms to the EU ETS and ETD modeled in the FIT55 scenario are implemented. However, in addition, the EU (including Lithuania) establishes an additional ETS for the road transport and buildings sectors, replacing carbon prices for non-ETS sectors in other member states from the FIT55 scenario.

Furthermore, the model used for these scenarios also takes into account the impact of the invasion of Ukraine by Russia and the response of governments globally. Specifically, it considers a scenario where select OECD countries impose restrictions on the import of fossil fuels from Russia. The results of the model cover the period up to 2030 and evaluate the impact of these fossil fuel import restrictions.

Smart Specialisation

To what extent does the roadmap/national programme/strategy take into account regional specifics and strategies?

The industry 4.0 group within the Lithuanian Ministry of Economy promotes the engagement of smart specialization, particularly in the areas of new manufacturing processes, materials, and technologies. This priority aims to facilitate efficient and sustainable business development, foster digital solutions utilizing new technologies, encourage collaboration between businesses and academia in the industrial sector, and enhance productivity, sustainability, added value, and energy efficiency.

Availability of resources

To what extent does the roadmap/national programme/strategy take in account the availability of resources (feedstock, energy, water, etc.)?

In every document and roadmap included in the NECP, an action plan with measures and financing is presented. This information is regularly updated and renewed to ensure its relevance and effectiveness.

Cross-sectoral themes

How important are cross-sectoral themes?

Lithuanian NECP measures need to be in line with the objectives set out in the National Energy Independence Strategy, approved in June 2018, the Agenda 2021 update and the National Air Pollution Reduction Plan approved in April 2019., which will not only contribute to achieving the European Green Deal objectives, but also to being competitive, to undertake a transformation away from fossil fuels, and to changing consumer behaviour.

This process involved the social partners, who were brought together in 5 decarbonisation working groups covering 5 economic sectors in Lithuania: agriculture and forestry, energy, industry, transport and waste/circular economy. The Decarbonisation Working Groups aim for an open and effective dialogue, to hear new ideas and different views, and to ensure information sharing among all stakeholders. By consulting and discussing with representatives of business, science, other organisations, and public groups a set of measures best suited for Lithuania to meet the challenges of climate change is under development.

Quantification of funding and investment needs	How were public and private investment needs quantified and defined? To what extent does the roadmap take into account business plans and financial parameters (e.g., Total cost of ownership, Return on investment)?
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The implementation of the NECP requires around EUR 14 billion of public and private financing in the clean energy transition. In 2021, EU and national recovery funds were disbursed under the National Resilience and Recovery Plan. Commendably, Lithuania has deployed significant stimulus funding, amounting to around 10% of its gross domestic product. To ensure the best use of EU and national recovery funds in the medium term, policies play a critical role for scaling up private/public investments and allow the private sector to take over. Boosting investments in clean energy technology innovation is a new and promising area. The Action Plan for an Energy Innovation Ecosystem was introduced in line with the IEA's technology and innovation framework. Lithuania's new Innovation Promotion Fund was created by the Ministry of Economy and Innovation, the Ministry of Finance, and the Investment and Business Guarantees (Invega), to boost energy sector investments.

Lithuanian Ministry of Finance with social and economic partners developed draft plan "New Generation Lithuania", which aims to additionally stimulate the green transition and the transformation of the Lithuanian industry, strengthening the resilience of the country's economy. The plan aims at ambitious goals for which an additional EUR 1.8 billion will be allocated, using the possibility of a borrowing instrument and the funds of the "REPowerEU" initiative. The plan "New Generation Lithuania" foresees up to EUR 1 billion financial instrument for the development of green, innovative, digital technologies and the production and export of high added value products. Currently, a model of a financial instrument is being prepared so that the Lithuanian business becomes a more active participant in the green transformation market. This instrument will contribute to the Green Finance Action Plan 2023-2026 prepared by the Ministry of Finance, which aims to green the public sector and administrative processes and to increase private sector financing and involvement in the green transition.

Industrial symbiosis	In which way does the roadmap/national programme/strategy consider industrial symbiosis?
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The impact and the needs to develop Industrial Symbiosis are foreseen in the Roadmap for Lithuania's industrial transition to a Circular Economy, the Roadmap for the integration of the Lithuanian industry into European value chains and the Lithuanian Bioeconomy strategy. All of them have become an integral part of the National Energy and Climate Plan.

Participation	Which stakeholder (industry, research, policy, etc.) were involved in the development of the roadmap/national programme/strategy and how were they mobilised?
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Lithuanian NECP and all related documents were developed or modified by involvement of stakeholders and social partners. For example, in the development of the Roadmap for Lithuania's industrial transition to a Circular economy the principles of co-creation were applied. They enabled all Lithuanian actors in the circular economy participate in the process and to develop a common understanding, knowledge and context and to work together.

Digitalisation	To what extent does the roadmap/national programme/strategy take into account support digital technologies, i.e., twin transition?
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In 2020 The Lithuanian Industry Digitisation Roadmap 2020-2030 was developed. It describes both EU and National perspective regarding industry digitisation, digitisation ecosystem, benchmark analysis with the selected EU countries, the most influential technologies and integration into international value chains. Based on this analysis, Lithuanian industry vision 2030 was developed

as well as strengths and weaknesses of the Lithuanian industry are identified. Finally, the strategic pillars supporting the vision and strategic actions are also presented. The provided information correlates with NECP.

Impact on R&D policy

What were the effects of the roadmap/national programme/strategy on R&D policy making on the national level? What were the effects to promote national priorities on the international level (e.g., alignment with EC programs)?

The developed documents and established Decarbonization working groups fostered the stimulation of research, innovation and knowledge production and the importance of R&I in defining sound policies and adapting to climate change. The role of science was stressed at different levels of decarbonisation processes, especially in industry, energy production, transport and construction.

Impact on investment policy

What were the effects of the roadmap/national programme/strategy on investment policy?

Lithuania has increased its domestic climate policy ambitions. The National Climate Change Management Agenda (NCCMA) adopted in June 2021 sets ambitious emission reduction targets with a view to reaching net-zero emissions by 2050. Lithuania aims to reduce emissions by 30% by 2030 compared with 2005 levels, targeting a 50% reduction the EU ETS sectors, and a further 25% reduction in non-ETS sectors.

This is a significant increase from the previous target of a 9% emissions reduction in non-ETS sectors, and even surpasses the 21% reduction proposed by the European Commission's under the Fit for 55 package. In order to meet these targets, Lithuania is planning to update its National Energy and Climate Plan (NECP) by 2023, in line with EU regulations.

Alignment on the international level

To what extent have roadmap been aligned with roadmaps in other countries or at EU/international level?

- The EU Green Course and 2050 Goals
- The European Green Deal
- New Industrial Strategy for Europe
- EU new circular economy action plan
- EU-Emissions Trading Scheme (ETS)
- Plan Next Generation EU
- Energy efficiency directive (EED)
- Renewable energy directive (RED)

All developed documents are aligned with the Sustainable Development Goals.

Table 7: Profile of MLE Country Lithuania

Latvia

Date of first development of the roadmap/national programme/strategy addressing the need of industry	When has the (first) roadmap/national programme/strategy been developed?
<p>2050 Climate Neutrality Strategy: The Strategy of Latvia for the Achievement of Climate Neutrality by 2050 is a national cross-sectoral strategy. Its main objective is to achieve climate neutrality of Latvia in 2050. It was adopted in 2019. (https://www.climate-laws.org/documents/2050-climate-neutrality-strategy_da6c)</p> <p>LATVIA'S NATIONAL ENERGY AND CLIMATE PLAN 2021–2030 link: https://energy.ec.europa.eu/system/files/2020-04/lv_final_necp_main_en_0.pdf</p> <p>The Plan was drafted in accordance with Cabinet Order No 210 of 7 May 2019 on the Government Action Plan to implement the declaration on the intended activities of the Cabinet of Ministers led by Arturs Krišjānis Kariņš” (task number assigned in the declaration – 062, Activity number 62.1).</p>	
Coverage of sectors	Which sectors does the roadmap/national programme/strategy cover? Are links to other sectors (e.g. transport, energy, building)
<p>The Strategy aims to make agriculture, forestry and fisheries more productive and sustainable. To this end, it seeks sustainable balance among different types of land use has been achieved in conformity with the climate, nature protection, economic, and social aspects; all forests of Latvia are managed in a sustainable manner; agriculture and forestry provides a significant contribution to bioenergy, concurrently not endangering provision of food and CO2 removals; agriculture and forestry of Latvia is resource-efficient – high productivity has been achieved, products with high added value are produced; research of organic soil has been conducted and corresponding use is applied thereto.</p> <p>The Plan should be implemented primarily by complying with economic development, energy and climate targets.</p> <p>The following action lines have been defined to achieve the objectives of the plan:</p> <ul style="list-style-type: none">• Improving the energy performance of buildings;• Improving energy efficiency and promoting the use of RES technologies in the heating and cooling and industry;• Promoting the use of negative emission technologies in electricity generation;• Promoting economically justified self-generation and self-consumption of energy;• Improving energy efficiency, promoting the use of alternative fuels and RES technologies in transport;• Energy security, reducing energy dependency, full integration of energy markets and modernisation of infrastructure;• Improving the efficiency of waste and wastewater management and reducing GHG emissions;• Efficient use of resources and reduction of GHG emissions in agriculture;	

- Sustainable use of resources and reduction of GHG emissions and increasing carbon sequestration in the sectors of land use, land-use change and forestry;
- Promoting the reduced use of fluorinated greenhouse gases (F-gases);
- ‘Greening’ of the tax system and improvement of friendliness to energy efficiency and RES technologies;
- Public information, education and awareness raising.

Link to the National Energy and Climate Plan (NECP)

What are the connections to the NECP? (Input, recommendations, same stakeholders etc.)

The Strategy is implemented by preparing and introducing national climate and energy plans (the first of them by 2030, taking into consideration the objectives of 2050 and the vision for 2050 laid out in the Strategy), the necessity of which is determined by the Energy Union. These plans consist of 5 dimensions: energy security, solidarity, and trust; fully-integrated European internal energy market; energy efficiency (including in transport); and decarbonising the economy; research, innovation, and competitiveness.

Vision and milestones

Does the roadmap/national programme/strategy reveal explicit goals and milestones? (on the sectoral level? specific technologies, etc?)

In order to increase the resilience of livelihoods to disasters, the Strategy aims for:

- reduction of GHG emissions in all sectors of national economy;
- increase of CO2 removals;
- restructuring of national economy;
- optimisation of processes in a cost-efficient manner without reducing competitiveness (ensuring stable and increasing decoupling of GDP from GHG emissions);
- increasing the resource-efficiency, including energy efficiency (principle: energy efficiency first);
- promoting the use of renewable energy sources;
- the State does not subsidise the use of fossil energy sources;
- development and commercialisation of green innovations and research;
- creation of new green working places;
- promotion of mutual communication, cooperation, symbiosis, and networking;
- horizontal integration of the abovementioned principles into all policies of national economy and investments of the public funding is ensured.

The Strategy further provides to ensure that:

- LCD aspects are integrated in all studies, low-carbon innovations and technologies are commercialised and transferred to all sectors of national economy;

- comprehensive energy efficiency in every sector of national economy;
- only renewable energy sources are used for energy generation in all sectors (where it is technologically possible), and that local energy sources are used and the energy market is completely connected and freely accessible to everyone;
- optimum transport infrastructure, to change the travel behaviour of inhabitants, to increase the use of resource-efficient and environmentally friendly types of vehicles;
- sustainable land management, achieving high productivity in agriculture, as well as managing the forests of Latvia in a sustainable manner;
- inhabitants of Latvia are implementing environmentally friendly lifestyle and companies have adapted to the tendencies of the global market and are successfully implementing circular economy;
- and sustainable development of local governments, promoting smart, climate-neutral, and flexible urban environment, inter alia, choosing the green infrastructure in the development of urban environment.

Scenarios, modelling and simulations	Does the roadmap/national programme/strategy use findings from quantitative modelling exercises?
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It is based on statistical information, analysis of current situation and best practices of other countries. The Strategy is the first policy planning document with such long-time horizon in Latvia.

Smart Specialisation	To what extent does the roadmap/national programme/strategy take into account regional specifics and strategies?
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Strategy is developed for cities and municipalities to provide a contribution to climate change mitigation, being **aware of their actual impact** on climate change, as well as their key role in achieving the national objectives for GHG emissions.

Availability of resources	To what extent does the roadmap/national programme/strategy take in account the availability of resources (feedstock, energy, water, etc.)?
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Essential factors in relation to the use of resources are the potential of bioeconomy, the efficiency of the use of resources, the consumption habits of households, the use of industrial raw materials of manufacturing, as well as waste management.

Cross-sectoral themes	How important are cross-sectoral themes?
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Important and considered

Quantification of funding and investment needs	How were public and private investment needs quantified and defined? To what extent does the roadmap take into account business plans and financial parameters (e.g., Total cost of ownership, Return on investment)?
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Optimum proportion of protected areas has been evaluated and ensured, achieving a balance between environmental protection, economic, and social needs.

Industrial symbiosis	In which way does the roadmap/national programme/strategy consider industrial symbiosis?
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The manufacturing models implemented by enterprises are based on innovations, they are directed towards efficient use of resources throughout the life cycle of the product, ensuring that resources

return into economic circulation. Enterprises implement mutual cooperation in the use of resources (the solutions of industrial symbiosis have been developed, as well as industrial clusters are being formed).

Participation

Which stakeholder (industry, research, policy, etc.) were involved in the development of the roadmap/national programme/strategy and how were they mobilised?

All stakeholders' groups were involved.

Successful development of the strategy required understanding and involvement, as well as consistent actions not only from the State, but also from local governments, non-governmental organisations, merchants, researchers, and every inhabitant of the State.

Digitalisation

To what extent does the roadmap/national programme/strategy take into account support digital technologies, i.e., twin transition?

The use of the Internet of things (IoT), currently taking into consideration cybersecurity and without violating the privacy of inhabitants, allows to supervise and control different systems (energy supply, public utilities, transport, security, etc.) efficiently and with a reduced consumption of resources in a remote manner, as well as to respond adequately to changes therein without delay. The concept of smart local government, i.e. complex solutions, combining investments into infrastructure with ICT, environmentally and climate friendly solutions, is also being extensively implemented for efficient provision of services.

Impact on R&D policy

What were the effects of the roadmap/national programme/strategy on R&D policy making on the national level? What were the effects to promote national priorities on the international level (e.g., alignment with EC programs)?

The development of research and innovations has provided a significant contribution to the implementation of the Strategy. The necessary funding has been mobilised, a stable, globally competitive human capital employed in research has been established, including a system for knowledge and technology transfer to all sectors of national economy has been developed.

Impact on investment policy

What were the effects of the roadmap/national programme/strategy on investment policy?

According to the initial indicative projections the additional investments for the implementation of the target scenario (achievement of climate neutrality) in comparison with the base scenario in the time period up to 2050 are approximately EUR 16 billion (in constant prices of 2010) or 1.35 % on average per year from GDP in the time period (2020–2050).

Alignment on the international level

To what extent have roadmap been aligned with roadmaps in other countries or at EU/international level?

It is projected that the awareness of inhabitants regarding the need to act for the mitigation of climate change in Europe, as well as in other countries of the world will increase.

The Communication published by the EC on 28 November 2018, A Clean Planet for all! A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy (EC Communication), explains that only the full implementation of the agreed EU legislation will already ensure reductions of GHG emissions of around 45 % by 2030 and around 60 % by 2050. However, the EU should strategically strive towards climate neutrality in 2050 which, like by the majority of EU Member States, is also supported by Latvia believing that the EU must take the leadership role in the fight against climate change, as well as expressing readiness to review the NDC submitted to the EU for the implementation of the Paris Agreement or the goals for the reduction of GHG emissions for 2030 (Position No. 2 of the Republic of Latvia of 11 June 2019. *On Communication of*

the European Commission: A Clean Planet for all! A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy).

As the Paris Agreement has been ratified by almost all countries of the world, it is assumed that all of them will move towards low-carbon development. Different industries are already becoming aware of the advantages of circular economy, thus the demand for energy-intensive raw materials will decrease, while the productivity of materials will increase, and the amount of generated waste will decrease.

Associations of different sectors have also expressed support and undertaken to take active measures in the field of climate change mitigation, voluntarily setting for themselves goals for climate change mitigation to be achieved by 2050, for example, the European Chemical Industry Council, the International Air Transport Association (IATA), and the Air Transport Action Group (ATAG).

The Strategy should be implemented as comprehensively, rapidly and efficiently as possible, thus both fulfilling the international goals and improving the living standard of inhabitants, and also strengthening the competitiveness of Latvian economy (by implementing such measures as improvement of energy efficiency, promotion of the use of local (renewable) energy sources, implementation of the circular economy and bioeconomy, promoting the development and manufacturing of climate technology innovations in Latvia).

Table 8: Profile of MLE Country Latvia

Portugal

Date of first development of the roadmap/national programme/strategy addressing the need of industry	When has the (first) roadmap/national programme/strategy been developed?
<p>The Roadmap for Carbon Neutrality 2050 (RNC2050) - Long-term Strategy for Carbon Neutrality of the Portuguese Economy by 2050 was published in June 2019. The National Energy and Climate Plan 2021-2030 (NECP 2030) was published in December 2019. Prior to that, in 2015, Portugal published already a few strategies concerning adaptation to the Climate Change, which served as a basis for the RNC2050, namely the National Climate Change Adaptation Strategy (EN AAC), the Strategic Framework for Climate Policy (QEPiC).</p>	
Coverage of sectors	Which sectors does the roadmap/national programme/strategy cover? Are links to other sectors (e.g., transport, energy, building)
<p>The RNC2050 covers almost the entire economy, including the power generation sector, mobility and transport, industry and industrial processes, construction, agriculture and forestry and waste and wastewater. It gives some particular attention to the following industries: refining and petrochemical industry, glass, ceramics, chemical products, iron and steel, cement and pulp and paper.</p>	
Link to the National Energy and Climate Plan (NECP)	What are the connections to the NECP? (Input, recommendations, same stakeholders etc.)
<p>The elaboration of the RNC2050 was carried out in parallel with the preparatory work for the NECP. Both activities benefited from the involvement of the same stakeholders, including a participatory dialogue with society and technical meetings with the various sectors. When drawing up the NECP, two distinct simulation models of the national energy system were used, including the TIMES_PT optimisation model, which was also used for the RNC2050 work. The RCN2050 also identifies the need to 'redirect financial flows to the promotion of carbon neutrality, fostering the development of a favourable framework for sustainable financing and greater involvement of the financial system, as well as the respective monitoring'. This serves as an input to the NECP in terms of financial resources. Finally, both initiatives set out a vision, the objectives and targets and the main lines of action which will determine the evolution of the national economy in the medium and long-term.</p>	

Vision and milestones	Does the roadmap/national programme/strategy reveal explicit goals and milestones? (on the sectoral level? specific technologies, etc.?)
<p>The RNC2050 provides clear and explicit goals and milestones, comprising both sectors and some specific technologies. For example, the roadmap provides estimations for the potential emission reductions in 2050 relative to 2005 for the overall country and by sectors. Using a scheme for the overall economy and by main sector, the roadmap shows for example, the type of energy production in 2050, type of agriculture or type of mobility, such as hydrogen vehicles.</p>	
Scenarios, modelling and simulations	Does the roadmap/national programme/strategy use findings from quantitative modelling exercises?
<p>The establishment of GHG emissions reduction targets was underpinned by the National Law Carbon Roadmap 2050 (RNBC), which was the first long-term modelling exercise of national emissions, carried out at a national level. The identification of GHG emission trajectories to achieve carbon neutrality is supported by modelling exercises that cover all sectors of the economy with significant contributions to national total emissions and all the important GHGs. RNC2050 is based on three alternative macroeconomic scenarios for development of the Portuguese economy and on two sets of objectives for each scenario. The roadmap presents in more detail two scenarios Peloton and Yellow Jersey scenarios (PL YJ) for the carbon neutrality trajectories, and for a question of simplicity, only the results of the Yellow Jersey scenario are presented graphically. It should be noted that these results reflect the modelling response, taking into account the assumptions defined, and serve as a basis for informing the policy choices made in the context of RNC2050 and PNEC 2030. Modelling was used to estimate GHG emissions and the economic impact of the transition (in this case using a GEM-E3_PT MODEL).</p>	
Smart Specialisation	To what extent does the roadmap/national programme/strategy take into account regional specifics and strategies?
<p>The RNC2050 makes no reference to the smart specialisation strategies. However, when referring to the governance and ensuring the integration of carbon neutral objectives in sectoral areas, the roadmap highlights the importance of promoting the development of carbon neutrality roadmaps at a regional and/or inter-municipal level, consistent with and linked to the RNC2050, which will enable a cohesive transition that is closer to the citizen, involving the active participation of regional actors and entities from different levels of territorial organisation. The roadmap also emphasises the importance of regional authorities to the achievement of the objectives.</p>	
Availability of resources	To what extent does the roadmap/national programme/strategy take in account the availability of resources (feedstock, energy, water, etc.)?
<p>When discussing the sector of agriculture and forestry, the roadmap considers the land use and livestock. For example, the roadmap recognises changes in the total agricultural area and in the area of different crops. It also acknowledges the need to increase the rate of new afforestation and ensure a large reduction in burned areas. In terms methane, part of it produced by landfills can be recovered and burned with energy recovery, which is an emissions reduction measure. In addition, the roadmap includes a subchapter on the role of circular economy in the transition to carbon neutrality, where it mentions, for example, the adoption of regenerative and more resource-efficient agricultural practices that will allow to save water and energy. Finally, when referring to the role of the energy system in the transition to carbon neutrality, the roadmap considers, for instance, the increased use of electrification and hydrogen in the future.</p>	
Cross-sectoral themes	How important are cross-sectoral themes?
<p>The RNC2050 includes a subchapter on the benefits of carbon neutrality to air quality and public health, including the impact of other air pollutants on air quality, acidification and eutrophication and respiratory and cardiovascular problems. In addition, the roadmap includes a subchapter on the contribution to national resilience and capacity to adapt to climate change, in particular, it emphasises the fact reducing emissions will help to allow adaption costs to be reduced significantly,</p>	

with clear economic savings; and several decarbonisation measures, including those linked to the agriculture and forestry sector, also contribute to the overall adaptation to climate change.

Quantification of funding and investment needs

How were public and private investment needs quantified and defined?
To what extent does the roadmap take into account business plans and financial parameters (e.g., Total cost of ownership, Return on investment)?

The roadmap estimates an overall aggregate amount of investment by 2050 close to EUR 1 trillion - of which round EUR 930 billion will be realised in any case as a result of the normal dynamics of modernisation of the economy, catalysed by ongoing policies to ensure the functioning of the energy system - which translates into an annualised value of EUR 27 to 29 billion. The additional investment needed to achieve carbon neutrality will be around EUR 85 billion for the entire period, i.e. around EUR 2.1 to € 2.5 billion per year (around 1.2% of GDP). There are no details about how the estimation was computed, except for a reference to the estimated amounts of the European Commission for the EU, in its long-term strategy. In terms of public and private investments, the roadmap provides information on the several European financing instruments that can be used to fund the decarbonisation of the economy such as InvestEU; on several national funding instruments such as the use of CELE (ETS) revenues; and on the role of several private financing instruments such as blended finance or corporate green bonds. The roadmap does not give very detailed information on business plans, but it considers the amount of investment associated to each industry and each technology such as heat pumps or batteries and how the transition will take place. It also considers the cost savings associated to the fossil fuel imports overtime.

Industrial symbiosis

In which way does the roadmap/national programme/strategy consider industrial symbiosis?

Under the industrial sector, the roadmap considers as one of the main decarbonisation drivers the industrial symbioses and resource reuse, in particular the greater incorporation of secondary materials and increased recyclability of the products produced that may bring gains on a medium and long-term time horizon. No further details are provided.

Participation

Which stakeholder (industry, research, policy, etc.) were involved in the development of the roadmap/national programme/strategy and how were they mobilised?

The scenarios proposed were widely discussed with the various stakeholders. The elaboration of RNC2050 was also a broad process of sectoral involvement and mobilisation of society throughout different stages and with different objectives. The construction of the macroeconomic scenarios that underlie the whole prospecting and modelling exercise went through different iterative phases that allowed the gathering of contributions from various national institutions and experts, which gave rise to the three scenarios considered. The cycle of technical workshops had the main aim of understanding the role of the circular economy in the future of different sectors, as well as informing the emissions modelling work over the time horizon up to 2050 through stakeholders' perceptions regarding the configuration of the sectors' value chain and of the evolution of some of the main assumptions and trends. This cycle included the following sectoral workshops: mobility; forestry activities; agri-food; construction; cities; energy; waste and wastewater. At the same time, a cycle of thematic events was held on the decarbonisation of society, with a total of four sessions focused on the themes of Mobility; Forestry Activities; Energy Transition; Fair Transition. The preliminary results of the roadmap were divulged for public consultation for a period of 3 months.

Digitalisation	To what extent does the roadmap/national programme/strategy take into account support digital technologies, i.e., twin transition?
<p>Under the transport sector, the roadmap underlines the need to reinforce the supply of public transport systems, and that coupled with even greater digitisation, will lead to progressively greater gains in efficiency. The roadmap also assumes under the yellow jersey scenario a high degree of decentralisation and digitisation of the energy system. Under the industry sector, the roadmap emphasises that options such as electric ovens, increased robotisation and the transformation of some sectors into a more digital 4.0 industry drive electricity consumption two times higher than current consumption in the sector and contribute to decarbonisation in line with carbon neutrality by 2050. Finally, under the construction sector, the roadmap mentions the role of digital technology that will mark the future of buildings and net zero energy buildings.</p>	
Impact on R&D policy	What were the effects of the roadmap/national programme/strategy on R&D policy making on the national level? What were the effects to promote national priorities on the international level (e.g., alignment with EC programs)?
<p>The roadmap devotes one chapter to the stimulation of research, innovation and knowledge production and the importance of R&I to defining sound policies and adapting to climate change. It recognises the role of science at different levels such as monitoring, estimations, or identification of long-term decarbonisation strategies. The roadmap also recognises the importance to ensure a connection between research, development and innovation and the production system. The roadmap identifies the Research and Innovation thematic agendas of the Science and Technology Foundation, the I.P. for Climate Change, circular economy, sustainable energy systems, urban Science and Industry and cities of the future as the precursors of the mobilisation needed to ensure the transition to a carbon neutral society. At the international level, the roadmap only refers to the EU financing instruments to R&D such as Horizon Europe or the LIFE Program.</p>	
Impact on investment policy	What were the effects of the roadmap/national programme/strategy on investment policy?
<p>Apart from the identification of various financing instruments at the European, national, and private level, the roadmap only states that tax policy should be aligned with the defined neutrality objective.</p>	
Alignment on the international level	To what extent have roadmap been aligned with roadmaps in other countries or at EU/international level?
<p>At the international level, the RNC2050 is aligned with the Paris Agreement. At the EU level, the roadmap is aligned with the 2030 Climate and Energy legislative framework, which includes the EU-level policy targets and objectives for the period of 2021-2030, and several corresponding directives; with the EU Communication “A Clean Planet for All”, of November 2018, which proposes a long-term strategic vision for a thriving, modern, competitive economy that permits the achievement of zero net GHG emissions by 2050. In addition, the roadmap refers to several countries as examples of other international commitments to carbon neutrality, without specifying a link with them, such as Norway, Sweden and Denmark. Portugal is part of “2050 Pathways” platform, a multilateral initiative set up to support the achievement of long-term zero GHG commitments.</p>	

Table 9: Profile of MLE Country Portugal

Sweden

<p>Date of first development of the roadmap/national programme/strategy addressing the need of industry</p>	<p>When has the (first) roadmap/national programme/strategy been developed?</p>
<p>The Riksdag (Swedish Parliament) adopted a climate policy framework consisting of a Climate Act and the goal that Sweden should have zero net emissions by 2045. To support this goal and hasten the work in different parts of society in 2015 the Government took the initiative of setting up Fossil Free Sweden. The Fossil Free Sweden initiative, led by a National Coordinator, is tasked with being a link between Government and business, municipalities, regions and organisations. The aim is also to identify and remove the obstacles to faster transition.</p>	
<p>Coverage of sectors</p>	<p>Which sectors does the roadmap/national programme/strategy cover? Are links to other sectors (e.g. transport, energy, building)</p>
<p>The Fossil Free action plan covers 22 different business sectors, and the effort is to make sure that the solutions proposed in the roadmap can be adopted by all the 22 sectors covered. Aviation industry, Cement industry, Concrete industry, Construction and civil engineering sector, Food retail sector, Forest sector, Heavy road haulage, Mining and minerals industry, Steel industry, Agricultural sector, Automotive industry passenger cars, The automotive industry heavy transport, Electricity sector, Fast-moving consumer goods industry, Gas sector, Petroleum and biofuel industry, Recycling sector, Ski resort sector, Maritime industry, Heating sector, Digitalisation consultancy industry and Aggregated Industries.</p>	
<p>Link to the National Energy and Climate Plan (NECP)</p>	<p>What are the connections to the NECP? (Input, recommendations, same stakeholders etc.)</p>
<p>The Fossil Free plan is strongly connected to the Swedish's Climate and Energy plan, in a way that national objectives and policies together with policies and measures, specifically address the dimension of Decarbonisation in addition to the dimension of Energy Efficiency, Energy Security, Renewable Energy and Research and Innovation competitiveness. The approach used for the National Climate and Energy roadmap is similar to the one used for the Fossil Free plan. The structure for collecting input and recommendations is defined by five stages:</p>	
<ol style="list-style-type: none"> 1. Involvement of the Parliament for the definition of the climate and energy bills, 2. Involvement of local and regional authorities, where business communities and other relevant stakeholders are involved in policy planning. 3. Consultation with stakeholders, including social partners and engagement of civil society, 4. Consultation with other Member States, specifically with other neighboring member states, which takes place in the Nordic council, 5. Iterative process with the European Commission which takes place within the structure of the technical expert group. 	
<p>The objectives and targets published in both roadmaps are connected since both stems from the Government Bill 2016/17:146. In June 2017, the Riksdag, adopted a proposal on a national climate policy framework for Sweden (Government Bill 2016/17:146). The climate policy framework consists of a Climate Act, new national climate targets and a climate policy council. It creates order and stability in climate policy and sets long-term conditions for the business sector and society.</p>	

Vision and milestones

Does the roadmap/national programme/strategy reveal explicit goals and milestones? (on the sectoral level? specific technologies? Etc.

The role of Fossil Free Sweden in developing Sweden into the world's first fossil-free welfare nation is to strengthen interaction between business and politics so that the pace of climate action can increase. The Swedish Parliament has set the goal of zero net emissions of greenhouse gas by 2045. The Fossil Free Sweden initiative was launched by the Government to gather and accelerate the climate efforts being made in the business sector, municipalities and regions. Fossil Free Sweden has drawn up a framework for the content of the roadmaps, but the sectors themselves have led the process by gathering their sector together, producing the content and securing support for the work. In most sectors it is the industry organisations that have led the work. The initiative operates through a small team led by a National Coordinator and has an independent status towards the Government. The mission is to speed up climate action in industry and push the Government to remove obstacles that could slow the transformation. The roadmap's vision is based on the concept that if the politicians provide the right conditions the business sectors are able and willing to make the transition to become fossil free. Sweden is the first country in the world where industry sectors voluntarily show how to become fossil-free already in 2045, while at the same time strengthening their competitiveness. In addition, they want to accelerate the pace of climate change adaptation through faster decision-making processes that make it possible to meet the growing climate market and to reach the Swedish climate target of net zero greenhouse gas emissions by 2045. The demand from the business community for a faster transition creates in itself unique opportunities for policymakers to take courageous and necessary decisions. The business sectors own their respective roadmaps and are responsible for the visions, goals, obstacles and solutions described. The roadmap processes have been managed by sector associations or companies. The roadmap presents targets for emissions associated to the different sectors addressed and it presents a monitoring from 2018 until 2020. Sweden must cut its net greenhouse gas emissions to zero and then achieve negative emissions. A maximum of 15% of emission reductions should come from additional measures by 2045 compared to 1990; 75% reduction in emissions from sectors outside the European Union's Emission Trading System (EU ETS). A maximum of 2% from additional measures by 2040 compared to 1990; 63% reduction in emissions from sectors outside the EU ETS. A maximum of 8% from additional measures by 2030 compared to 1990; 70% reduction in emissions in the transport sector by 2030 compared to 2010; 40% reduction in emissions from sectors outside the EU ETS. A maximum of 13% from additional measures by 2020 compared to 1990; 50% of final consumption of energy to be covered by renewable sources by 2020; 100% renewable electricity generation (this is a target not a deadline for nuclear energy) 2040; 50% improvement in energy efficiency 2030 compared to 2005.

Scenarios, modelling and simulations

Does the roadmap/national programme/strategy use findings from quantitative modelling exercises?

There is no indication in the roadmap that modelling, or simulations have been used for the development of the strategy, but it needs to be specifically asked since the management of the roadmap for the different sectors has been led by the industry associations themselves.

Smart Specialisation

To what extent does the roadmap/national programme/strategy take into account regional specifics and strategies?

The roadmap takes into account specific regional needs, since regions are among the stakeholders in the roadmap development. The extent to which regions are taken into account for targets definition is not explicitly described in the Fossil Free plan, but it is extensively described in the National Climate and Energy Plan. The way in which regions have participated to the National Climate and Energy plan is through County Councils. They are to coordinate regional climate and energy initiatives and support regional actors, for example by information collection and dissemination. Strategies are designed in collaboration with other regional and local actors to contribute to effective measures and synergies. In addition, they take action in areas such as environmental assessment and surveillance, local and regional spatial planning, regional development and growth policy and infrastructure planning. The regional government offices (County Administrative Boards, or CABs) are responsible for coordinating the regional adaptation work and supporting local actors in their

adaptation work. The CABs adopted in 2014 regional action plans on which they report annually to the government about the actions taken to adapt to climate change.

Availability of resources

To what extent does the roadmap/national programme/strategy take in account the availability of resources (feedstock, energy, water, etc.)?

Availability of biofuels, biomass, energy are discussed in the roadmap and for some industry sector some recommendations are proposed. The common aspect across sectors is that there is a strong need to increase resources availability.

Cross-sectoral themes

How important are cross-sectoral themes?

The Fossil Free roadmap is structured in a way each sector has developed and managed their roadmaps and it is indeed published by sectors. There is no explicit discussion on cross-sectoral themes, although it becomes clear that energy, heat recovery and biomass/biofuels availability are presented as common themes across the sectors.

Quantification of funding and investment needs

How were public and private investment needs quantified and defined?
To what extent does the roadmap take into account business plans and financial parameters (e.g., Total cost of ownership, Return on investment)?

Estimates of the size of the financing requirement vary slightly between different sources because the amount of the investment is affected by the underlying assumptions and the scope of the investments. According to calculations by Material Economics, additional investments of just over EUR 100 billion will be needed to reach net-zero in Sweden for transport, buildings, heavy industry, heating and electricity. Over 25 years, up to 2045, this is equivalent to approximately 1 per cent of Sweden's GDP. [source: The Banking Industry framework publication].

Need more information on business plan and return on investment.

Industrial symbiosis

In which way does the roadmap/national programme/strategy consider industrial symbiosis?

Not specifically discussed and identified – need more information on that.

Participation

Which stakeholder (industry, research, policy, etc.) were involved in the development of the roadmap/national programme/strategy and how were they mobilised?

As described in the Methodology section, the Parliament for the definition of the climate and energy bills, local and regional authorities, where business communities and other relevant stakeholders are involved in policy planning. Other stakeholders, including social partners and engagement of civil society were also involved in the process of the development of the roadmap.

Digitalisation

To what extent does the roadmap/national programme/strategy take into account support digital technologies, i.e., twin transition?

Digitalisation consultancy is considered one of the sectors defined in the roadmap. By promoting new business models, behaviours, regulations and organisational approaches, strategic digitalisation has the potential to radically reduce greenhouse gas emissions, increase competitiveness and generate high growth in exports of transformative solutions. Firms in the digitalisation consultancy industry that have joined forces behind this roadmap are united in their ambition to help society become aware of and tap the potential of digitalisation.

The vision of the digitalisation consultancy industry is: By 2045, they will have helped Sweden and the rest of the world reduce its energy consumption to the point where there is a chance of keeping

the rise in temperature below 1.5 °C. In so doing, they also aim to support increased international collaboration.

The commitment of the digitalisation consultancy industry for contributing to implementation of sustainable fossil free solution is defined as following.

By 2030: Cut the industry's energy use by at least half by 2030, with the ambition of reaching zero emissions by 2045 (in accordance with the IPCC's low-energy scenario).

By 2020:

- Agree a minimum level of knowledge among our employees regarding the impacts of digitalisation from a climate and sustainability perspective.
- Carry out training initiatives to ensure that our employees meet the minimum level (above) within one year after they join the firm.
- Agree a framework to report positive and negative contributions (Scope 1-4, including avoided emissions).
- Find resources for building and launching a web platform where industry firms' capacity and contributions to a national knowledge boost are made available to each other, clients, academia and government. We recommend that the platform should include:
 - Presentation of cases including climate impact
 - Training materials, methods and reports
 - Information about joint initiatives
 - Contact details for individuals with particular expertise
- Adopt new commitments up to 2022 based on conditions in 2020.

Impact on R&D policy

What were the effects of the roadmap/national programme/strategy on R&D policy making on the national level? What were the effects to promote national priorities on the international level (e.g., alignment with EC programs)?

No information filled in.

Impact on investment policy

What were the effects of the roadmap/national programme/strategy on investment policy?

The roadmaps have defined the need for investments and together with the banking industry association have started analysing the different mechanisms of incentives/funding that need to be implemented in order to achieve the targets.

Alignment on the international level

To what extent have roadmap been aligned with roadmaps in other countries or at EU/international level?

In the development of the roadmap there has been a consultation with other Member States, specifically with other neighbouring Member States, which takes place in the Nordic council, and iterative process with the European Commission which takes place within the structure of the technical expert group.

Table 10: Profile of MLE Country Sweden

Slovakia

Date of first development of the roadmap/national programme/strategy addressing the need of industry	When has the (first) roadmap/national programme/strategy been developed?
<p>The Low-carbon Development Strategy of the Slovak Republic until 2030 with a view to 2050 was approved by the Slovak Government on the 5th of March 2020.</p>	
Coverage of sectors	Which sectors does the roadmap/national programme/strategy cover? Are links to other sectors (e.g., transport, energy, building)
<p>The Low-Carbon Strategy covers the following sectors of economic activity: industry, the energy sector and energy efficiency, agriculture, LULUCF, transport and waste management including macroeconomic analyses and impacts of selected proposed measures. The Low-Carbon Strategy aims at selecting and analysing measures in a cost-effective way. Support of the relevant departments and the interconnection and consolidation of individual sectoral and cross-sectoral policies will be necessary for its implementation.</p>	
Link to the National Energy and Climate Plan (NECP)	What are the connections to the NECP? (input, recommendations, same stakeholders etc.)
<p>NECP was approved in October 2019 and Low-carbon Strategy in March 2020 so there are a lot of cross references to NECP, and it built to some extent on NECP.</p>	
Vision and milestones	Does the roadmap/national programme/strategy reveal explicit goals and milestones? (on the sectoral level? specific technologies? Etc.
<p>This Strategy aims to identify measures, including additional measures, to achieve climate neutrality in Slovakia by 2050. An essential part of the vision is the horizon of the nearest strategic decade, which is crucial for the achievement of the 2030 climate and energy targets. On top of that is includes also goals identical to NECP for energy efficiency, renewable energy and for non ETS sectors like industrial processes, transport, energy, agriculture, LULUCF, waste. It includes also indicative milestone for 2040 and 2050. Of course, we need to update this strategy to reflect current Fit for 55 proposals and another important task in updating the strategy will be to model the impact of other additional measures (NEUTRAL) which are stated at the end of each sectoral chapter and have not been modelled, and which should facilitate Slovakia's climate neutrality in 2050.</p>	
Scenarios, modelling and simulations	Does the roadmap/national programme/strategy use findings from quantitative modelling exercises?
<p>Strategy includes a scenario with existing WEM measures, a scenario with additional WAM measures and a scenario NEUTRAL with possible measures to reach climate neutrality.</p>	
<p>Selecting individual measures so that the selection is based on cost-effectiveness principles and finding out how these measures will influence emission abatement and the national economy is a rather complicated task. For this reason, the Slovak Ministry of Environment signed an Agreement on Cooperation with the World Bank (WB) in November 2016. The cooperation project with the WB resulted in a Low-Carbon Growth Study for Slovakia: Implementing the EU 2030 Climate and Energy Policy Framework (with an outlook to the year 2050). This Low-Carbon Growth Study was the basis</p>	

for the development of the Low-Carbon Development Strategy of the Slovak Republic. The Low-Carbon Strategy was prepared with two models. The first one was the Compact Primes Model (CPS) model Slovakia from the WB (mainly related to the energy sector, industry and transport, i.e., those in which fuel is burned), the other one was a macro model – ENVISAGE-Slovakia (CGE). The two models were applied in a coordinated fashion, with the CPS model providing detailed energy outputs to the CGE model. Using them, WB experts, in cooperation with national experts, modelled the macroeconomic effects of individual proposed policies and measures in sectors where emissions from fuel combustion (energy, including transport) arise. Other sectors such as industrial emissions, fugitive emissions, LULUCF, agriculture, waste management and transport were modelled into scenarios by an expert approach, also based on the measures used by the WB. The COPERT model was also used in the transport sector. More detailed information on the models as well as on the approach to each sector is provided in Annex II of Low-carbon Strategy.

Smart Specialisation	To what extent does the roadmap/national programme/strategy take into account regional specifics and strategies?
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See above – Low-Carbon Strategy is prepared to reflect Slovak conditions. On top of that according to Governmental Resolution to this Strategy regional and local conception strategic document have to take into account vision, milestones and goals in Strategy.

Availability of resources	To what extent does the roadmap/national programme/strategy take in account the availability of resources (feedstock, energy, water, etc.)?
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Our strategy built on NECP where all the availability of resources should have been taken into account. On top of that our Adaptation Strategy on Climate Change and subsequent Action Plan for the implementation of Adaptation Strategy to Climate Change looked at the impact of climate change on all sectors and suggested some adaptation measures.

Cross-sectoral themes	How important are cross-sectoral themes?
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According to governmental resolution to this strategy each and every state administration have to take into account vision, milestones and goals in preparation of respective strategies, laws...

Quantification of funding and investment needs	How were public and private investment needs quantified and defined? To what extent does the roadmap take into account business plans and financial parameters (e.g., Total cost of ownership, Return on investment)?
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As it was mentioned above, we used CPS model Slovakia from the WB (mainly related to the energy sector, industry and transport, i.e. those in which fuel is burned), the other one was a macro model – ENVISAGE-Slovakia (CGE).

CPS model includes also sectoral investments.

The macroeconomic model, named the ENVISAGE-Slovakia applied general equilibrium (Slovak-CGE) model, has been customised to reflect the particular features of the Slovak economy. Importantly, demand for energy commodities across households and firms is price sensitive, and various electricity generation options are captured.

Industrial symbiosis

In which way does the roadmap/national programme/strategy consider industrial symbiosis?

Since the very beginning, the industry was involved in preparation of this strategy. The main purpose of this strategy is to set goals, milestones and vision together with some measures which have to be fulfilled and will guide the development in the years to come. All strategic documents, laws have to be in line with this strategy. Some measures can also be qualified as industrial symbiosis, e.g. optimisation of district heating systems – shift from fossil fuels to biomass and natural gas and installation of combined heat and power (CHP) units in district heating systems. Industrial Combined Heat and Power (CHP) plants produce industrial steam, which can also be used for district heating, or is a secondary use of industrial steam. Other measures are also taken into account (e.g., improving the efficiency of district heating systems (DHS), installing innovative district heating technologies, improving heat supply from combined heat and power plants).

Participation

Which stakeholder (industry, research, policy, etc.) were involved in the development of the roadmap/national programme/strategy and how were they mobilised?

The Ministry of Economy cooperated with other relevant departments as well as representatives of the general professional public and academia in the preparation of the Low-Carbon Strategy. The Ministry declared its interest in preparing the Strategy in May 2018 via a publicly accessible questionnaire through which both the general and professional public could enter and directly participate in the proposal of characteristic measures in the individual chapters proposed. All responses have been assessed and processed and, if a respondent agreed with publication, they were published on the Ministry's website together with a textual evaluation of the entire questionnaire. The public also had the opportunity to join and participate in the preparation of the document in the Interdepartmental Comments Procedure process. Finally, the public participated in the preparation of the document in the SEA process.

In August 2018, an "ad hoc working group on the preparation of a low-carbon strategy" was established, composed of representatives of the state administration as well as representatives of academia and employers' associations. The basis of the working group was the already existing working group for the preparation of the Low-Carbon Strategy, which had been set up under the Commission for the Coordination of Climate Change Policy at the level of State Secretaries. In addition to this working group, six working groups set up by individual sectors began operating in November 2018.

Digitalisation

To what extent does the roadmap/national programme/strategy take into account support digital technologies, i.e., twin transition?

Generally, all technologies that can decrease emissions of GHG should be accepted. E.g. Energy efficiency policies for the energy sector include encouraging the use of new innovative technologies in industrial production (BAT techniques); in the transport sector they are policies focused on infrastructure as well as soft measures for greater efficiency, install and deploy smart metering systems in energy systems and installations, support SMART solutions for technical services in towns to streamline waste management etc.

Impact on R&D policy	What were the effects of the roadmap/national programme/strategy on R&D policy making on the national level? What were the effects to promote national priorities on the international level (e.g., alignment with EC programs)?
<p>In this low-carbon strategy, there is also special chapter dealing with Policies and Measures for Related Research, Development and Innovation.</p>	
<p>In 2021 the Slovak Government approved Research and Innovation Strategy for Smart specialisation of the Slovak Republic 2021-2027 which is a strategic document defining the objectives, policy system and measures in the field of research, innovation and human resources that will support the structural change of the Slovak economy towards growth based on increasing research and innovation capacity and excellence in the segments with the highest competitive potential. It is the core document setting the baseline for the content of the European Union Cohesion Policy funds for the period 2021-2027. Mentioned strategy is in line with the low-carbon strategy.</p>	
Impact on investment policy	What were the effects of the roadmap/national programme/strategy on investment policy?
<p>As the main goal of the low-carbon strategy is to provide complex long term strategic outlook of the transition to low-carbon economy it has certainly impact on investment policy. It helps investors to plan their own development and to take into account the list of measures with the possible financial tools.</p>	
Alignment on the international level	To what extent have roadmap been aligned with roadmaps in other countries or at EU/international level?
<p>The obligation to develop this Strategy is based on international, European and Slovak law. According to the Paris Climate Agreement, all parties, including the EU, are obliged to develop and submit by 2020 at the latest their long-term low-emission development strategies to take effect by 2050.</p>	
<p>On the EU level it is in line with the Regulation (EU) 2018/1999 of the European Parliament and of the Council on the Governance of the Energy Union and Climate Action, adopted in 2018. According to Article 15 of the Regulation, MS are obliged to submit a long-term low emission strategy by 1 January 2020. Annex IV to the Regulation specifies the content of the national strategies, which this strategy follows.</p>	

Table 11: Profile of MLE Country Slovakia

Slovenia

Date of first development of the roadmap/national programme/strategy addressing the need of industry	When has the (first) roadmap/national programme/strategy been developed?
<ul style="list-style-type: none"> • 2020 - A comprehensive strategic project of the denuclearisation of Slovenia through the transition to a circular economy. • 2021 - Slovenia's long-term climate strategy 2050 	
Coverage of sectors	Which sectors does the roadmap/national programme/strategy cover? Are links to other sectors (e.g. transport, energy, building)
<ul style="list-style-type: none"> • Industry (especially energy-intensive industries) • Energy supply • Traffic and mobility • Buildings - households and service activities • Agriculture • Land use, land use change and forestry • Waste • Consumption and production processes for a low-carbon circular economy 	
Link to the National Energy and Climate Plan (NECP)	What are the connections to the NECP? (Input, recommendations, same stakeholders etc.)
Harmonised directions and the same strategic goals.	
Vision and milestones	Does the roadmap/national programme/strategy reveal explicit goals and milestones? (on the sectoral level? specific technologies? Etc.
Yes	
Scenarios, modelling and simulations	Does the roadmap/national programme/strategy use findings from quantitative modelling exercises?

Yes, various scenarios were prepared based on the data.

Smart Specialisation	To what extent does the roadmap/national programme/strategy take into account regional specifics and strategies?
The activities and orientations of the renewed Smart Specialisation Strategy are also key to achieving the goals of the climate strategy.	
Availability of resources	To what extent does the roadmap/national programme/strategy take in account the availability of resources (feedstock, energy, water, etc.)?
The strategy deals with natural resources and energy sources.	
Cross-sectoral themes	How important are cross-sectoral themes?
The strategy is considering and directing the society to cross-sectoral and interdepartmental integration, awareness raising and public involvement.	
Quantification of funding and investment needs	How were public and private investment needs quantified and defined? To what extent does the roadmap take into account business plans and financial parameters (e.g., Total cost of ownership, Return on investment)?
An assessment of the necessary investments to achieve the goal of climate neutrality has been made. The estimated investments do not cover the entire transition to achieving net zero emissions, but they offer a framework for the necessary investments.	
Industrial symbiosis	In which way does the roadmap/national programme/strategy consider industrial symbiosis?
Symbiosis is only mentioned in the case of measures for interconnection of energy systems and better connection or integration of industry into the network and for energy storage.	
Participation	Which stakeholder (industry, research, policy, etc.) were involved in the development of the roadmap/national programme/strategy and how were they mobilised?
All stakeholder (industry, research, state...)	
Digitalisation	To what extent does the roadmap/national programme/strategy take into account support digital technologies, i.e., twin transition?
The strategy includes the automation and digitisation of operation management, the introduction of digital platforms, the digitisation of energy, and the digital transformation of the economy.	

Impact on R&D policy	What were the effects of the roadmap/national programme/strategy on R&D policy making on the national level? What were the effects to promote national priorities on the international level (e.g., alignment with EC programs)?
Totally aligned with EU programs.	
Impact on investment policy	What were the effects of the roadmap/national programme/strategy on investment policy?
The impact of the climate strategy is reflected in the public incentives, which have in their purpose and goal the reduction of greenhouse gas emissions. Impact is also in efforts and financial resources (public and private) for investments in renewable energy sources. In addition, the promotion and awareness of the importance of circular models (industry and society) has increased, and there is more and more emphasis in the media on reducing dependence on fossil fuels, creating green jobs and improving the quality of life through less environmental pollution.	
Alignment on the international level	To what extent have roadmap been aligned with roadmaps in other countries or at EU/international level?
Full alignment of the national strategy with the EU strategies.	

Table 12: Profile of MLE Country Slovenia

Türkiye

Date of first development of the roadmap/national programme/strategy addressing the need of industry	When has the (first) roadmap/national programme/strategy been developed?
Türkiye has started its decarbonisation studies in July 2021, with the launch of European Green Deal Action Plan of Türkiye, under the coordination of the Ministry of Trade. Türkiye has realised its first Climate Council in the beginning of 2022. We have led the studies of Science and Technology Commission of the Council, whose technical outputs has acted as the inputs for technological objectives of Green Growth Technology Roadmap study. The mid-results of the roadmap study have also fed into the Türkiye's NDC which has also been presented to UN in April 2023.	
Coverage of sectors	Which sectors does the roadmap/national programme/strategy cover? Are links to other sectors (e.g. transport, energy, building)
Green Growth Technology Roadmap is comprised of individual technology roadmaps on Iron and Steel, Aluminum, Chemicals, Plastics, Cement, Fertilizers sectors.	

Link to the National Energy and Climate Plan (NECP)

What are the connections to the NECP? (Input, recommendations, same stakeholders etc.)

The Türkiye National Energy Plan was published in December, 2022 by the Ministry of Energy and Natural Resources. While there is no direct connection between the Green Growth Technology Roadmap (GGTR) and NECP, they are compatible in terms of hydrogen and renewable energy topics. NECP puts forth the objectives on the energy production and distribution sector, while GGTR presents objectives for energy use in industry.

The Climate Council draws the main framework for the Climate Mitigation and Adaptation Action Plan. Also, inputs from the Green Growth Technology Roadmap studies have been provided to the NDC efforts. The Ministry of Environment, Urbanisation and Climate Change of Türkiye prepares Türkiye's Climate Change and Adaptation Strategy, and inputs from TYH studies have been provided to this work.

In summary, GGTR have strong ties with the EU Green Deal efforts, climate change strategies and NDC of Türkiye for Paris Agreement.

Vision and milestones

Does the roadmap/national programme/strategy reveal explicit goals and milestones? (on the sectoral level? specific technologies, etc?)

In GGTR, technological objectives and critical products/technologies have been set for each industry included in the roadmap. In total, 31 technological objectives and 72 critical products and 189 RDI themes were defined for Iron and Steel, Aluminium, Chemicals, Plastics, Cement, Fertilizers sectors. Pioneering R&D and innovation-based solutions have been defined as objectives for the years 2026, 2030, and 2035 in line with our country's 2053 net zero emissions target and green development policy, in collaboration with all stakeholders in the ecosystem.

Scenarios, modelling and simulations

Does the roadmap/national programme/strategy use findings from quantitative modelling exercises?

At the beginning of the Technology Roadmap studies, critical production technologies and critical processes were identified with a product life cycle approach with Sectoral Focus Groups and online forms for industry to gather their technological needs. Technological needs have been identified by consolidating the most frequently mentioned needs. Technological solutions corresponding to the identified needs and objectives have been defined together by numerous joint meetings of Academic Advisory Groups and Sectoral Focus Groups. GGTR have technological objectives with specific progress towards technology readiness levels rather than emission reduction targets in defined sectors.

However, emission reduction targets have been defined in sectoral decarbonisation roadmaps prepared by The Ministry of Technology and Industry. These roadmaps, prepared so far for iron-steel, aluminium, cement and fertilizer industries, have been developed by utilizing quantitative emission data and reduction scenarios. The Green Growth Technology Roadmap reveals the technological solutions for the quantitative targets stated in these projects As TÜBİTAK, we have worked in cooperation with the team who prepared sectoral decarbonisation roadmaps within The Ministry of Technology and Industry.

Smart Specialisation	To what extent does the roadmap/national programme/strategy take into account regional specifics and strategies?
<p>The Green Growth Technology Roadmap of Türkiye does not take into account regional specifics and strategies. However, prominent companies and organisations are mentioned in the section on national/international practices.</p>	
Availability of resources	To what extent does the roadmap/national programme/strategy take in account the availability of resources (feedstock, energy, water, etc.)?
<p>The Green Growth Technology Roadmap of Türkiye does not explicitly take into account the availability of resources. However, the feasibility of technological solutions within the country has been taken into account implicitly because the technological solutions in various sectors are developed by experts from academia and industry. Nevertheless, feasibility studies are expected to be carried out in the future especially on big budget issues.</p> <p>In addition, The Green Growth Technology Roadmap includes experts' and academicians' views on the current situation and needs regarding the implementation of solutions identified in areas such as legislation, infrastructure, and human resources.</p>	
Cross-sectoral themes	How important are cross-sectoral themes?
<p>In the Green Growth Technology Roadmap, horizontal topics (energy, waste management, digital technologies - also called as enabling technologies) have been addressed separately for each sector. Overlapping issues such as (ammonia, hydrogen, etc.) are addressed specifically within the sector where their production takes place. Advanced studies are also planned to be conducted for the implementation of circular economy practices.</p>	
Quantification of funding and investment needs	<p>How were public and private investment needs quantified and defined?</p> <p>To what extent does the roadmap take into account business plans and financial parameters (e.g., Total cost of ownership, Return on investment)?</p>
<p>In the Green Growth Technology Roadmap, the investment needs have been defined by obtaining budget estimates from experts in private sector and academics; in technological objective or critical technology/product level. These estimates were differentiated for RDI expenditures and for investments on production facilities. The estimates were very rough, to get a glimpse on the order of magnitude for the investments for meeting the needs identified. More detailed estimates through various methods- including bottom-up analysis, sectoral modelling, and macroeconomic simulations- will be made during the preparation of implementation plans.</p> <p>Although The Green Growth Technology Roadmap of Türkiye recognises that private sector investment is critical to achieving the transition to a green economy and includes measures to encourage private sector investment through financial incentives, public-private partnerships, and other mechanisms; business plans and financial parameters are not explicitly reflected in the roadmap.</p> <p>It is presumed that while choosing or defining the technological solutions these parameters are reflected implicitly within the views of industrial experts. Further studies are needed to ensure the feasibility and sustainability of the proposed critical products and technologies during the preparation of implementation plans.</p>	

Industrial symbiosis	In which way does the roadmap/national programme/strategy consider industrial symbiosis?
<p>The Green Growth Technology Roadmap of Türkiye does not have direct objectives on industrial symbiosis. However, some of the identified technological solutions explain in detail the needs and pathways for industrial symbiosis.</p>	
Participation	Which stakeholder (industry, research, policy, etc.) were involved in the development of the roadmap/national programme/strategy and how were they mobilised?
<p>All stakeholders who will affect the green transformation processes -the private sector, non-governmental organisations, government, and academia- have been included in the Green Growth Technology Roadmap. These actors will be mobilised with various incentives and loans.</p> <p>The 'Technological Transformation/Development Specialisation Working Group', which is the main governance group for Green Growth Technology Roadmap, conducted its activities with the participation of 13 public institutions and 27 private sector umbrella representatives. The technological needs in the Iron-Steel, Aluminium, Cement, Chemicals, Plastics, and Fertilizer sectors were identified in 'Sectoral Focus Groups' established with 371 private sector representatives. Along with approximately 100 competent academics and researchers, technological solutions were created for the needs identified for the private sector's green transformation, through more than 60 meetings lasting 3 months.</p> <p>The stakeholder engagement and representation of ecosystem actors in technical and governance groups has been at the highest level.</p>	
Digitalisation	To what extent does the roadmap/national programme/strategy take into account support digital technologies, i.e., twin transition?
<p>Digital technologies also called as enabling technologies have been addressed separately for 6 industries. One dedicated objective has been set for iron-steel and aluminum industries, separately. In other sectors, the goals related to efficiency improvements have included the aspects of utilising digital technologies for green transformation.</p>	
Impact on R&D policy	What were the effects of the roadmap/national programme/strategy on R&D policy making on the national level? What were the effects to promote national priorities on the international level (e.g., alignment with EC programs)?
<p>The RDI themes defined in the roadmap will be included in the priority RDI themes for TÜBİTAK's support programs. In this context, a dedicated Industrial Innovation Networks Call has been published in the beginning of 2023, specifically on the technological needs identified for sectors in GGTR. Moreover, within the scope of the World Bank's "Turkey Green Industry" project, credit will also be provided in addition to R&D and innovation grants.</p>	

Impact on investment policy	What were the effects of the roadmap/national programme/strategy on investment policy?
<p>The Green Growth Technology Roadmap is the technological section of sectoral decarbonisation roadmaps prepared by the Ministry of Industry and Technology. Therefore, investment supports will also be shaped around the identified technological objectives, critical products and RDI themes in the GGTR.</p>	
Alignment on the international level	To what extent have roadmap been aligned with roadmaps in other countries or at EU/international level?
<p>Within the scope of EGD Action Plan of Türkiye, studies are being conducted for compliance with the legislation. The Green Growth Technology Roadmap of Turkey includes both BAT reference documents and emerging technologies.</p> <p>Türkiye has been working to align its policies and strategies with those of the European Union, particularly in the area of energy and climate change. Türkiye has implemented a number of policies and measures that are similar to those of the EU, such as energy efficiency standards and renewable energy targets. The Green Growth Technology Roadmap of Türkiye also highlights critical products and technologies needed in specific sectors to be compatible with European roadmaps.</p>	

Table 13: Profile of MLE Country Türkiye

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The first thematic report has been prepared in the context of the Mutual Learning Exercise on Industrial Decarbonisation involving 12 committed participating countries. The report gives an overview of roadmaps and strategies at national level focusing on industrial decarbonisation, along with the initial first ERA industrial technology roadmap on low-carbon technologies in energy-intensive industries of the Commission. After presenting selected key findings and proposed actions of the first ERA industrial technology roadmap, an overview of lessons learned from past roadmapping exercises at national level is given.

Studies and reports

