Mistra Carbon Exit
Programme Plan - Phase 2 (2021-2025)
Part A

1 March, 2021

Summary

The Mistra Carbon Exit (MCE) programme was formulated in response to Mistra's research call "*Transformative changes in society to achieve challenging climate goals*" and was approved for funding from Mistra with 56 million SEK in December 2016, starting in April 2017. In addition, some 30 organizations support the programme with 26 million SEK of in-kind funding.

The MCE programme addresses the technical, economic and political challenges facing Sweden in its efforts to reach the target of net-zero greenhouse gas emissions by Year 2045[1]. This target will require transformative pathways for virtually all industrial processes and their associated products and services. Mistra MCE adopts a novel approach to address this problem by focusing on opportunities and barriers related to mitigating carbon emissions along the industry supply chains: from the input of raw materials, through the primary and secondary activities, to the final products and services demanded by the end-user.

Phase 1 of MCE has shown this to be a successful approach, gathering together key Swedish industries with strong connections to the research activities of MCE. MCE covers the supply chains of *buildings*, *transportation infrastructure* and *transportation*. These selected supply chains allow the capture of at least 75%[2] of Sweden's CO_2 emissions.

By identifying pathways and policies, we aim to show how Sweden and Swedish companies can become frontrunners in transforming Society and industries, providing low-carbon products and services while at the same time addressing market risks. This will make Sweden an important international example for other countries to follow, from the technical, social and policy perspectives.

Our work in Phase 1 has identified the technical pathways, including initial assessments of the opportunities and the barriers for their implementation. We have identified and analyzed a set of policy instruments that can trigger these transformative changes, and we have started to understand for the factors that are crucial for the successful transition of the supply chains investigated. The work proposed in Phase 2 will allow us to focus on key areas related to technologies, governance, behaviors, and policies. We will continue our dialogue with authorities in Sweden and EU so as to provide them with timely inputs for climate policymaking. We will expand implementation by engaging our end-

[1] In line with the Swedish target of net-zero greenhouse gas emissions by Year 2045.
[2] This is an approximate value, based on the production-based emissions within the Swedish borders.

users in applied joint projects with researchers and practitioners. We will enhance integration between work packages and create the cross-disciplinary linkages.

In Phase 2, which will run from 2021 t0 2024, the programme will consist of four academic work packages: WP1, *Technology assessments for buildings, transport infrastructure and energy*; WP2, *Technology assessments for transportation*; WP3, *Governance and policy process*; and WP4, *Policy design options*. In addition, WP5, *Benefits to end-users - implementation, local arenas and integration* will provide various instruments for enhancing integration and implementation. A communication package serves to disseminate the programme results in the forms of publications, seminars, newsletters and media. We will place special emphasis on those parts of the EU's *Green Deal* that overlap with Sweden's climate priorities, for instance the EU ETS, carbon capture and storage, green public procurement, carbon border adjustments and renewable energy.

The MCE consortium involves a broad representation of researchers and actors, including four universities [Chalmers University of Technology (Chalmers), University of Gothenburg (GU), Gothenburg Centre for Sustainable Development (GMV), Linköping University, and the Royal Institute of Technology (KTH)], four research institutes (IVL Swedish Environmental Research Institute (programme host), Resources for the Future (RFF), The German Institute for Economic Research (DIW), and the Centre for European Policy Studies (CEPS)), and some 20 companies, authorities and non-governmental organizations.

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Blue-marked sections: addresses recommendations by evaluation panel

1 Vision, aims and expected effects

We are encouraged by the positive responses to MCE we have received from the stakeholders involved in the programme, as well as from other important actors in Society. Therefore, the overall vision (see box), aims, and expected effects of Phase 2 of the Mistra Carbon Exit (MCE) programme are basically the same as those for Phase 1 of MCE. This means that in Phase 2 of MCE, we will continue in the same principal direction as in Phase 1 while developing further the outcomes from the Phase 1 research.

The **vision** of the Mistra Carbon Exit programme is to demonstrate how the supply chains of buildings, infrastructure and transportation can be transformed to comply with the Swedish target of net zero greenhouse gas (GHG) emissions by the year 2045, addressing the technical, policy, economic and market opportunities as well as barriers in the transformation. Our vision is to provide insights and solutions for reducing the present Swedish GHG emissions to net zero emissions, by using effective policy instruments while promoting economic growth and innovations. It is clear that the changes need to be transformative on a scale that encompasses the whole of Society – small incremental changes in the right directions are not enough. Our vision is also that Sweden and Swedish companies will become frontrunners in transforming society and industries, providing low-carbon products and services, while at the same time addressing market risks and meeting the UN sustainable development goals.

1.1 Aims

The overarching aim of MCE is to develop societal and technological pathways for transformative change of the supply chains of buildings, transportation infrastructure and transportation - from inputs and raw materials, through primary and secondary activities, to the final products and services – so as to fulfil the Swedish target of net- zero GHG emissions by Year 2045.

We apply the concept of supply chains to provide a framework for understanding and analyzing the activities and flows of energy and materials involved in the supply of products and services to customers. The notion of supply chains here refers to the typically cross-sectoral networks of facilities and distribution channels that are involved in the sourcing and primary production of materials, as well as the further processing and assembly and delivery of the product or service to the customer (Mentzer et al., 2001). By focusing on supply chains, rather than individual economic sectors, we will be able to identify key challenges and mitigation opportunities from the primary production of materials to final end-uses and to identify the ideal conditions for collective actions among the actors along the supply chains. The involvement of different stakeholders – including industries involved in the production of basic materials, as well as various actors in the vehicle and building and construction industries and public agencies – will make it possible to identify and address in an innovative manner the range of perspectives as to how to improve effectively the overall performances and reduce the climate impacts of the respective supply chains.

Listed below are the specific aims for Phase 2 of MCE, which build on the aims of Phase 1 (see Progress Report), and an explanation on how they are adjusted for Phase 2. Detailed aims at the levels of work packages and tasks are given in the individual work packages. Compared to Phase 1, we will extend the implementation efforts to further stressing the dialogue and knowledge exchange with key decision-makers. Based on the results from Phase 1, we have formulated more explicit and focused aims in all the research areas, as given in each task description. We will put more emphasis on the EU Green Deal. Where relevant, we also aim to consider the effects of the COVID-19 pandemic, which obviously was not an issue when the Phase 1 aims were formulated. In this respect, we have added a task devoted to investigating the challenges and opportunities associated with Green economic recovery packages. In summary, the specific aims of MCE Phase 2 are:

- To develop further our understanding of how low-carbon supply chains in buildings and the transport infrastructure can be decarbonized – now at a more detailed level integrating technology, economics and different policy measures;
- To strengthen the implementation of the MCE results for actors along the value chains of buildings and the transport infrastructure. Our work in Phase 1 has revealed significant challenges to the implementation of the technologies and practices identified. Therefore, Phase 2 has the aims to increase the dialogue with stakeholders involved in the implementation, to identify barriers, and to propose how to overcome these problems. This will be achieved in part by means of "implementation projects" that engage end-users in co-productions with our academic teams. In addition, a scenario tool will be developed with the aim of enabling stakeholders to identify opportunities and potential competing goals and to understand the effects of policies and actions aimed at reducing emissions from the built environment;
- To refine the approaches as to how low-carbon supply chains in the transport sector can be realized by integrating technologies, economics and different policy instruments in the modeling work, as well as through stakeholder interactions. In addition, special emphasis will be placed on further analyzing the roles of self-driving vehicles and various sharing models;
- To analyze the impacts of potential policies on the demand for cars (and different types of cars), as well as the traveling distances with cars and other modes of passenger transport;
- To analyze proposals in the EU Green Deal that may overlap with Sweden's climate priorities, for instance EU ETS, carbon capture and storage, Green public procurement, and renewable energy;

- To investigate how the EU ETS can be improved to support a transition to a low-carbon economy, and to develop and analyze complementary policies to carbon pricing and understand how they can interact with the EU ETS. We will also investigate policy instruments that can target actors in the supply chain that are not directly covered by the EU ETS;
- To understand the conditions for efficient procurement from quantitative economic analysis of drivers and the barriers for climate-friendly public procurement, combined with qualitative case studies of experiences gained from implementing new procurement practices in the construction sector;
- To assess if and what ways private initiatives, such as buyers' coalitions and transformation funds, might allow actors along the supply chains for basic materials, such as steel and cement, to contribute collectively to securing financing and de-risking investments in low-, zero- or negative-emissions technologies;
- To continue to assess the value chain with respect to other (apart from climate) Sustainability Development Goals and to assess the challenges and enable conditions for just transformations toward climate neutrality;
- To maintain and strengthen further and expand the network between academia, industry, and governmental and non-governmental organizations that has been established in Phase 1, with the aim of serving as a platform for discussing and evaluating transformative pathways for key business sectors with the focus on buildings, infrastructure and transport systems;
- To develop further the MCE scientific community towards leadership in integrated supply chain analysis involving techno-economic, policy and business model analysis, i.e., to support the acceleration of the transformation of Swedish industry towards climate neutrality; and
- To continue to ensure broad communication of the programme results, including scientific dissemination and public and stakeholder outreach.

1.2 Expected effects

The main societal impacts from MCE Phase 2 are – similar to those of Phase 1 - expected to be the:

- Creation of a high level of awareness of the opportunities and barriers for the Swedish and international community to follow transformative pathways that can comply with the COP21 agreement and Swedish national emissions targets (SOU2016:47);
- Provision to decision makers in industry and governmental organizations of descriptions of net-zero technologies and practices along the supply chains from raw materials to services;
- Provision of assessments to governmental agencies and industry regarding the optimal combination of policies and measures to unlock and accelerate the transformation of the investigated supply chains, while minimizing the risk for industry;
- Continued refinement of MCE to foster unique knowledge exchange with key actors along the supply chain from raw materials to end-use products;
- To investigate how low-carbon business models can be incentivized, including through governmental support and regulation, and from procurement processes;
- Further establishment of MCE as the meeting place for knowledge exchange between academia, industry and governmental organizations, thereby contributing to the initialization of transformative pathways for key business sectors along the supply chains; and
- Enhancement of cross-sectoral studies in the international research community arising from the establishment of a scientific community and improved knowledge of integrated supply chain analysis involving techno-economic, policy, business and sustainability assessments that have impacts on national and international policies and industries.

2 Scientific value of the programme

The supply-chain perspective, rather than the normal sectoral approach, is in focus in MCE. This makes it possible to integrate a range of economic sectors into a single supply chain and envisage important cross-sectoral interactions within and between these chains. Here, supply chains refer to the typically cross-sectoral networks of facilities and distribution channels that facilitate the sourcing and primary production of materials, as well as the further processing and assembly and delivery of products or services to the customer (see, for example, Stevens (1990). The supply chain concept is tightly linked to the concept of the value chain, which focuses on the value creation and the margin that can be obtained from a certain supply-chain business (see original work of Porter, 1985 and Mentzer et al., 2001 and references therein). Activities along a value chain (and its corresponding supply chain) generate emissions, and if there is a cost associated with these emissions (e.g., as from the EU ETS), these must obviously be less than the profit margin of the value chain if the business is to be economically sustainable (*cf.* Porter and Reinhardt, 2007). Previous works by the authors and others (Allwood et al., 2011; Skelton and Allwood, 2013; Rootzén and Johnsson, 2016; 2017) have revealed that investing in new low-CO_2 steel-making and cement-making processes – despite the fact that these plants are associated with high upfront investments - has only a marginal effect on the overall costs – and thereby the price - facing the end-users of steel- or cement-containing products, provided that the costs are passed through to end-use products in a transparent way. The fact that deep mitigation measures will exert only a marginal effect on the overall costs at the end-user side calls for a cross-sectoral analysis along these value chains rather than analyses of individual sectors.

In Phase 1, we successfully applied a supply chain analysis to the *building* and *construction industry*, including a road construction work in which we quantified the activities and carbon emissions along the supply chain and the measures available to reach zero emissions from such construction work (Karlsson et al., 2020). We have shown that there is significant potential for reduction in carbon emissions using today's commercially available technologies and measures. Yet, such incremental measures are not sufficient to meet the targets of net-zero emissions, which require transformative technologies, such as the application of CCS technologies in the cement and refinery industries and hydrogen or CCS in the iron and steel industry. During Phase 1, the research on the *transport* supply chain had a dual focus on: (1) the supply chain characteristics for different technology solutions (primarily battery-based solutions) towards zero-GHG emissions; and (2) the use of vehicles with the focus on how self-driving cars and car sharing may influence car usage patterns. For example, even though the GHG emissions in the supply chain using electric cars may be substantial given current battery and electricity production processes, these can readily be abated using available technologies (see Section 2.2.1 in the Progress Report and Bauer et al, 2015, Knobloch, 2020). Furthermore, even though the new trends involving automation and the sharing of cars may confer substantial benefits in terms of more-energy-efficient travel and fewer cars servicing a greater traveling demand (ITF, 2020), there are serious concerns that these technologies and business models may very well cause extended urban sprawl, higher numbers of cars on the road, additional traveling, and lower occupancy rates than is currently the case (see Section 2.2.1. in the Progress Report and the papers of Schäfer & Yeh, 2020; Rebalski & Johansson, 2020). As pointed out by Papa & Ferreira (2018), research on how to realize the transport-efficient outcomes that automation and sharing can facilitate is needed. In Phase 2, we will continue to analyze the techno-economics of the supply chains of buildings, the transport infrastructure and the transport sector. Nonetheless, there will obviously not be a sufficient transformation of these supply chains without a sufficiently strong climate policy.

Climate policy has evolved significantly over time. The expansion of the neoclassical policy toolbox to include other types of policies can be seen both in policymaking in practice and in policy research in general (for a recent policy overview, see Meckling and Allan, 2020). The needs to address the challenge of decarbonization with careful design of policy packages, as well as acknowledge important aspects of policy processes such as policy acceptance (Matti, 2009), and the potential effect of climate leadership (see Section 3.3.2 in the Progress Report), are central to the policy and governance research in MCE. The preliminary results from Phase 1 clearly show that combinations of different policies are needed to strengthen carbon-pricing signals, address different technological development stages and types of abatement options, as well as to refine the decision modes of actors if the technologies needed to reach the 1.5°C target are going to be adopted (see Sections 3.4.2 and 3.4.3 in the Progress Report). Our ongoing research also indicates that governance and policy design that induce transformative changes need to adopt a supply chain perspective in designing complementary policy packages along the supply chain of buildings, infrastructure, and transport. In Phase 2, we will continue to study the extents to which complementary policy instruments should address other actors in the supply chain besides the actors already addressed by EU ETS. Achieving net-zero emissions across the supply chain also alters the landscape of policy design options. This suggests the value of a holistic policy design approach that addresses complementary polices along the supply chain. An example is road-pricing mechanisms. Despite its benefits, fully internalized road pricing remains a rarity, as the difficulties that limit the implementation of appropriate pricing mechanisms are not technical in nature, but political, being rarely adopted because the public or market actors do not support these policy measures. According to Dreyer et al (2015), policy makers should therefore carefully tailor their policy campaign strategies to maximize acceptance or support. In Phase 2, our research will therefore move towards measuring and understanding the acceptability by the public and market actors of stringent policy measures that may be introduced for transformative changes in transportation and building supply chains.

Climate leadership deserves attention because there are many examples where nations, firms and municipalities seek to decarbonize faster than the jurisdictions in which they operate. For instance, Sweden has more ambitious climate objectives than the EU and, therefore, needs to understand the implications of being a frontrunner and decide what positions the country should adopt *vis-à-vis* EU climate policymaking (Burtraw et al 2018). Firms see opportunities in being frontrunners with potentially higher market shares, although there are also risks associated with the uncertainty as to how climate policy will develop. Firms and policymakers are dependent upon each other and need to move in a somewhat synchronized way. Several municipalities in Sweden have climate targets that are more ambitious than those of Sweden as a whole. However, we have found that there are several challenges in practice, for instance split incentives within the municipality to decarbonize. In Phase 2, we will study the potential benefits and costs associated with climate leadership (WP3).

The supply-chain approach of MCE acknowledges **cross-sectoral involvement**, for which conditions have grown more favorable over time, with a high degree of consensus being achieved between different market actors on the necessity to meet climate targets (in accordance with the Paris Agreement). This is important, as reducing global GHG emissions is obviously a collective action problem (Ostrom, 2010), i.e., the costs of contributing are concentrated while the benefits are shared (for a general discussion on the preconditions for large-scale collective action, see Jagers et al., 2020). Different authors, such as Ostrom (2010), have claimed that such problems must be addressed at multiple scales and levels, i.e., following a polycentric approach. The results and experience from Phase 1 create a unique base of experience and starting point for the MCE consortium to analyze effectively the opportunities and barriers at different scales along the supply chain and to propose policy interventions for accelerating the transition towards carbon neutrality. As can be seen from the work package descriptions below, MCE spans several scientific disciplines and combines these in a transdisciplinary way, applying supply and value chain perspectives. We will analyze the technologies and mitigation measures for buildings and infrastructure (WP1) and transportation (WP2), the conditions for policies and policy implementation (WP3), including those for successful procurement, and finally we will propose how to re-design existing policies or suggest new policies or policy packages to drive forward deep cuts in emissions along the supply chain (WP4). Table 2 gives an overview of the work packages (WP1 etc.) with associated tasks (1.1 etc.) and lists the persons responsible for each task.

3 Benefits to society of the programme

The vision of MCE is to "*is to provide insights and solutions for reducing the present Swedish GHG emissions to net-zero emissions in Year 2045*" and we believe that we can have a real impact on Society, particularly for the supply chains covered by the programme. To achieve this, we are working closely with our end-users - policymakers in Sweden and internationally and industrial representatives - and for this purpose we have developed several activities:

Policy dialogue with Swedish authorities
The programme has had, since it started, an ongoing dialogue with Swedish authorities with the objective to have an impact on Swedish policymaking by providing timely reports and other types of decision-making support. For this purpose, we have made a special effort to monitor the climate policy agendas of Sweden and the EU. Our aim has been to produce relevant outputs at the right time and in the right format, so that our results feed into the decision-making processes both in Sweden and internationally.

Policy dialogue with EU institutions

With the new EU Commission in place since 2019, we have noted that central parts of the EU Commission's Green Deal overlap with what we study in MCE – for instance, in the areas of low-carbon roadmaps, CCS, carbon pricing, and public procurement. Consequently, we have intensified our exchange with the EU institutions, and we have written several policy briefs that have been communicated to the new EU Commission. (Engaging in a dialogue with EU institutions is important for several reasons. First, Sweden is dependent upon the EU and needs to understand how EU climate policy affects Sweden's possibilities to achieve our own climate objectives. Second, although it is a relatively small (population-wise) EU Member State, Sweden is seen as a progressive country in terms of climate action, and we are often invited to share our experiences with the EU institutions and other Member States.)

Participatory methodology with Swedish industry for the development of roadmaps
A participatory methodology has been used to assess the transformation of the transport infrastructure construction (Karlsson et al., 2020) and the building industry (ongoing work). The method is also partly used for analyzing energy carriers. The methodology (adapted from Rootzén and Johnsson, 2018) combines theoretical analysis and modeling work with stakeholder workshops.

We have created platforms for information exchange between researchers and end-users in the form of **seminars, workshops and monthly webinars**.

In Phase 2, these efforts will continue.

We will follow the recommendation by the Evaluation panel that "*Each task should bring its conclusions to bear on the implications for the Swedish industry, society and governance specifically, as well as understanding the implications of the global context with respect to the dependencies and risks of international markets for both exporting and importing materials.*". This will be done as part of our already ongoing dialogue and collaboration with industry and authorities (participatory methodology). It may be noted that each task explicitly describes the expected benefit to end-users. The international context is integrated in our tasks. For instance – the supply chain of Volvo is very global, and we analyze the implications of other countries climate action on Volvo. We also strengthen the international context through two dedicated efforts – Analyzing implications of the EU Green Deal (Task 3.9) and Post-Covid19 - Design for Green Recovery (Task 3.10).

4 Organization of the programme

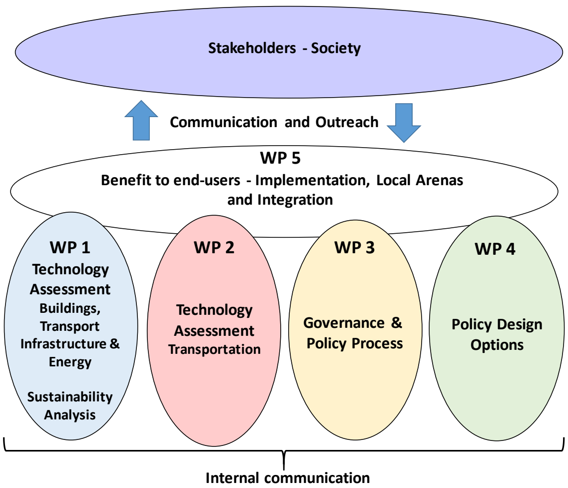


Figure 1. Structure of MCE Phase 2 with the five different WPs.

Figure 1 gives an overview of the structure of MCE Phase 2. The programme consists of four academic work packages: WP1, *Technology assessments for buildings, transport infrastructure and energy*; WP2, *Technology assessment, transportation*; WP3, *Governance and policy process*; and WP4, *Policy design options*. Informed by the wider governance and policy context in WP3, the focus of WP4 will be on identifying the policy design options needed to enable realization of transformative pathways along the supply chains. For this reason, WP3 and WP4 will be jointly managed. WP5, *Benefits to end-users - implementation, local arenas and integration* will provide various instruments and activities for enhancing integration and implementation. A communication package serves to disseminate programs results in the forms of publications, seminars, newsletters and media.

The Phase 2 programme will be managed with some minor changes based on the Phase 1 experiences. Thus, the following structure, illustrated in Figure 2, will be applied.

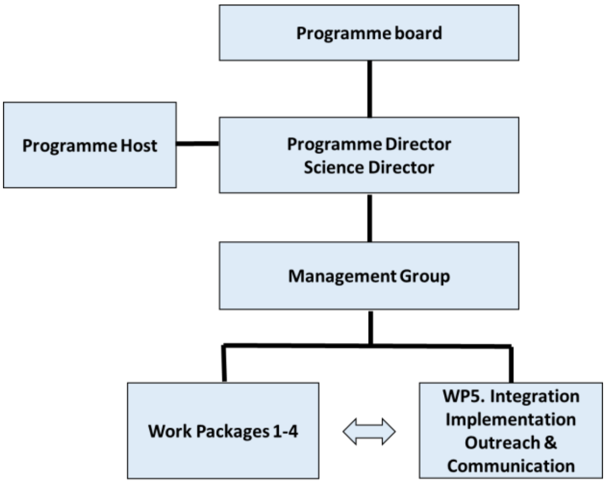


Figure 2. Management structure of MCE Phase 2.

Programme Board. The Programme Board is appointed by the programme host (IVL) in consultation with Mistra and will have overall responsibility for the programme. These responsibilities will include the adoption of strategies and budgets for the programme, the submission of annual plans and reports to Mistra, the making of decisions of strategic significance for the programme in collaboration with the management team (see below) and monitoring the research. The programme board also serves as an advisory board. In Phase 1, the Programme Board consists of the following six members: Peter Nygårds (Chair), Birgitta Resvik (Sameko Management), Stefan Nyström (The Swedish EPA - *Naturvårdsverket*), Anna Dennell (Vasakronan AB), Erik Eriksson (Formas), and Kristina Sundin Johnsson (Municipal Director – Skellefteå municipality). The Programme Board meets four times per year. We propose to continue with the same board members and meeting schedule in Phase 2. **Programme Host**. IVL Swedish Environmental Research Institute will act as the Programme Host. The responsibilities of the host include the administration of the funds awarded, the signing of contracts with all consortium partners, and the preparation and submission of administrative and communicative reports to Mistra. The **Programme director** is responsible for the coordination of the programme and for ensuring that the programme is fulfilling its objectives in terms of overall performance and deliverables, including programme administration and relations with the Programme Board and Mistra. The Programme Director is also responsible for the outreach activities. We propose Lars Zetterberg, who was Programme Director in Phase 1, to continue as Programme Director in Phase 2. The **Programme Assistant** supports the Programme Director with administrative responsibilities. **Scientific Director**. The Scientific Director is responsible for monitoring and enhancing the scientific progress of the programme, including organizing meetings and activities for scientific exchange and integration. The Scientific Director will replace the programme director when he is not available. For this position in Phase 2, we propose to appoint Filip Johnsson from Chalmers, who was Vice-Director of the programme in Phase 1. In Phase 2, the **Management Group** will consist of the Programme Director, the Scientific Leader, the Work Package Leaders (from Chalmers, GU and IVL), the Communications Officer, the Programme Assistant, and one representative each from KTH, LiU and GMV. The responsibilities of the Management Group will be to inform about the progress made in the work packages, to prepare the administrative and communicative reports to be submitted to Mistra, to take initiatives for improving exchanges between researchers and integration across the programme, and to plan outreach activities. such as seminars, conferences and publications. The Management Group members will also provide the Programme Director with input for the board meetings. The Management Group met 4–

5 times per year in Phase 1 and will follow a similar schedule in Phase 2. **Work package leaders** are responsible for executing the research in the work packages and will be senior scientists from the academic centers. We propose the following work package leaders for Phase 2: Filip Johnsson (WP1), Daniel Johnsson (WP2), Magnus Hennlock and Åsa Löfgren (joint coordinating leadership of WP3 and WP4), and Johan Rootzén (WP5). Lars Zetterberg and Filip Johnsson will be responsible for implementation and integration, and Helena Larsson (IVL) will be responsible for the communication activities.

5 Skills and networks

5.1 Academic partners

The MCE consortium involves a broad representation of researchers and actors, including four universities [Chalmers University of Technology (Chalmers), University of Gothenburg (GU), Linköping University, and the Royal Institute of Technology (KTH)], four research institutes (IVL Swedish Environmental Research Institute (programme host), Resources for the Future (RFF), The German Institute for Economic Research (DIW), and the Centre for European Policy Studies (CEPS)], and some 20 companies, authorities and non-governmental organizations. See Appendix A for detailed descriptions.

5.2 Non-academic partners

The external partners engaged in this programme represent a range of enterprises with production facilities and markets in Sweden and abroad, including vehicles (personal and freight), construction (components, buildings and infrastructure), and energy supply and distribution. Included are also national and local authorities, with strong engagements in, and responsibility for, future climate abatement measures and policy. Additional partners include organizations, NGOs, and think-tanks that are active in research, disseminating information and promoting action on climate and related issues. Together, these partners reflect a broad representation of societal actors engaged in the transformative change to a zero-emissions Sweden by Year 2050. We also aim to link new partners to the programme. The proposed partners for Phase 2 are:

Volvo Cars, Volvo Construction equipment, Cementa, JM, NCC, Skanska, Thomas Betong, A-Betong, PEAB, Skandiafastigheter, Outokumpu, Stena Metall, Voestalpine, Fortum, Energiforsk, Danske Bank, Swedish Transport Administration (*Trafikverket*), Swedish Environmental Protection Agency (*Naturvårdsverket*), VGR (West Sweden Region), Uppsala klimatprotokoll, Hagainitiativet, FORES, Byggvesta AB and Sweco. Appendix A lists these partners with their web pages for additional information.

Following the recommendation by the Evaluation panel to "*include more 'middle actors' along the respective supply chains*", we will expand the consortium to include the consultant Sweco, the housing company Riksbyggen and the architect company White (to be confirmed). We plan to include more middle actors in our interview studies, that is in addition to our partners in the consortium.

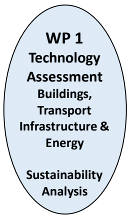
6 Descriptions of work packages, deliverables and expected benefits

Table 6.1. List of tasks in Phase 2

WP1. Technology Assessment, Buildings, Transport infrastructure & Energy	**Lead: Filip Johnsson (ET)**
1.1. Low-carbon supply chains in buildings and transport infrastructure construction	Ida Karlsson
1.2. Material use in the low-carbon transition	Johan Rootzén
1.3. Sectoral collaboration - system and sector perspectives	Lisa Göransson
1.4. Implementation - buildings and transport infrastructure	Filip Johnsson

1.5. Implementation – buildings and transport infrastructure in Uppsala	Stina Stenqvist
1.6. Sectoral collaboration -the end-use perspective	Lisa Göransson
1.7. Supply chain-specific sustainability indicators for stakeholder engagement and transparency	Anders Ahlbäck
WP2. Technology assessment, transportation	**Lead: Daniel Johansson (FRT)**
2.1. Synthesis: Integrated modeling of travel and supply-chain consequences of different policies, consumer behaviors, and technologies	Daniel Johansson
2.2. Climate impacts of different electrification and biofuel mixes	Julia Hansson
2.3. The role of different transport fuels	Julia Hansson
2.4. Vehicle lifetime in different mobility solutions	Johannes Morfeldt
2.5. Implementation - battery turnover and its implications	Johannes Morfeldt
2.6. Supply-chain impact analysis of electrifying Swedish on-road transport with electric road systems	Sonia Yeh
2.7. Large-scale application of vehicle sharing: implications for travel volume and supply chains	Sonia Yeh
2.8. Future scenarios based on different use cases and stakeholder perspectives	Ella Rebalski
WP3. Governance and policy processes	**Leads: M Hennlock (IVL) and Å Löfgren (GU)**
3.1. Determinants of climate leadership	Kajsa-Stina Benulic
3.2. Public acceptance of road tax reforms for electrification of the Swedish vehicle fleet	Magnus Hennlock
3.3. The value of being a frontrunner	Thomas Sterner
3.4. Leadership and policy diffusion	Dallas Burtraw
3.5. On the effects of Consensus on Climate Policy	Jessica Coria
3.6. Governance, capabilities and incentives to enhance climate-friendly public procurement in the construction sector	Anna Kadefors
3.7. Funding of large, transformative investments	Filip Johnsson
3.8. Quantitative assessment of the effect of public procurement	Olga Chiapinelli
3.9. Implementation - policy dialogue in Sweden and the EU	Lars Zetterberg
3.10. Post-COVID-19 – design for Green recovery	Victoria Wibeck
WP4. Policy design options	**Leads: M Hennlock (IVL) and Å Löfgren (GU)**
4.1. Price-based and informative instruments for transformative changes	Magnus Hennlock
4.2. Carbon pricing and coordination of investments	Åsa Löfgren
4.3. Flexible performance standards	Åsa Löfgren
4.4. Designing the EU ETS to accommodate companion policies	Lars Zetterberg
4.5. Analytical assessment of policy packages for industrial decarbonization	Karsten Neuhoff
4.6. Policy packages and risk in hard-to-abate sectors	Åsa Löfgren
4.7. Trade and climate policy: Border Carbon Adjustments and alternatives	Karsten Neuhoff
4.8. Designing policies for negative emissions	Lars Zetterberg
4.9. Understanding Electric Vehicle adoption – the cases of local and national policies	Magnus Hennlock
4.10. Implementation – parking as a policy instrument in VGR	Anders Roth
WP5. Benefits to end-users - implementation, local arenas and integration	**Lead: Johan Rootzén (GU)**
5.1 Enhancing implementation among end-users	Management Group
5.2 Implementation projects (Tasks 1.4, 1.5, 2.5, 3.9, 4.10)	(See tasks)
5.3 Arrangements for collaboration, integration and synthesis	Management Group

6.1 WP1 Technology assessment, buildings, transport infrastructure and energy



Building on the technical roadmaps developed during Phase 1 (Karlsson et al., 2020a; 2020b, Toktarova et al., 2020), this WP will assess how the integration of new, low-CO_2 technologies and practices along the supply chains of buildings, transport infrastructure and energy may best be managed, and how the coupling between sectors can be set up so as to maximize synergies, minimize systems costs, and ensure sustainable use of scarce materials and renewable energy resources. The objective is also to translate the findings from Phase 1 and from the continuing work in Phase 2 into actionable recommendations that can have an impact already today, and to provide a methodological framework for how to assess how the supply-chain climate transitions in relation to the sustainable development goals (SDG).

Task 1.1. Low-carbon supply chains in buildings and transport infrastructure construction

Aim: While the first phase of the research programme developed a series of technical roadmaps for the development of material and energy flows and the associated GHG emissions, the second phase will refine the analysis to include both technical and non-technical constraints that are specific to building construction respectively infrastructure construction, to derive costs and to identify different strategic choices along the roadmaps towards zero emissions. Whereas the technical measures and their costs are largely known (Karlsson et al. 2020a; Karlsson et al., 2020b), the barriers to their implementation are less clear, although they certainly involve a wide range of different aspects including, for example, organizational constraints, inadequate communication between actors in the supply chain, overly conservative norms and lack of information.

One of the key messages from the work focused on the buildings and transport infrastructure in Phase 1 of the research programme is the importance of, on the one hand, not allowing the pursuit of 'low-hanging fruits' (e.g., material efficiency measures) become an excuse for not acting to lay the foundation for the high-cost, long lead-time measures (zero-CO_2 basic materials) that will be required for decarbonization, and, on the other hand, not letting the promise of, for example, low-CO_2 steel or cement be an excuse for not acting to unlock the potential of measures that that already exist today. Successful decarbonization of the supply chains for buildings and infrastructure, including the production of basic materials, will involve the pursuit – in parallel – of emission abatement measures with very different characteristics.

Method and activities: With the technical roadmaps developed in Phase 1 forming the basis for the work, we will continue to analyze how different technological and strategic choices can contribute to reducing GHG emissions related to buildings and transport infrastructure construction. We will perform our materials and energy flow analysis (Karlsson et al. 2020a) in dialogue with actors in industry and governmental organizations. Together with other researchers in the programme, we will feed into the research related to climate policy (WP3 and WP4) that targets the construction sector. This includes, for example, research on procurement (Tasks 3.6 and 3.8), which is regarded by many as a powerful tool in the transformation of building and construction processes but which to date has had a limited effect on transforming construction work towards a reduced climate impact. There is also a need to find ways to facilitate risk sharing and funding in the early phases of the development and implementation, and we will provide information and knowledge on the potential importance of other policies and support mechanisms (which will be further analyzed in WP 4). We will also continue to analyze the cost implications from the supply-chain perspective. Emphasis will be placed on the production, supply and use of the four categories of materials/activities that account for the majority of the GHG emissions associated with most construction projects: Concrete (mainly due to CO_2 emissions from the cement clinker production); Steel (reinforcement steel and construction steel); Heavy transports; and Construction machinery. This work will include the role of low-CO_2 electricity in the decarbonization of these materials and activities (which will be dealt with in Task 1.3).

However, although infrastructure and building construction obviously have much in common when it comes to work practices, equipment used, and key materials and products – concrete and steel in particular – there are also important differences with respect to the possibilities for materials substitution and practices. Thus, in Phase 2, attention will be given both to emissions reduction measures of a general character and to measures that tend to be specific to building construction respectively infrastructure construction. Thus, we foresee the following Subtasks in the Phase 2 work:

- **Subtask 1**. To perform an analysis that matches specific technology solutions with short-term and long-term goals, so as to identify key decision points and potential synergies, competing goals, and possible lock-in effects. This will include analyses of opportunities and challenges related to increased wood construction, which has not been covered in depth in Phase 1.
- **Subtask 2**. To analyze and identify the risks associated with the transformation, to identify who will carry the risks associated with different abatement measures, and to propose how these risks can be minimized and/or shared.
- **Subtask 3**. To identify robust approaches to measuring carbon performance and carbon neutrality on a project level. This is important in order to facilitate a carbon accounting code of conduct – including biogenic and avoided/delayed emissions. This will be carried out in co-operation with stakeholders and will build on previous proposals linked to Environmental Performance Declarations (EPDs).
- **Subtask 4**. To develop and propose a framework for analysis of the supply chain and end-user abatement cost implications – taking into account the costs linked to material substitution and material efficiency measures. This will build on previous work conducted by Rootzén and Johnsson (2016, 2017) for cement and steel, as well as on the value chain analysis of road construction work (Karlsson et al., 2020a, 2020b) and of buildings (ongoing).

The analysis work will combine quantitative analysis methods, including scenarios analysis and stylized models, with participatory processes involving relevant stakeholders in the assessment process, so as to identify and analyze the measures, policies and key decision points required to achieve net-zero emissions. Thus, we will build on and expand the methodology developed in Phase 1 in connection with the case study on the Road 44 project by the Swedish Transport Administration (STA) by Karlsson et al. (2020a; 2020b). The work will be carried out as the second part of the PhD work of Ida Karlsson, in co-operation with Task 1.4 as well as with Task 1.5, with the focus on interacting with practical initiatives.

Expected deliverables: We expect to publish two or three peer-reviewed journal papers, which together with the journal papers from Phase 1 will form the PhD thesis work of Ida Karlsson. Thus, one qualified PhD will result from this task. **Benefit to end-users**: We foresee important outputs to and interactions with industry, including providing important knowledge to projects conducted by STA. In particular, we will contribute to the so-called “Ostlänken”, in response to a request from STA. Our work with the Road 44 STA project in Phase 1 has received significant attention from a wide range of actors, including those representing two of the Swedish Roadmaps within Fossil Free Sweden (the Building and Construction industry and the Concrete industry). The implementation work will be carried out with the help of Tasks 1.4 and 1.5.

Task 1.2 Material use in a low-carbon transition

Aim: To contribute, in communication with stakeholders in industry and governmental agencies including the Swedish Environmental Protection Agency (EPA) and the Swedish National Board of Housing, Building and Planning (NBHBP), to developing scenario tools that will enable stakeholders to identify opportunities and potential competing goals and understand the effects of policies and actions aimed at reducing emissions from the built environment.

From Phase 1 of the research programme, it is clear that there are still significant deficiencies in the methods used to assess the climate impact from construction. Recent estimates of the climate impact from building and transport infrastructure construction in Sweden range from approximately 8–13 MtCO_2/year (for Year 2015) (Karlsson et al. 2020c). The Swedish EPA and the NBHBP, both of which have been actively involved in Phase 1, have together initiated a process to improve the methods used to assess the future development of emissions from the construction and real estate sectors. Thus, we will work in close co-operation with these organizations to develop and apply the tool to determine embodied emissions in construction work and evaluate how these can be expected to decrease under different scenario assumptions.

Method and activities: Emphasis will be placed on the embodied emissions associated with the supply of building materials used to sustain and improve basic services such as housing, transport infrastructure, water and sanitation. The work will be carried out iteratively in two subtasks-

- **Subtask 1, Model development:** We will employ bottom-up stock model tracking of material flows and related GHG emissions along the supply chain related to building and infrastructure construction in Sweden. The work is based on a first model that has been developed during Phase 1 of the programme (Karlsson et al., 2020a; 2020b) to explore how material use and embedded carbon (related to building and infrastructure construction) change over time given different strategic choices. The model describes material use per functional unit (per m^2 or km^2) from new construction in relation to category (building or infrastructure), type (e.g., residential, non-residential, road, railways, tunnels and bridges), sub-type (e.g., multi-family/single family, industrial/commercial, road class, etc.) and frame/shell type (e.g., concrete, steel or cross-laminated wood). In Phase 2, the model will be further developed to provide a more detailed representation of the material flows and associated costs and GHG emissions, as well as to make the modeling more easy to use, with clear and transparent representation of the results, which can form a solid basis for Subtask 2 below.
- **Subtask 2, Scenario analysis**: Future demand in the construction industry is dependent upon a number of interconnected variables. Here, we will utilize the model developed in Subtask 1 to carry out a scenario analysis that explores how changes in key variables (e.g., rate and type of new construction and rate and type of renovation) affects material use and embedded GHG emissions over time.

The work will be carried out by a new PhD student, with co-supervision from Chalmers and IVL. The task work will be synced with the work carried out in Task 2.6 and the method development will be carried out in cooperation with the academic partners in WP2.

Expected deliverables: Two or three peer-reviewed journal publications and a licentiate exam for the new PhD position. We hope that the PhD student can be hired to start directly when Phase 2 starts and, if so, the work in Phase 2 should cover a large share of the PhD programme. **Benefit to end-users**: The ambition is to develop a scenario tool that will enable stakeholders to identify opportunities and potential competing goals and understand the effects of policies and actions aimed at reducing emissions from the built environment. The tool will relate to existing tools, such as *Klimatkalkyl* used by the STA.

Task 1.3. Sectorial collaboration on electricity - system and sector perspectives

Aim: To investigate the preconditions for sustainable electrification with focus on the steel and cement industry and road transportation.

In the roadmaps that illustrate possible ways of decarbonizing the supply chains of buildings, roads and transportation, electricity as the energy carrier has been put forward as one important option. Electrification challenges the electricity supply side by requiring that higher levels of carbon-neutral generation capacity be installed. However, electrification of industry, heat and transportation may also offer flexibility to the electricity system, thereby supporting the integration of wind and solar power.

In Phase 1, it was found that a strategic collaboration between the electricity system, an electrified steel industry, and an electrified transport sector in the form of passenger EVs and residential heat supply could reduce the total system cost by 8% in the north European electricity system, as compared to a situation without such a collaboration. Flexibility provision by new electricity consumers enables a faster transition from fossil fuels in the European electricity system and reduces thermal generation. From a sector perspective, strategic consumption of electricity for hydrogen production and EV charging and discharging to the grid reduces the number of hours with very high electricity prices, resulting in a reduction in annual electricity prices of up to 20%.

Method and activities: In Phase 2, we will further refine this work by means of advanced energy systems modeling, thereby further developing these models. We will focus on the following subtasks:

- **Subtask 1**. Investigations of how electricity, hot briquette iron (HBI), and hydrogen can be used as parallel energy carriers in the steel industry to provide flexibility of electricity consumption, temporally as well as geographically. Here, we will include the option of Swedish export of HBI, i.e., a more extensively refined product than the normally exported pelletized iron ore.
- **Subtask 2**. Investigation of the role and potential flexibility of electricity-based heat in the cement industry, i.e., how and when in time electricity could provide high-temperature (by means of plasma) heat to the cement process, including assessments of the possibilities for heat storage and alternative fuel options.
- **Subtask 3**. Investigation of likely electricity consumption profiles in scenarios that assume shared autonomous passenger vehicles. This will be carried out in connection with the work on transportation (Task 2.1).
- **Subtask 4**. Assessment and evaluation of electricity-based hydrogen (EVs with fuel cells) and electric roads systems (for EVs) for heavy transportation. This builds on work already carried out in Phase 1. In Phase 2, we will refine the analysis and include spatial dimensions (i.e., electric road systems will use significantly less electricity than hydrogen, whereas hydrogen-powered vehicles will not be dependent upon a new road infrastructure, but rather upon hydrogen filling stations, and will consume more electricity – assuming that the hydrogen is generated from electricity).

Expected deliverables: Two or three peer-reviewed journal papers, which together with the journal papers from Phase 1 will form the PhD thesis work of Alla Toktarova. Thus, one qualified PhD researcher will result from this task. **Benefit to end-users**: The ambition is to continue the dialogue with key industries within the focus of these activities, i.e., the electricity industry (e.g., Vattenfall), steel and cement industries, and the automotive industry.

Task 1.4. Implementation – buildings and transport infrastructure

Aim: To strengthen the implementation of the MCE project results along the value chains of the buildings and transport infrastructure.

The participatory inventory work performed in the first phase of the research programme has resulted in a better understanding of the key opportunities and the challenges and knowledge gaps that need to be overcome to meet the goal of net-zero GHG emissions from the construction sector by Year 2045. However, given the organizational complexity and the wide range of carbon abatement measures that could be applied within infrastructure construction projects, it may be difficult for project members or teams to obtain an overview of the full range of opportunities and their effects and how each could be part of an overall mitigation portfolio. Increased knowledge of the entire construction process and an understanding that changes in one part of the supply chain can have consequences, which in turn can pose challenges and require adjustments for other actors, are required. The goal of this task is to translate the findings from Phase 1 and from the Phase 2 Tasks 1.1 and 1.2 into actionable guidelines and recommendations that will support practitioners who are seeking to lower the climate impact from infrastructure construction projects.

Method and activities: This work aligns with the work in Tasks 1.1 and 1.2 and feeds into existing forums and processes, including for example *Anläggningsforum* (a forum for collaboration and knowledge sharing between actors involved in infrastructure construction under the auspices of the Swedish Transport Authority (STA) and the continued implementation of the Swedish construction and civil engineering sector Roadmap for fossil-free competitiveness). The work will be carried out by a team of MCE researchers and experienced consultants with whom we already in Phase 1 have started to co-operate with respect to identifying barriers for implementing the measures and technologies analyzed in Phase 1.

In terms of execution, this task will be a continuous process along the entire duration of Phase 2, and will be linked to the above-listed subtasks under Task 1.1, and also those under Tasks 1.2 and 1.3.

Expected deliverables: This task will present the results from Tasks 1.1, 1.2 and 1.3 in key forums and projects within the construction industry (and implementation results will be delivered as different publications in Tasks 1.1. and 1.2). **Benefit to end-users**: The outcomes from this task should be of benefit to practitioners along the value chain of buildings and construction infrastructure. It is obvious from Phase 1 that an iterative strategy between research and implementation will be needed to advance the knowledge as to how to reduce emissions from the construction industry.

Task 1.5. Implementation – buildings and transport infrastructure in Uppsala

Aim: This task will translate the findings from Local Arena Uppsala in Phase 1 and from the continued work in Tasks 1.1 and 1.2 into Science-based recommendations that can be turned into practice by cities. It will also generate feedback for the continued analysis work.

In Sweden, cities have often had more ambitious climate targets than the Swedish national target. For instance, some cities, among them Uppsala, has signed a declaration of intent to become climate-neutral by Year 2030. In Phase 1, we worked with Uppsala and the Uppsala Climate Protocol (a local climate agreement between the private and public sector) to test MCE's transformative solutions for building construction in a city context. The goal was to influence the municipality's work and thereby generate concrete results in terms of reduced carbon dioxide emissions. MCE's roadmap for building construction was adapted to the local context, and the stakeholder prerequisites and Science-based recommendations were developed as the basis for the municipality's work on an action plan (*färdplan*) for the climate. We also gathered practical experiences as inputs to the research. The aim of this task in Phase 2 (similar to Task 1.4) is to continue to develop further this process for the exchange of analytical and practical experiences. We will continue to work with the building construction process to find solutions for the problems encountered in the business models, working methods, and local regulations. We will also produce an action plan for the municipality's work on emissions from the transport infrastructure and construction sector. Finally, we will customize the working method so that it can be used by other municipalities to spread the knowledge and working method. This work also feeds into our work on procurement in Tasks 4.6 and 4.8.

Method and activities: The roadmaps developed in MCE will provide the basis for recommendations as to the implementation of different measures. Through workshops and/or in-depth interviews with the municipality and stakeholders, we will map out how they work today and what obstacles and opportunities exist to implement the changes. Based on this, we will develop an action plan to overcome the obstacles and exploit the opportunities.

Expected deliverables: The working method and the experiences gained will be published in a report, and the knowledge will be disseminated through a workshop series. **Benefit to end-users:** The objective is to inform the municipality's work to transform to net negative emissions with science-based recommendations that can be turned into practice. An area of attention will be Uppsala's new large district in the south-eastern part of the city. We will also disseminate to other municipalities the working methods and the knowledge gained.

Task 1.6. Sectoral collaboration on electricity - the end-use perspective

Aim: To identify and quantify drivers and barriers for electrification in industry and transportation from the end-use perspective.

This work will follow up the academic work in Task 1.3 by investigating electrification from the user perspective. In bilateral talks with industry and stakeholders, we will identify the drivers and barriers for sustainable electrification. In Phase 1, initial talks on the future electricity system were held with industry partners Voestalpine and Volvo Cars. Both challenges (e.g., the amount of electricity required for steel production) and opportunities (e.g., to apply smart charging strategies for increasing the value of wind and solar power) were identified in these talks. This work will also be coordinated with the North European Energy Perspectives Project (NEPP) hosted by Energiforsk. Thus, this task will benefit from the long-time cooperation with Energiforsk and its associated network of market actors in the area of energy.

Method and activities: We will use the results obtained from energy systems modeling to identify the potentials and limitations related to the flexible end-use of electricity. We plan the following subtasks:

- **Subtask 1**. To investigate the *potentials* and *limitations* related to flexibility in electricity consumption on the end-use side.
- **Subtask 2**. To assess the *potential costs and efforts* required from end-users to attain different levels of flexibility.
- **Subtask 3**. To investigate the impact of the flexibility on the price and sustainability of the electricity consumed, i.e., the *potential benefits*.

In Phase 2, we will incorporate the results from the dialogues in the academic work to create an iterative work flow between academia and industry in Subtask 1, further improving the discussions in Subtasks 2 and 3. The aim of this work is to identify what is required to create sector coupling in practice, i.e., to exploit the potential from sector coupling, as identified in the academic modeling work.

Task 1.7. Supply chain-specific sustainability indicators for stakeholder engagement and transparency

The experience gained from the SDG impact assessments carried out in Phase 1 indicates that using an open-ended qualitative approach to synthesizing expert opinion is a credible starting point towards identifying impacts on the SDGs from the MCE pathways. The results indicate that relevant SDG impacts are spread across the supply chain as both direct consequences of the net-zero GHG emission target and indirect spillovers internationally. Thus, achieving *sustainable* mitigation of GHGs will require communication and cooperation across supply chains, based on transparent, objective and comprehensible information.

Aim: Introducing supply chain-specific indicators through stakeholder involvement would serve three main purposes: 1) providing transparent and systemic representations of SDG impacts; 2) creating quantitative elements as complements to the qualitative analysis developed in Phase 1; and 3) pinpointing potential target conflicts and synergies with corresponding actor dependencies. The tool and methodology developed in Phase 1 will be further refined to take into account the supply chain perspectives of the MCE pathways, with greater possibilities for stakeholder input and relevance. The indicators as such will be based on the following criteria:

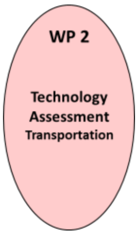
- *Relevant and specific*, i.e., able to track relevant sustainability aspects of supply chains.
- *Quantifiable and comparable*, i.e., based on existing data and an expressed magnitude of impact.
- *Useable*, i.e., comprehensible and operative in real-world usage.

Method: The derivation of sustainability performance indicators (SPIs) will be based on the following activities:

i. *Literature overview* – indicators of sustainable performance have been used elsewhere, although very few have been based on the Agenda 2030 framework. What experience can we learn and take inspiration from?
ii. *Dataset inventory* – mapping of available data to suggested SPIs, such as the UN official SDG indicators, SDG Index (SDSN), SCB and relevant industry.
iii. *Stakeholder involvement* – suggested SPIs will be tested together with the stakeholders from industry and society represented in the MCE programme. The aim is to examine the relevance and usability of the SPIs.

Expected deliverables*:* SPIs specific for each of the MCE pathway-associated key elements (solar PV, wind power, EV batteries, and climate-neutral concrete) and refined SDG Impact Assessments based on developed SPIs. **Benefit to end-users:** Streamlining the SDG analysis with SPIs will provide a tangible approach to improving and quantifying the SDG analyses for solar PV, wind power, EV batteries, and carbon-neutral concrete, ensuring a high level of usability for industrial and societal actors.

6.2 WP2 Technology assessment, transportation



In Phase 1, we developed a vehicle stock turnover model that is able to capture the demand response and supply chain impacts of different car technology options, as well as analyze existing transport characteristics regarding occupancy rate. In other parts of the programme we have analyzed how Connected and Autonomous Vehicles (CAVs) can affect the transport system, as well as different policy approaches for the transition towards net-zero GHG emissions, such as subsidies for EVs and parking policies. To move this research forward, we we want to combine insights from Phase 1 and from the research in other WPs in Phase 2 to develop a more coherent picture. More specifically, we will focus on the:

1. Complexities in the supply chain and material turnover for the transport system and its relationships to: 1) the climate impacts of different technologies and policy options; and 2) energy markets (Tasks 2.1–2.5);
2. Analysis of the travel volume and supply chain consequences of: 1) different policy options designed for enabling a transition to zero GHG emissions; 2) different behavioral trends regarding shared mobility; and 3) technology pathways that focus on electrification and CAVs (Tasks 2.7 and 2.8); and
3. Synthesis of the insights using an integrated modeling approach (Task 2.1).

Central to much of the work in this WP are the interactions with industry and governmental agencies. Stakeholder knowledge is critical for making the research both excellent in terms of quality and relevant for Society at large. In particular, we will seek cooperation with our programme stakeholders for Task 2.1 (Swedish EPA, Swedish Transport Administration, and Volvo Cars), Task 2.2 (Swedish EPA), Task 2.3 (Volvo Cars and Polestar), Task 2.4 (Volvo Cars and Stena Metall), Task 2.5 (Volvo Cars, Polestar, and Stena Metall), Task 2.6 (Volvo Cars and Polestar), Task 2.7 (Swedish EPA), and Task 2.1 (Swedish EPA, Volvo Cars and Polestar).

Task 2.1. Synthesis: integrated modeling of travel and supply chain consequences of different policies, consumer behaviors, and technologies

Aim: In this task, we will integrate and synthesize the insights obtained during Phase 1 and in the other tasks of this WP, as well as relevant research in other WPs, to enhance our understanding of supply chain consequences (with the focus on energy and GHG impacts) and the travel volume consequences of different pathways towards a passenger transport system with net-zero GHG emissions. In particular, in this context, we want to focus on issues related to the electrification of passenger cars, the introduction of CAVs, and various sharing models.

Method: In order to use the vehicle stock turnover model developed in Phase 1 for analyzing the impacts of different technology options and policy instruments (for example, vehicle-km taxes, bonus-malus) on vehicle stock turnover, travel distances etc., the interactions between different modes and consumer preferences need to be considered explicitly (and not treated as largely exogenous factors, as in the existing version of the vehicle stock model). Thus, a nested structure for the choice of having an individual car or not and the choice of mode for a given trip will be implemented. The calibration of these choice functions will be developed with insights from existing Swedish as well as international vehicle and modal choice models (Beser Hugossona et al, 2016). The international literature will provide additional inputs regarding the calibration of choice function when CAVs, as well as plausible sharing models are potential alternatives (Haboucha et al, 2017). Insights gained from Tasks 2.7 and 2.8 will also be critical for this modeling step. The mode choice model has to be dealt with in an aggregated way based on a suitable regional aggregation for the model, similar to, for example, the work of Kröger et al (2019). The aggregation approach will be based on insights from Task 2.7 and from related model developments in the EU Horizon 2020 project NAVIGATE. The uncertainties regarding consumer preferences are substantial, and we will approach this by careful and detailed sensitivity analyses using a scenario approach and/or a Monte Carlo approach. The potential policies that would be relevant to analyze will be developed together with key stakeholders involved in MCE, as well as together with the findings from Tasks 2.8, 3.2, 3.9, 4.2, and 4.10. Tasks 2.2–2.6 will provide crucial knowledge for an appropriate analysis of the supply chain consequences.

Planned Deliverables: One or two research papers. **Benefit to end-users**: The model output and insights obtained should be useful for Swedish governmental agencies, such as The Swedish EPA and Swedish Transport Administration, both for the development of travel scenarios and analyses of policy instruments.

Task 2.2. Climate impacts of different electrification and biofuel mixes

Aim: Building on the scenario work performed in Phase 1, the future climate impact of Swedish car travel will be analyzed for scenarios in which the path to climate neutrality goes through electrification and biofuel use, to varying degrees.

Method: Emissions from the production and use of cars (based on the results from Phase 1 and Task 2.4) will be further analyzed and assessed from a climate impact perspective. In order to characterize accurately the climate impact of biofuels and the impact on the carbon stock in the forest, we will move beyond simple assumptions related to the climate impact of biofuels and utilize a carbon cycle model, as well as a simple climate model to estimate the impacts of different strategies directed towards net-zero GHG emissions. The assessment will clarify how car travel propelled with different types of energy carriers affects global warming across different time horizons, and how global warming depends on whether CO_2 emissions originate from fossil fuels or biofuels. **Benefit to end-users**: The findings will be related to current accounting approaches to emissions and emission removals used within the UNFCCC and the EU, to reveal potential discrepancies. The task aims to provide advice on the assessment of the climate impact of using forest biofuels and to provide a framework for assessing that impact in relation to the GHG emissions generated during the production and use of batteries for electric cars. This task will be initiated already in Autumn 2020 in order to create a dialogue and influence public inquiry regarding the phase-out of fossil fuels and the imposition of a ban on selling new gasoline- and diesel-powered cars (*Utredning om utfasning av fossila drivmedel och förbud mot försäljning av nya bensin- och dieseldrivna bilar*; M 2019:04), in which the vehicle stock model developed in Phase 1 will be used for the impact assessment of potential policies.

Planned Deliverables: One to two research papers, seminars with stakeholders and governmental agencies.

Task 2.3. – The role of different transport fuels

Aim: In order to provide decision-making support for the transport industry, we will assess and compare the total costs of different transport fuel chains, considering in particular "drop-in" forest-based biofuels, electrofuels, and fuels that require a dedicated distribution infrastructure (including the costs for production, distribution and vehicles).

Method: Cost estimates for fuel production, distribution, and vehicles for the included transport fuel chains will be mapped and updated. The combined costs for the different pathways will be compared. The scenario work performed in Phase 1 will be considered in this assessment. This work will indicate the roles that different fuels may play in the future energy system when considering a broader cost perspective that is relevant for the transport industry, policymakers, and Society as a whole. This work will build on an ongoing project assessing the climate impacts and costs of different biofuel pathways, in which several industry partners are engaged.

Planned Deliverables: Policy brief and conference proceeding. **Benefit to end-users:** The work will be supported by the relevant industrial partners (e.g., Volvo Cars) and will provide decision-making support for these actors, as well as for policymakers.

Task 2.4. Vehicle lifetime in different mobility solutions

Aim: In Phase 1, we analyzed the impact of car sharing on supply chain energy needs and CO_2 emissions. Potentially key aspects identified in our analysis that have not received much attention from the environmental or resource perspective are the ways in which: 1) different utilization rates of vehicles affect their longevity; and 2) how batteries and electric motors may further constrain or enhance the service lifetime of vehicles. Based on this, the aim of this task is to analyze and improve our knowledge as to how cradle-to-grave energy requirements and CO_2 emissions for different transport system solutions (shared *vs* individual mobility) depend on the lifetime of the car and the constraining lifetime factors (calendar age *vs* cumulative mileage).

Method: We will do this by: a) developing a mathematical model that captures how the vehicle lifetime is dependent upon the intensity of its usage and whether or not it is electrified. This will be done by analyzing the relationships between scrappage, age and mileage in the Swedish car registry, and by developing a simple battery-aging model based on a literature review; and b) implementing the lifetime models in the vehicle stock turnover model developed in Phase 1, so as to enhance the analysis of how cradle-to-grave energy requirements and CO_2 emissions depend on individual *vs* shared mobility solutions (i.e., the intensity of the car usage).

Planned Deliverables: Two research papers focusing on the energy and CO_2 consequences of shared *vs* individual mobility for the Swedish personal transport system. **Benefit to end-users:** The results will be useful for public and private stakeholders in understanding how new mobility solutions can contribute to climate change mitigation, as well as increased resource efficiency. The research will be realized in dialogue with Volvo Cars, Polestar, Stena Recycling, and the STA and Swedish EPA, to ensure that the approach will produce relevant results.

Task 2.5. Implementation - battery turnover and its implications

Aim: Based on the vehicle and battery lifetime models developed in Task 2.4, we will analyze the different strategies regarding battery use over its lifecycle and determine how this affects the material turnover on a societal level, as well as how the different strategies influence the electricity market.

Method: The electricity market impacts will be analyzed with an agent-based model (Yang et al, 2020) developed within the ENSYSTRA project. The material consequences will be analyzed with the vehicle stock turnover model developed in MCE Phase 1 and refined in Task 2.4. The two models will be soft-linked in order to understand the consequences in terms of the system costs and material turnover levels the different strategies. Strategies that will be assessed include:

- Car batteries are used for vehicle-to-grid applications, i.e., short-term storage. This could generate an extra revenue stream for car owners, although it may lead to degradation of the battery quality and potentially earlier scrappage of the battery (and also the car if battery replacement is not an option).
- Batteries that are no longer fit for use in a car are used for 2nd life applications in the electricity market, as stationary batteries for short-term storage. This would generate revenues for the battery owner but would withhold potentially valuable battery materials from recycling.
- Batteries are recycled immediately after their use in a car, in order to produce new batteries from recycled material for vehicle use.

The different strategies would have different impacts on the electricity market, the stock of batteries in Society, the inflow of raw material, and the amount of recycled material. These aspects will be assessed in the task.

Planned Deliverables: One or two research papers. **Benefit to end-users:** The results will be useful for public and private stakeholders in understanding the interplay between new mobility solutions, recycling of vehicle batteries, and short-term electricity storage. The results will highlight optimal strategies that could contribute to climate change mitigation as well as increased resource efficiency. The research will be realized in co-operation with Volvo Cars.

Task 2.6. Supply-chain impact analysis of electrifying Swedish on-road transport with electric road systems (ERS): implications for batteries, materials, costs and infrastructure

Aim: Research performed during Phase 1 suggests that Electric Road Systems (ERS), which have been designed to benefit heavy-duty trucks, can also benefit passenger vehicles. Using realistic driving patterns of a Swedish household, our study suggests that ERS can reduce by up to 72% the battery requirements for passenger cars and the needs of non-home charging infrastructure. This new task aims to explore the supply-chain implications of the electric road system for passenger EVs, including the materials for battery production, vehicle lifetime, and infrastructure developments in terms of energy use, Lifecycle Assessments of GHG emissions, and investment costs. The case study is an extension of Tasks 2.4 and 2.5 applied in the cases of ERS, batteries, and charging infrastructure.

Method: The impacts of ERS on reduced battery capacity requirements and charging infrastructure needs will be analyzed using geographic information systems (GIS) based on the Swedish Car Movement Database. The impacts on materials used for battery production, vehicle lifetime, energy, GHG emissions, and investment costs will be based on the vehicle lifetime model developed in Task 2.4, in combination with a literature review of LCA studies and the energy system model from Task 2.5 plus economic modeling. Furthermore, the task will benefit from cooperation with Task 1.2.

Planned Deliverables: Two or three research papers, bilateral meetings with stakeholders. **Benefit to end-users:** The outcomes will be relevant for different vehicle development strategies, as well as for *Trafikverket* in their infrastructure planning.

Task 2.7. Large-scale application of vehicle sharing: implications for travel volume and supply chains

Aim: Based on the scenarios that we explored in Phase I (regarding, for example, battery-powered EV (BEV) penetration, connected and autonomous car (CAV) penetration, shared *vs* individual mobility), we will further explore using a bottom-up approach the large-scale application of vehicle sharing. For example, what would be an optimized and yet sustainable transport system without private vehicles in which transport services are provided by various combinations of transit and CAV mobility services? What would be the implications in terms of travel time (considering both waiting time and time on the road), societal costs (GHG, energy, congestion), and private cost (cost per mile plus disutility costs), as compared with a business-as-usual strategy (moderate penetration of BEVs) and a 100% BEV scenario without CAVs and sharing? Our goal is to explore how transformative transport technologies and services, specifically EVs, CAVs and share mobility, can be used to meet our future travel needs.

Method: We will use an agent-based modeling approach to conduct a scenario analysis, in which we will calculate the impacts on travel time and disutility costs, in combination with tools such as the LCA tool developed in Phase 1 to calculate the impacts on energy use, lifecycle GHG emissions, and an economic model to calculate the private *vs* societal cost implications. The agent-based model combines two modeling tools: synthetic population and MATSIM, both of which are widely used and well-established modeling techniques for transport planning. “Synthetic Sweden” is a large-scale, agent-based model that provides a scaffold on which to build decision-making support tools to model and analyze future scenarios. It replicates a statistically accurate representation of real populations but is completely synthetic, which means that: (a) it does not violate any privacy issues; and (b) it can be modified easily to create alternative scenarios. It is the latter feature that makes the model an ideal tool for modeling and analyzing future scenarios. As found in Phase 1, the appeal of Automated Vehicles increases the risk of increasing trip demand, energy use and GHG emissions. Therefore, it would be especially important to look at the possibility of Automated Vehicles being used either as shared fleets or as “last-mile” options that complement public transport, in order to explore the synergies between the trends of automatization, electrification, and shared mobility, and to maximize the environmental benefits.

Planned deliverables: Two or three research papers. **Benefit to end-users:** The modeling tool can be a valuable planning and visualization tool for public and private stakeholders in Sweden. The Swedish Transport Administration (*Trafikverket*) has shown interest in building a national model based on the synthetic population /agent-based approach that we will use in this task.

Task 2.8. Future scenarios based on different use cases and stakeholder perspectives

Aim: In Phase 1, we studied how travel behaviors (using data from the Swedish Travel Survey) can change if someone’s Value of Travel Time (VoTT) is reduced due to the introduction of CAVs. The results show that changes in VoTT can make CAV adoption financially attractive for a large share of drivers in Sweden, and that this could in turn create an increase in travel demand. Furthermore, in a parallel study, we analyzed the driving and restraining forces that facilitate or hinder the transition towards the expansion of CAVs at the city level. A Multi-Level Perspective (MLP) was used to map the different stakeholders, representative of the driving/restraining forces, and we assessed the current level of knowledge regarding CAVs among the stakeholders. In Phase 2, we aim to build on these studies by addressing new questions from the user and stakeholder perspectives.

1) How can different use cases for CAVs (e.g., car sharing privately or publicly, transporting children to activities, transporting people who cannot drive themselves) contribute to either increased system energy efficiency in transportation or increased car reliance with an increase in car traffic volume?

2) What are the readiness levels and the perceived possibilities regarding governance structures and policies at different jurisdictional levels (municipal to national) in Sweden that can be used to steer the introduction of CAVs so that benefits can be reaped and potential risks can be avoided regarding the use cases outlined in the previous question?

Method/activities: The first research question will be addressed using literature reviews, a statistical assessment of the Swedish Travel Survey, and additional quantitative scenario modeling similar to the VoTT-based scenario modeling in Phase 1. Scenarios will be developed for the travel demands associated with different use cases and user groups, and the findings will be fed into the modeling in Tasks 2.1 and 2.7, in order to estimate the impacts on vehicle kilometers travelled, as well as the energy and environmental consequences. The second research question will be addressed through interviews with stakeholders at different jurisdictional levels in Sweden, possible follow-up surveys, and a qualitative analysis. The results will include a description of the current state of preparedness for CAVs at the municipal and national levels, with respect to the use cases in the first research question, and analyses of how governance structures/planning tools/policies might affect different use cases given certain conditions. The findings from this analysis will be fed into Task 2.1.

Planned Deliverables: Two or three research papers. **Benefit to end-users:** For policymakers: understanding how different policy tools can steer CAV implementation in Sweden under certain conditions, so that increased accessibility benefits of different user groups can be achieved while potential increases in energy use and CO_2 emissions are minimized. For industrial partners: information on the types of use cases that may be more prevalent in the future, and on what vehicle features or models are best suited to those use cases.

6.3 WP3. Governance and Policy Process

Objectives: This work package will advance the studies from WP3, Phase 1, on the transformative pathways towards net-zero emissions in Sweden, focusing on the links between policymaking, institutions and market actors along the supply chains, and including production, business models, and consumption. In Phase 2, we will bring this research closer to the policymaking scene.

For this reason, we will use the concept of policy processes to provide a framework for understanding and analyzing the interactive activities and dialogues that occur between policymaking and market actors during policy implementation. The concept of policy process is here regarded as a series of sequential stages: a) problem emergence; b) agenda setting; c) consideration of policy options; d) decision-making; e) implementation; and f) evaluation of policy (Jordan and Adelle, 2012). To support the overarching objectives at the programme level, this work package aims to study and follow the climate policy processes in Sweden and the EU with the following objectives:

- Identify policy pathways and issues related to problem emergence, agenda setting, policy options, decision-making, implementation, and evaluation of policy.
- Cover a wide range of issues in the policy process, such as legitimacy, credibility, public acceptance of new policies, coordinated leadership between actors and across sectors and governance levels, opportunities, and the impacts and risks for Sweden and the EU in being a frontrunner in creating a society with net-zero GHG emissions.

- Provide a policy context for the research on specific policy design options in WP4, the results of which also feed into the policy process. To maintain an integrated leadership between WP3 and WP4, as they will have a joint leadership.
- Maintain the ongoing dialogue with Swedish and EU authorities and institutions in order to inform about our research results and have impacts on Swedish and EU policymaking processes.

Task 3.1. Determinants of climate leadership

Aim: The evolvement of climate action post-Paris imposes new demands on climate leadership, which will be even more pronounced in the post-COVID-19 recovery era. First, subnational and non-state actors emerge as critical leaders in a polycentric landscape of governance and actions. Second, as nations, business and municipalities increasingly aspire to use societal transformations to achieve their climate goals, new types of leadership demands emerge. Most of the literature to date has analyzed climate leadership pre-Paris with a state-centric focus involving incremental and issue- or sector-oriented governance efforts. Initiatives such as the European Green Deal and the recommendations made by the Swedish Policy Council require a polycentric and sector-transgressing leadership that can relate to Society-wide implications and distributive changes.

This evolving demand for leadership is also demonstrated in the focus groups on climate leadership in MCE Phase 1. Key actors in Swedish local and regional politics, the business sector and government administration highlighted the challenges embedded in the collective and relational dimensions of leadership central to societal transformations towards sustainability, such as how responsibilities are assumed and concerted action can be taken among various actors when there are potential leaders at many levels, within different sectors (Benulic et al. 2020). Although the previous literature has highlighted collaboration as an essential leadership quality, the question as to how roles and responsibilities should be assumed in collaborative leadership remains unexplored, in particular in the context of the development of climate action in the last decade.

This task aims to explore the evolving leadership roles and demands across sectors and governance levels in Sweden and Europe. It will analyze the requirements for legitimate and effective climate action in light of the transformative climate efforts.

Methodology: The task will be conducted through participant observations in: 1) informal and formal meetings with governmental and subnational agencies, and political representatives regarding the implementation of the Swedish Climate Action Plans and the European Green Deal; and 2) meetings between non-state representatives of the building and transport sectors. Leadership aspects will be further scrutinized in follow-up interviews and/or focus groups with key actors.

Deliverables: The task will result in at least two peer-reviewed papers. **Benefit to end-users:** In the upcoming years, the climate leadership of public bodies and private companies will be enacted within a governance landscape in which the Swedish Climate Action Plan and the European Green Deal will be the two key frameworks. Both address the sectors of buildings and transport infrastructure, as well as transportation, but also industry, energy, and agriculture. This task will contribute with knowledge as to the preconditions for leadership for transformative change towards a society with net-zero GHG emissions, especially concerning the division of roles and responsibilities, which is of importance in a multi-stakeholder and cross-sectoral governance landscape, and for the implementation of the Swedish Climate Action Plans and the European Green Deal.

Task 3.2. Public acceptance of road tax reforms for electrification of the Swedish vehicle fleet

Aim: Research from WP3 in Phase 1 shows that electrification of the Swedish vehicle fleet requires a reassessment of current transport policies, as they generate a future target conflict between GHG reduction, regulating traffic volume and tax revenue to fund public infrastructure and the charging infrastructure. As electrification progresses, fuel taxes need to be switched to mileage taxes for EVs. The aim of this task is to measure the willingness of the public to accept such a road tax reform, as well as important policy communication approaches when implementing such a tax reform towards a fossil-free vehicle fleet and a developed charging infrastructure in Sweden.

Methodology: Experimental methods, embedded in online surveys to representative samples of the Swedish population, will be used to derive causal explanations by varying certain aspects of policy design, as well as policy communication across respondent groups. We will test how different policy communication approaches affect potential voters. The approach uses and introduces insights from behavioral economics, social psychology, including psychological reactance theory to existing models of transport policy acceptance. The findings will be empirically tested using focus groups and online surveys, consisting of framing and choice experiments. Insights from the work in Task 2.1 will be used in the development of the survey, and knowledge gained from this task will also be used to inform the work on policies in Tasks 2.1 and 2.8.

Planned deliverables: Two scientific articles, policy briefs, and presentations to authorities. **Benefit to end-users:** Informing policymakers in Sweden about the public acceptability and policy communication approaches of road tax reforms during electrification of the Swedish vehicle fleet. The research will inform about the acceptability of such a policy reform, as well as important policy process parameters to consider when implementing such a tax reform. Sustainable transition scholars may find insights into change resistance informative, and communication researchers and social psychologists will find well-established concepts from their fields being applied to policy research.

Task 3.3. The value of being a frontrunner

Aim: To understand and measure the value that Swedish citizens place on "being a frontrunner". Sweden has, as of January 2018, an ambitious climate change act with the goal of achieving net-zero carbon emissions by Year 2045. While there is a broad political consensus regarding the long-term overall goal of reducing carbon emissions, the political parties in Sweden hold different views on how best to reach the target. In particular, there has been a discussion as to whether Sweden should be a frontrunner in this area, more specifically if Sweden should reduce emissions more than, for example, those levels agreed within the EU, and if emission reductions should be made in Sweden or if Sweden should rather pay for reducing emission reductions in other countries where it is cheaper (the cost-efficiency argument). Proponents often argue that there is a value linked to Sweden being a frontrunner, in addition to the actual emissions reductions. This value is commonly said to arise from Sweden becoming more competitive (for example, by selling climate technologies to other countries) or that Sweden could inspire others to reduce emissions more than what they would otherwise do (see the Swedish All-Party Committee on Environmental Objectives in *A climate and air quality strategy for Sweden – Part I* (SOU, 2016)). This project is a continuation of a project conducted in Phase 1 on the preferences and attitudes to climate mitigation and policy. The focus of this task in Phase 2 will be on understanding the value that Swedish citizens place on being a frontrunner and the determinants that explain such preferences. In addition, we will be able to study differences within and between Sweden and other EU countries. The results will serve as important inputs to the policy process and discussions among policymakers (and also among the public) regarding Sweden as a frontrunner and the public demand for climate policies. The results will also provide inputs as to why some countries take greater responsibility for the global climate problem while others do not.

Methodology: The research will be conducted using survey experiments. **Planned deliverables:** The research will be published in two peer-reviewed articles and communicated through policy seminars and one policy brief. **Benefit to end-users:** The results from the task will provide evidence-based inputs to the debate among policymakers (and also among the public) regarding the public demand for climate policies and the value and desirability of being a frontrunner.

Task 3.4. Leadership and policy diffusion

Aim: Curbing global GHG emissions requires countries to make reductions that have a significant marginal impact on themselves. Several countries have made ambitious domestic emission reduction commitments despite their relatively small share of global emissions. That these countries might expect to have an impact on emissions beyond their borders, either through technology or policy diffusion, might go a long way towards explaining their ambitious stances.

This task will combine the leadership and diffusion perspectives by explicitly accounting for situations in which the expectations/prospects for future technology or policy diffusion affect the initial decision. The key to this is whether or not citizens/stakeholders believe (credibly) that they can make a difference beyond their borders, either at the country level or within specific economic sectors. In other words, whether they believe they can 'leverage' their leadership in some way.

Methodology: Multi-country analytical partial or general equilibrium model; econometric analysis. **Deliverables:** The research will be published as peer-reviewed articles and communicated through policy seminars and policy briefs. **Benefit to end-users:** The results from the task will inform policymakers about the potential effects that climate leadership can have on the diffusion of technology in other countries or jurisdictions.

Task 3.5. On the effects of Consensus on Climate Policy

Aim: Policymaking is facilitated by consensus. A common problem in climate change regulation is the existence of uncertainties about the costs of climate policies. An interest group is an organized group with a narrowly defined viewpoint, which protects its position or profits. For example, industry groups are likely to communicate high estimates of the costs of climate mitigation in a way that reduces the chances of implementing regulation and/or regulatory stringency. By generating controversy about the costs of climate policy, firms are likely to slow or prevent regulation. The purpose of this project is to investigate whether (and to what extent) firms can influence the implementation of climate policy by overstating costs and whether or not a higher degree of consensus has facilitated the implementation of climate policies across countries.

Methodology: To address our research question, we will make use of: 1) international opinion polls conducted worldwide, e.g., the Gallup Poll that has surveyed individuals from 128 countries in comprehensive studies of global opinions. Proxies for concern and knowledge about climate change among the general population will be used as explanatory variables on the level of stringency and number of climate policies implemented by different countries; and 2) a systematic literature review of retrospective studies of the costs of climate policies, to determine whether there exists a systematic bias towards overestimating climate mitigation costs.

Deliverables: We expect to publish the results in a scientific paper and a policy brief. We also plan to present the results in workshops and conferences. **Benefit to end-users:** Increased knowledge on to what extent firms can influence the implementation of climate policy and whether or not a higher degree of consensus has facilitated the implementation of climate policies across countries have important implications for policy efficient design.

Task 3.6. Governance, capabilities and incentives to enhance climate-friendly public procurement in the construction sector

Aim: The aim of this task is to provide an in-depth assessment of the main drivers and barriers to the implementation of climate-friendly public procurement in the Swedish construction sector. In Phase 1 of the research programme, case studies were performed of procurement requirements and strategies for carbon reduction in projects carried out by internationally leading infrastructure construction clients, including the Swedish Transport Administration (Kadefors et al., 2019; 2020). Major barriers were identified related to a lack of knowledge and resources on the procurer side, combined with - and causing - weak learning capabilities on the institutional/system level. Phase 2 will build on these experiences and address how knowledge in the field of climate-friendly procurement is established and disseminated between relevant actors in the Swedish construction sector. The aim of this task is to suggest policies and governance structures with the potential to support effectively the development of procurement practices in this field.

Methodology: Currently, several industry-level initiatives and platforms are established by regional and national actors in response to goals and policies for carbon reduction. Based on interviews and observations, we will study the learning processes within and between such collaborative innovation eco-systems. The task will identify key actors, knowledge repositories and knowledge flows, as well as the main drivers for and barriers to learning. The focus is on procurement, but we will also acknowledge how this instrument interacts with other measures. The task will be coordinated with Tasks 1.4 and 1.5.

Planned deliverables: Academic papers, policy reports/briefs, and presentations at policy, industry and academic events. **Benefit to end-users:** The task is expected to bring tangible benefits to policymakers, as well as to contracting authorities, suppliers and knowledge brokers.

Task 3.7. Funding of large transformative investments

Aim: To obtain a better understanding of the possibilities and challenges related to complementary policy interventions and/or private initiatives to secure financing and de-risking investments for decarbonization of the basic materials industry. The aim is to assess if and how private initiatives, such as buyers' coalitions (Bataille, 2019) and transformation funds (Rootzén and Johnsson, 2017b; IMO, 2019), could allow actors along the supply chains for basic materials, such as steel and cement, to contribute collectively to secure financing and de-risk investments in low-, zero- or negative-emission technologies. The work in this task will be informed by and coordinated with WP1 (in particular by Tasks 1.1 and 1.4).

Methodology: The analysis work will include data collection, development of possible set-ups (Revenue model, Funding sources, Risk management instrument, Capital and ownership), and quantitative assessments of different models for distributing costs/risks and possible revenues. **Planned deliverables**: At least one scientific paper. **Benefit to end-users:** There is an obvious need to find new ways to share the risks associated with investments in high-cost transformative technologies. In Phase 1, we have started to work with a bank (the partner bank in MCE) to find ways in which our work on a "transformation fund" can be implemented. The Phase 2 work will continue this implementation work.

Task 3.8. Quantitative assessment of the effect of public procurement

Aim: Reaching the goals for carbon mitigation will inevitably require changes in public procurement practices, especially in the highly client-led and emission-intensive sectors such as the construction sector. In this task, economic analysis of drivers and barriers for climate-friendly public procurement will be used to assess policy needs and options for the acceleration of adoption of climate-friendly procurement practices.

Methodology: Quantitative economic methods (applied microeconomic theory, econometrics, and modeling analysis) and possibly qualitative methods will be adopted to investigate the following themes: 1) assessment of whether and to what extent including climate-friendly requirements in public procurement auctions increases the purchasing and/or transaction costs for the procurer and how to design support policies (e.g. financial and training schemes) to address these costs, and2) assessment of whether and to what extent should climate-friendly procurement be mandated and how effective (mandatory) requirements should be designed to be compatible with contracting authority capacity constraints and robust to asymmetric information issues. The work will be coordinated with the research conducted in Tasks 3.6, 1.4 and 1.5. **Planned deliverables**: Academic papers, policy reports/briefs, organization of stakeholder events, presentations at various policy and academic events **Benefit to end-users:** The task is expected to bring tangible benefits to policymakers and stakeholders in the industrial decarbonization arena, as well as to contracting authorities in Sweden, Germany and other European states, as a qualitative and quantitative assessment of drivers of and barriers to climate-neutral public procurement can be crucial for the design of targeted policy actions to enhance implementation.

Task 3.9. Implementation - policy dialogue in Sweden and the EU

Aim: In Phase 1, we have had an ongoing dialogue with Swedish and EU authorities and institutions in order to: 1) inform about our research results and in this way have an impact on Swedish and EU policymaking; and 2) understand which issues are prioritized in Sweden and EU, so that we can focus on these issues at the right time. As described in the Progress Report, we have been very active in providing research results to these institutions and we have testimonies to the effect that these have had an impact. For this purpose, we have established a network of contacts at the Swedish EPA, Swedish Energy Agency, The Ministry of Environment, Swedish National Board of Trade, and the Swedish permanent representation to the EU in Brussels. At the EU level, we have established contacts at the EU Commission (DG CLIMA, DG GROW) and in the European Parliament. In addition, through CEPS, Fores, IVL and Hagainitiativet, we have access to complementary platforms for communication with Swedish and EU institutions.

In Phase 2, we will continue to work closely with authorities and institutions in Sweden and the EU with the objective of having an influence on climate policymaking. We will align our work with the climate policy agenda in Sweden and the EU so that our input to the policy process is timely and relevant. We will particularly focus on parts of the EU Green Deal that may overlap with Sweden's climate priorities, for instance the EU ETS, CCS, Green public procurement, trade and climate and renewable energy.

Task 3.10. Post COVID-19 – design for Green recovery

Aim: To explore efforts to achieve societal transformations towards sustainability in conjunction with the COVID-19 recovery packages with the focus on formulating conditions for designing powerful recovery packages for repositioning businesses towards sustainability, while creating Green jobs in Sweden, ensuring coherence with the European Green Deal and EU recovery packages, and maintaining a balance between Swedish self-reliance and recovered trade flows/relations.

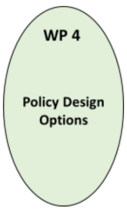
Method and activities: This task will explore the roles of recovery packages from a business perspective (their capacity and willingness to act) and a policy perspective (recovery package design). We will analyze:

The business perspective: A sample of small, middle-sized, and large Swedish companies in the transport, transport infrastructure, and building sectors (including MCE stakeholder partners) will be assessed with regards to their capacities (e.g., the fossil-fuel dependency of their businesses and possibilities for Green substitution) and explicit or publicly communicated intentions to act to transform their businesses in line with the Paris Agreement (including what relates to their Scope 1, 2 and 3 emissions), and as to how the COVID-19 pandemic has affected their businesses. Based on the responses, we will construct interview guides and identify relevant informants in these companies for in-depth interviews. We will explore participants' views on, for example, the challenges and opportunities for companies to transform, the meaning of lock-in effects, whether and how companies' pathways and choices have been affected by the economic downturn and recovery plans. We will also map the changes that the companies have undertaken and are planning in response to the COVID-19 pandemic. In response to the recommendation of the Evaluation panel, we will also include questions related to *what governs the demand for carbon efficient products from private firms*. *The policy perspective:* We will: A) analyze recovery plans and proposals ex ante; B) follow up on how these plans are implemented; and C) based on previous mapping of recovery plans and proposals and the experience gained from the business assessment, construct interview guides and identify relevant informants among policymakers for in-depth interviews.

Using the insights from the business and policy investigations, the goal will be to identify the most potent recovery packages for repositioning businesses towards sustainability. We will also investigate to what extent recovery strategies are compatible with the Swedish climate policy framework and the European Green Deal, and the types of goal conflicts that may arise.

Planned deliverables: Two papers in peer-reviewed journals and one policy brief. **Benefit to end-users:** This task will contribute with systematic in-depth analysis of key actors' perceptions of the challenges and enabling factors in the design of post-COVID-19 Green recovery packages. The analysis will help to identify support structures for companies to achieve Green recovery and for policymakers to assess and design recovery policies and measures.

6.4 WP4 Policy Design Options



Objectives: The overall aim of this work package is to investigate how best to design policy instruments and instrument packages to induce transformative changes towards a society with net-zero GHG emissions. Informed about the wider policy context in WP3, the focus of this work package is on the specific policy measures that are needed to enable the realization of transformative pathways, specifically along the supply chains. For this reason, WP3 and WP4 are managed by an integrated leadership. While the research will take its starting point in the Swedish context and existing policy instruments, there will also be tasks that involve country comparisons and more general policy research when such projects are considered important to fulfil the key objectives of the programme. Specifically, this work package will:

- Design and analyze policies, while accounting for real-world policymaking complexities, such as acceptance, social norms, bounded rationality, lobbying, jurisdictional interactions, and policy sequencing;
- Enhance the state-of-the-art research on policy effects for predicting and isolating market actors' behavioral changes in response to specific climate policies, as well as policy combinations;
- Carry out integrated model studies on the combined effects of complementary climate policies along the supply chains; and
- Identify and analyze policy instruments and governance measures that support transformation, taking into consideration politically important issues such as policy stringency, economic efficiency, distributional effects, carbon leakage, and international market risks.

The research tasks in WP4 are organized as follows: Tasks 4.1–4.3 focus on the design and effectiveness of specific policy instruments, while Tasks 4.4–4.6 focus more broadly on different aspects of the policy packages. Task 4.7 has an international outlook with the focus on trade and the design of policy instruments, while Task 4.8 takes on the issue of design of policy instruments to incentivize negative emissions. Finally, in combination with the research in WP2 (Tasks 2.1 and 2.8) Tasks 4.9 and 4.10 focus specifically on policy design for transport.

Task 4.1. Price-based and informative instruments for transformative changes

Aim: The experimental studies in Task 3.2 in Phase 1 on managers in Swedish industry indicate that it is cognitively demanding to make effective investment decisions in response to only a price signal, such as the EU ETS or a CO_2 tax. This ineffectiveness of the price signal seems to be greater when cost-efficient measures involve transformative changes in the long term. Based on the results from Phase 1, this task will develop and analyze informative instruments complementary to the price signals of the EU ETS and the CO_2 tax, which will improve the effective response by decision makers to the price signals of these instruments.

Methodology: The complementary policies developed based on the experiments in Phase 1 will be tested in new experiments involving 200 managers from Swedish industry and 1,000 end-consumers of cars (transport) and private houses (buildings), to complement the price signal. The task employs the technology scenarios from WP1 and WP2 and the results from Phase 1 for hypothesis formulation. We will use focus groups, experimental surveys, and two-sided survey experiments. This research will extend the state-of-the-art research within behavioral economics on decision making, in which there is now ample evidence that non-economic incentives are also important. **Planned deliverables:** Besides the publications of two papers in scientific journals and policy briefs on the effects of climate policy on human decision-making from this task, a Behavioural Science Lab for Policy Effects will be set up permanently as a new research unit at IVL. The purpose of this research laboratory is to develop new knowledge on a permanent basis about the cause and effects of environmental policy design, human decision-making and behaviors. The laboratory will apply state-of-the-art research experimental methods and modeling from the research frontier to study the effects of environmental policies on human decision-making and behaviors. **Benefit to end-users:** The Behavioural Science Lab for Policy Effects is a new research unit in policy research and it may be used for future research and consulting in sustainable management, the marketing of carbon-neutral as well as Green products by industries, and the design of environmental policies.

Task 4.2. Carbon pricing and coordination of investments

Aim: In this task, we aim to investigate the role of carbon pricing in coordinating technologies and investments. When there are multiple (long-run) equilibria with coordinated technology choices it is not obvious that a Pigovian price is a sufficient or preferred policy strategy to induce coordination of the preferred equilibrium. Carbon pricing is an important part of any effective climate policy mix and is an instrument that is increasingly used across the world (World Bank, 2019). Compared to other policies, carbon pricing has several major benefits: it is cost-effective, provides incentives for firms to invest in cleaner technologies, and creates a revenue stream for governments that may be used to, for example, support climate-friendly technologies. Despite these benefits, it is not certain that carbon pricing alone, or in combination with R&D support to internalize any positive innovation externalities, will be sufficient to decarbonize the economy. Most importantly, technology complementarities and the need for investment coordination are crucial in achieving deep decarbonization (Davis et al, 2018). For example:

i. Widespread uptake of EVs requires investments in a network of charging stations, which in turn will only render a positive financial return if EV uptake is sufficiently high.
ii. Successful implementation of carbon capture and storage (CCS) technologies in the steel and cement industry requires simultaneous investment in public and private infrastructures. Investments are long-term and, therefore, risky, and a reluctance to invest by one market party may cause other actors to refrain from CCS investments as well.

Methodology: We aim to adopt a general equilibrium (GE) model in which firms make complementary investment decisions. It is important to analyze our research question in a general equilibrium; we are interested in large technological changes that will likely affect relative prices and other markets. A GE framework allows us to account for such effects. Investment decisions will be influenced by policy, but also by the expectation of other firms' investment choices. We complement this analysis with a numerical assessment, allowing us to offer further insights into policy solutions depending on the characteristics of industrial sectors. Insights gained from the work conducted in Tasks 1.1. and 1.3 on the preconditions, as well as the barriers for sustainable electrification in the steel and cement industry and road transportation will serve as an important basis for this task.

Planned deliverables: The results will be reported as: (i) one scientific article published in a peer-reviewed economics journal; and (ii) a policy report aimed towards regulators. **Benefit to end-users:** The task is expected to provide policy advice regarding the potential and limitations of carbon pricing to decarbonize the economy, thereby complementing the research in several of the tasks in WP3.

Task 4.3. Flexible performance standards

Aim: The industrial and manufacturing sectors face intense international competition, and this creates a practical obstacle to implementing carbon prices that are sufficiently high to achieve Sweden's carbon reduction goals. In contrast, performance standards sacrifice efficiency but have the advantage that they suppress the change in product prices compared to carbon pricing, thereby reducing the threat from international competition. Performance standards can be implemented independently or can overlay carbon pricing to achieve more powerful incentives for innovation and investment than often can be achieved with carbon pricing alone. This research extends the conceptual work completed in Phase 1 (Fischer 2019, Lofgren et al. 2020) to examine pathways towards the introduction of performance standards. Adding flexibility to the design of performance standards enables alternative compliance payments if a performance standard is not met, as well as payments to a firm that surpasses the standard, providing continuous marginal incentives to reduce emissions. As the number of industrial firms in Sweden is small, trading of credits relative to the standard is not practical within one industry. This research examines four alternatives: government-provided taxes and subsidies, trading across industries with separate, product-specific benchmarks, linking performance standards for industry with standards in transportation, and expanding performance standards across other EU Member States.

Methodology: The research will be conducted using analytical methods and simulations. The work in this task will inform Tasks 4.4.–4.6 and will apply insights gained from the work conducted in WP1 and WP2 on costs related to the electrification of the steel and cement industry and road transportation. **Planned deliverables:** One scientific article published in a peer-reviewed article and one policy brief. **Benefit to end-user:** Sweden faces a coordination challenge within the EU and looks for ways to exercise leadership and achieve nation-specific climate goals. Performance standards provide an incentive-based approach to strengthen outcomes without harming the competitiveness of Swedish industry. Flexible performance standards complement carbon pricing and may provide an on-ramp to expanded carbon pricing in the future.

Task 4.4. Designing the EU ETS to accommodate companion policies

Aim: Both price-based and non-price-based companion policies have certain advantages. While price-based policies are likely to achieve least-cost emissions reductions in the short term, non-price-based policies can improve political viability and reduce leakage and they may be essential for driving the energy transformation required by, for instance, cement and steel production to meet long-term climate goals (Task 1.1). In the EU, several Member States have introduced or are planning to introduce policies that will overlap and may interact with the EU ETS. The results from Phase 1 show that even when price-based instruments and non-price-based instruments partly overlap in their effects, the losses in effectiveness and potential synergies can be substantial. This task aims to identify the types of companion policies that are preferred in terms of not undermining the EU ETS but rather, improving the effectiveness of reaching the climate objectives of Member States and of the EU. We will analyze how the EU ETS can be designed and reformed in order to accommodate more effectively national companion policies and if possible, amplify them. In addition, we will study the combined effects of and the extent to which complementary policy instruments should address other actors in the supply chain or the same actors as are already addressed by EU ETS. We will carefully monitor the EU Green Deal proposals that target the EU ETS, to evaluate to what extents these will strengthen the linear reduction factor, improve the function of the market stability reserve, phase out free allocation, and expand the scope of the ETS to include international shipping into the ETS.

Methodology: This task will identify a set of current and potential Member State policies, for instance the British price floor, the German decarbonization of coal-based power, the Dutch CO_2-tax, and Swedish investment support for carbon-free cement and steel production. We will analyze how they interact/would interact with the EU ETS. For parts of our analysis, we will use a model developed in Phase 1 that analyzes how the market stability reserve reacts to supply-demand imbalances. Furthermore, this task takes a novel approach to policy research by using integrated general equilibrium modeling of instruments along the supply chain and adding new complementary polices, such as multilevel pricing, as well as studying already introduced policies such as the UK price floor and the market stability reserve. The work in this task will be coordinated with the research conducted in Tasks 4.1-4.8 and the knowledge gained from research on individual policy instruments will inform the identification of current and potential companion policies of the Member States.

Planned deliverables: One report, two policy briefs, and three scientific papers. We will also give several presentations and write opinion pieces for Swedish newspapers. **Benefit to end-users:** As in Phase 1, we will continue our ongoing dialogue with staff at the Swedish EPA, Ministry of Environment, and the Swedish permanent representation to the EU, to discuss and present our results and to seek guidance from them on which issues are important for Sweden. To this end, we will provide policy briefs and papers and organize seminars for Swedish authorities and the EU Commission. We believe that this dialogue will have important impacts on the formulation of Swedish climate policy and on the Swedish position in EU negotiations on the EU ETS and the EU Green Deal policy.

Task 4.5. Analytical assessment of policy packages for industrial decarbonization

Aim: Phase 1 of the programme provided preliminary individual assessments of key policy instruments. However, to guide policy design, additional analyses are needed to understand the institutional details of the policy instruments and the incentives that they create in all steps of the supply chain. The ultimate goal of this task is to define the roles and functions of different policy packages, as well as the implications of their interactions for optimal policy design. Some of the in-depth analysis of the instruments will be conducted as part of other tasks in WP4 (Tasks 4.1–4.4). In addition, the work on how the policy package can address mitigation potential in the post-production steps in the value chain will be conducted in close cooperation with other research and policy partners in the programme (specifically, Tasks 1.1–1.3).

Methodology: Quantitative economic methods (applied microeconomic theory, econometrics, and modeling analysis) and possibly qualitative methods will be adopted to investigate the following themes: 1) *Assessment of the policy package from the enterprises' perspective.* The role of policy instruments and their interactions will be assessed from the perspective of strategic decision making by enterprises, in order to analyze the aggregated impact of policy packages on the creation of incentives along the entire value chain; and 2) *Assessment of the policy package from the government's perspective*. Since policies need to be continuously adapted, the question of how governance structures should be put in place is just as important as which policy instruments produce a meaningful policy mix. **Planned deliverables**: Academic papers, policy reports, organization of stakeholder events, presentations at various policy and academic events. **Benefit to end-users:** The task is expected to bring tangible benefits to policymakers and stakeholders in the industrial decarbonization arena, as the discussion of individual policies moves towards packages and their concrete implementation. The results of the analysis will be presented at a number of stakeholder events, to ensure that they inform the political debate in a timely manner.

Task 4.6. Policy packages and risk in hard-to-abate sectors

Aim: Focusing on four risk dimensions (market, technology, institutional, and coordination risks), the aim of this task is to develop a conceptual framework that provides the basis for describing and systematically analyzing how the current policy mix in Sweden mitigates the barriers and risks in the "hard-to-abate sectors". The model will also be used to analyze how effective the policies and policy packages developed and discussed in Tasks 4.1–4.5 are at mitigating the barriers and risks as outlined in the model, and potential policy gaps will be identified. The basic assumption is that these four risks hinder investments, and that any policy or intervention must mitigate the risks in order for the investments to be realized. Market risk refers to the price sensitivity of consumers, while technology, institutional, and coordination risks represent different aspects of the risk that a technological investment may not be successfully developed or deployed despite money and effort being spent on the project.

Methodology: In devising the conceptual framework, we will combine lessons from the economics literature dealing with system failures that result in under-investments in the development and deployment of low-CO_2 technologies in the harder-to-abate sectors. Knowledge gained from Task 1.1 will be important for the derivation of the different risk aspects. **Planned deliverables**: One scientific article published in a key journal in the subject area. **Benefit to end users:** An important outcome of this work is a series of "policy- workshops" aimed at disseminating the analytical framework and obtaining inputs from industry and policymakers.

Task 4.7. Trade and climate policy: Border Carbon Adjustments and alternatives

Aim: This task aims at providing a more detailed assessment of the interactions between trade and climate policy (i.e., the role of embedded carbon), in particular the instruments used for addressing carbon leakage. In the **EU Green Deal**, Border Carbon Adjustments (BCAs) are receiving explicit consideration; however, alternatives are available, such as charges on consumption (e.g., "Climate Contributions") and industrial policy measures. This work package analyses the roles of the instruments in achieving carbon cost internalization, mitigation of carbon leakage risk, and how these policy instruments interact with low-carbon innovation and deployment. While some initial analysis was provided in Phase 1 of the programme, follow-up questions arose that need to be answered to ensure a comprehensive and appropriate policy design.

Methodology: Quantitative/qualitative assessment of border-based *vs* consumption-based mechanisms will be provided and the implications for policy design will be drawn. In particular, the following aspects will be investigated: 1) fundamental choices made under the auspices of border-based or consumption-based mechanisms such as decarbonization incentives created by the schemes along the value chain (material efficiency, product substitution etc.); 2) European implications, such as compatibility with the interests and priorities of other EU Member States and compatibility with other policy packages (linkage to Task 4.1), as well as the implications from the coronavirus crisis and recovery regarding value chain resilience/fragility, and the potential for trends towards protectionism or self-sufficiency and the implications for climate policy; and 3) international implications, such as the roles in different national contexts (e.g., USA), and engagement with the EU neighborhood, especially in the context of BCA for electricity (Energy Community countries, including Ukraine, Russia, Turkey, Northern Africa).

Planned deliverables: Academic papers, policy reports and opinion pieces/commentaries, organization of stakeholder events, presentations at various policy and academic events. **Benefit to end-users:** The task is expected to bring tangible benefits to policymakers and stakeholders in the industrial decarbonization arena. An assessment of the basic aspects of the instrument, such as its distributional impact or how it builds on current policy instruments, is crucial for their social acceptance and concrete implementation. The results of the analysis will be presented at a number of stakeholder events to ensure that they inform the political debate in a timely manner.

Task 4.8. Designing policies for negative emissions

Aim: In order to meet Sweden's and the EU's net-zero emission targets, there will need to be substantial implementation of negative-emission technologies (NET) in 10–30 years. In Phase 1, we found that there are no natural incentives for producing negative emissions, so these incentives will have to be created by the state or some other regulator. The Polluter Pays Principle (PPP) is not applicable, as there are no emissions, but instead negative emissions, which are of benefit to society. Being a common positive externality, one could argue that negative emissions should be paid from the state budget. The aim of this task is to investigate models for creating incentives and for financing negative emission technologies in Sweden and the EU. One important technology in this context is Bio-CCS, although we will also investigate how to finance fossil CCS for use in the cement and steel industries.

Methodology: This task will: 1) identify different models that can create incentives and financing for Bio-CCS and CCS. We will take departure from our Report from Phase 1 (Zetterberg et al. 2019) which will be complemented by a literature study and a workshop with experts from Sweden and the EU; 2) analyze these models in terms of potential volumes, costs and distribution for different actors, effectiveness, and potential competitiveness concerns; and 3) analyze the interactions of different models of NET-credit demand with EU climate policy frameworks, including the EU ETS and Effort Sharing legislation and the developments of the Circular Economy Action Plan, which calls for a regulatory framework for carbon removal by Year 2023. **Planned deliverables:** One report/policy brief and one scientific paper. We will also deliver several presentations at scientific conferences. **Benefit to end-users:** We will present and discuss our results with policymakers and potential producers of NET-outcomes in Sweden and in an EU forum.

Task 4.9. Understanding Electric Vehicle adoption – the cases of local and national policies

Aim: The research in Phase 1 indicated that increasing the number of public charging points causally increases the adoption rate of EVs, especially in urban municipalities. Differences in the expansion of the public charging infrastructure across municipalities could explain why the adoption rate of EVs has been higher in some municipalities. Expansion of the charging infrastructure is therefore indicated as an effective instrument to increase the share of EVs. The aim of this task is to use updated data on the municipal variation in battery electric vehicles (BEV) adoption rates and local policy instruments in Sweden, to investigate causally the impacts of local policy instruments on BEV adoption in Sweden.

Methodology: Using the most recent data, advanced econometric modeling will be used to test for a so-called 'reverse causality' between the charging infrastructure and the electrical vehicle share. Effects will be compared across urban municipalities, suburban zones and rural municipalities. A survey addressing the status quo charging infrastructure and intentions to extend the infrastructure further will be conducted for all Swedish municipalities. A specific case study of the Gothenburg vehicle fleet, covering the supply chain perspective, will estimate the effects on lifecycle emissions from the switch to EVs. The work in this task will be coordinated with the research conducted in WP2 and in particular Tasks 2.1 and 2.8. **Planned deliverables:** One scientific article, a policy brief, and presentation at seminars and conferences with municipalities. **Benefit to end-users:** Strengthening the hypotheses that public procurement of EVs is an effective policy instrument and that local policy instruments for charging infrastructure should be differentiated based on the characteristics of the municipalities, so as to increase their effectiveness.

Task 4.10. Implementation – parking as a policy instrument in VGR

Aim: During Phase 1, local arena the West Sweden Region (VGR) has been used for studying transport policy implementation in a broader context. In Phase 2, the ambition is to focus on parking as an instrument for policy implementation. This corresponds closely with the ongoing work in VGR where one of the focus areas concerning transport is to implement parking policies in municipalities. The work in this task will be coordinated with the work in Task 2.8.

Methodology: One of the findings from Phase 1 was that the causality between minimum parking requirements (MPR) and changes in mobility patterns is difficult to establish and that there is a need for more data. One of the tasks will be, therefore, to study ongoing larger projects with low MPR, in order to gather more data about travel patterns and car ownership. By studying these larger projects and by having control groups, the risk for self-selection will decrease.

Even if MPR has the potential to be an important parking planning tool for decreasing car ownership and car travel, it is still mainly concerned with new buildings and areas. To shift the mobility patterns of residents in existing housing and developments, another task will be to study and recommend parking policy implementation on a broader scale. This work will involve a survey of the 49 municipalities in VGR concerning their parking measures and policies. The results will be evaluated and compared to policy recommendations from the literature on cities that have the ambition to direct travel patterns in a sustainable direction.

The third task will examine the perspectives of local political representatives from different municipalities. It will include semi-structured interviews to discover their perceptions of measures related to parking policies.

Planned deliverables: By combining the local political view with the research recommendations and insights from the other tasks, we will compile comprehensive policy recommendations on parking for cities and municipalities within the VGR, i.e., small as well as larger cities/municipalities, as compared to the City of Gothenburg. **Benefits to end-users:** The formulated policy recommendations will directly benefit the municipalities and cities in VGR and will also be informative for other cities in Sweden.

6.5 WP5. Implementation, local arenas and integration

Based on the experiences gained from Phase 1 (as well as from a number of other applied projects), we find that the most important implementation is achieved by engaging stakeholders during the course of the work. In Phase 1, we have been working closely with our end-users - policymakers in Sweden and internationally and industrial representatives – through the following activities:

Dialogue with end-users. We have an ongoing dialogue with representatives from various authorities and industry. This is a two-way discussion – it helps us understand the priorities of our end-users so we can adjust and focus our research appropriately, and it gives us the opportunity to inform our end-users about our results directly. The members of our **Programme Board** also represent key actors in Swedish Society. Meeting them four times a year has given us excellent opportunities to receive feedback on our research and for information exchange. A **participatory methodology** has been used for co-producing results with our end-users (as in the case of the Road 44 case study presented by Karlsson et al., 2020). We have also used representatives from industry and authorities as study objects in our behavioral study of climate leadership. We have created platforms for information exchange between researchers and end-users in the forms of **seminars, workshops** and **monthly webinars**. For a more detailed description of these activities in Phase 1, please refer to the chapter *Benefit to end-users* in the Progress Report. In Phase 2, these efforts will continue.

Implementation and local arenas

In Phase 2, we will – as expressed above - in all our research place the emphasis on implementation. In addition, five of the above tasks are directly dedicated to enhancing the implementation of the research results with our end-users, either by engaging our end-users in a dialogue or by co-producing results through teams that included both researchers and practitioners. These tasks – given above - are:

- Buildings and transport infrastructure (Task 1.4)
- Buildings and transport infrastructure in Uppsala (Task 1.5)
- Battery turnover and its implications (Task 2.5).
- Policy dialogue in Sweden and the EU (Task 3.9)
- Parking as a policy instrument in VGR (Task 4.10)

For practical reasons, the implementation tasks are managed under WP1–WP4. Once a year, WP5 will organize an activity during which all the implementation projects will be presented and there will be an exchange of experiences. The Uppsala and VGR tasks build on and continue the *local arenas* in Phase 1. The local context is important, since Swedish municipalities and regions often have more ambitious climate targets than the Swedish national target and are willing to move faster (for instance, Uppsala and Västra Götaland aim to be fossil-free by Year 2030). This may reflect a situation in which local political and industrial decisions can more rapidly be turned into actions owing to shorter decision paths and better anchoring in the local community. However, decisions made at the local level will also have a more direct linkage to what is possible in terms of reaction from the public, including negative reactions, as have for example been seen in connection to the introduction of congestion fees in the Cities of Göteborg and Stockholm. Thus, regions serve as an important arena for testing out what is possible to achieve through political decisions and industrial initiatives. Typically, regions form initiatives between academia, industry and the local government, which is the case for the two local initiatives linked to our programme: The Uppsala Klimatprotokoll (UKP) and the VGR "Towards a fossil-free VGR in 2030". Since transformation is already underway in these initiatives, there are already important lessons to be learned and these will be enhanced by our programme, offering a thorough analysis of technology choices and policy measures.

In order to speed up decarbonization, Skellefteå municipality has launched a broad range of climate initiatives within transportation, buildings, and renewable energy. The director of Skellefteå municipality is on our programme board and we have initiated a dialogue with Skellefteå municipality to create a local arena project here.

Arrangements for collaboration and integration within the programme

In WP5, we will continue the successful and widely appreciated activities from Phase 1 to enhance collaboration and integration within the programme:

- Our technical work packages have produced technical roadmaps that describe how the value chains of transport infrastructure can achieve net-zero emissions by Year 2045. We will continue to refine these roadmaps with the aim of providing the most comprehensive description of how to decarbonize transport infrastructure with respect to technologies, practices, financing and policies.
- In phase 1, we have established collaboration across work packages and tasks. As recommended by the Evaluation panel, we will start Phase 2 by mapping these linkages and identify mechanisms for enhanced collaboration on these linkages. Our roadmaps (developed in WP1 and WP2) provide a starting point for our research in WP3 Governance and WP4 Policy processes.
- Our case studies (The Road No 44 project – a road procured by the Swedish Transport Administration) have identified technical opportunities to reduce climate-affecting gas emissions. They have also identified non-technical barriers to these changes – a work that is ongoing. We will continue to develop this work by adding buildings and integrating with the new tasks for enhancing industrial implementation (Tasks 1.1. and 1.3).
- Scientific exchanges between different work packages will continue through scientific conferences, bilateral talks and visiting scholars.
- We will continue the highly appreciated monthly webinars that inform about and discuss the ongoing work. The participation has been encouraging, with some 25–30 participants in each meeting, including researchers, industrial partners and members of authorities.
- We have produced one multidisciplinary synthesis report and two more are under development that include technical, policy and behavioral aspects of climate transformation. We will continue this work in Phase 2.

Although we are encouraged by the positive responses from our end-users, due to the interdisciplinary aspects and geographic spread of the programme we have the aim to enhance further the internal exchange and information activities across the different parts of the programme. There is also interest from industry to acquire knowledge beyond their current field of business. For example, a couple of the industrial partners with good insights in the technical aspects of transport infrastructure have expressed an interest in learning more about policy and behavioral issues. Therefore, we intend to implement some additional measures for improving information exchange, collaboration and integration, as described below.

Academic exchange and collaboration:

- **Digital scientific meetings** that include our international partners will be organized on a regular basis. The aims of these meetings are to exchange research results between the participating organizations and work packages and to enhance collaboration. These meetings will take place on three occasions per year.
- **Exchange of scholars** between organizations will be encouraged and there will be an earmarked budget for travel costs. We aim for at least two people per year to spend at least 1 week at a partner organization.
- **Fellowship.** The fellowship in Phase 1 has been very successful in increasing collaboration between CEPS, IVL and Chalmers (for details, see our Progress Report). In Phase 2, we will investigate if we can have one more fellow from one of the participating organizations.

6.6 PhDs and Fellowships

Phase 1 had four PhD students (two at Chalmers ET, one at Chalmers FRT and one at DIW), three of whom were fully devoted to work as part of MCE. One of the PhD students has been awarded the degree and the remaining three students will continue to work in Phase 2. More details about our PhD students are given in the Progress Report. Two new PhD students will be recruited and devoted to MCE in Phase 2. One of these will be at Chalmers ET and the other one from IVL but performing her PhD studies at Chalmers FRT.

The fellowship in Phase 1 has been very successful in increasing collaboration between CEPS, IVL and Chalmers (see our Progress Report for more details). In Phase 2, we will investigate whether we can arrange to have one more fellow from one of the participating organizations.

7 Communication and implementation

Written publications constitute a central part of our communication plan, either as **peer-reviewed articles** in journals or through **reports, policy briefs** and **white papers,** tailored to target specific end-users. **Outreach activities** in the form of **seminars, workshops and conferences** are important and will continue in Phase 2. We will also participate in external conferences and seminars. **Media exposure**. MCE has taken an active part in the public climate discourse, mainly through press activities. Opinion pieces and targeted press releases for the daily press and ether-based media have been important means of communication for us and we intend to continue doing this in Phase 2. **Website**. In Phase 2, the MCE website will continue to serve as our main hub for sharing research results both externally and internally. The site will provide links to publications and inform about seminars, other activities and news. We will continue to publish our newsletter four times a year and an annual report every year. **Strategic arenas:** Our collaboration with CEPS in Brussels has allowed us to communicate our results to EU institutions, organize workshops, and engage in dialogue. Through CEPS, we will strengthen our connection with the EU Commission and their work on the EU Green Deal. In 2019, MCE was early in providing the EU Commission with policy briefs and reports, as the president-elect (at the time) Ursula von der Leyen was formulating her climate policy and drafting what was to become the EU Green Deal. MCE focuses on several issues that are prioritized in the Green Deal, for instance the reforming of the EU ETS, climate and trade, carbon capture and storage, and low-carbon production of materials. We will continue to monitor closely the developments with the EU Green Deal, in order to share results and engage in dialogue with the EU

Commission. The **Mistra Secretariat** has also, through their seminars and workshops, been instrumental in helping us present our results to a broader audience and to increase the number of external communication events. In Phase 2, these strategic arenas will continue to be important for the dissemination of results and promotion of dialogue.

Syntheses

In the evaluation report, the panel writes: *"the insights across WPs must be synthesised and published. The dissemination channels and findings must be tailored to specific stakeholders to better align with their roles and decisions."*

We would like to emphasize that we already consider the work in Phase 1 to have established a solid way of synthesizing and disseminating the results. Perhaps the most important synthesis work already takes place through the continuous dialogue and the exchange of knowledge we have with industry and authorities, including the monthly webinars we conduct (with an average of 30 participants). Several tasks have a significant element of synthesis as they include technical assessments, behavior, policy design and stakeholder dialogue (see for instance Tasks 1.1, 1.4, 1.5, 1.6 and 2.1). In addition, we are currently working on two synthesis reports – one for transportation and one for the buildings supply chain. These will be a starting point for discussions with stakeholders. We will also use the output from the research task on just transition (Phase 1) as a basis for synthesizing exercises with end-users, with the aim to provide policy recommendations.

Internal communication

In addition to our website and newsletter, we have a common **project site,** currently *Microsoft Sharepoint*, for sharing documents and other information among the project partners. Each year, we will continue to organize an **annual meeting** for all programme partners, including both academic and non-academic centers, in which we will present and discuss major results and plans for future work. We will have **management group meetings** four to five times per year that will include all seven Swedish academic centers. The goals of these meetings will be to inform each other about progress, to prepare administrative and communicative reports to Mistra, to enhance exchange between researchers and integration across the programme, and to plan outreach activities, such as seminars, conferences and publications. In Phase 2, we will involve the communication officers from academic partner organizations other than IVL in order to improve information sharing across the organizations and enhance outreach initiatives. The communications budget will be strengthened accordingly.

Implementation

WP5 provides details on our plans for implementation.