

Annual Report
Mistra Carbon Exit

2019

MISTRA
CARBON
EXIT ▶▶



Project leader: Jessica Kriström, IVL Swedish Environmental Research Institute

Graphic design: Mia-Maria Hedberg, IVL Swedish Environmental Research Institute

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“A transition to net zero emissions will require extraordinary decisions by actors in all affected sectors.”

A few words from the board

The overall purpose of Mistra Carbon Exit is to provide analyses to aid Sweden reach the politically set goal of net zero greenhouse gas (GHG) emissions by 2045. The programme focuses on buildings, transportation infrastructure and transportation supply chains, including those of energy carriers and base materials producers. A transition to net zero emissions will require extraordinary decisions by actors in all affected sectors, such as government, businesses, and consumers. To ensure an impact on these actors the project has chosen to include stakeholders at very early stages of the programme and to involve them in all relevant activities. The success of the project will depend on an ability to stimulate change across technical, economic and political perspectives.

2019 was the third year of Mistra Carbon Exit programme, and the board is very pleased to note the results delivered by all the various sub-projects. These results include low-carbon technical roadmaps, policy instrument analyses and investigations into attitudes among industrial leaders. It has also been very encouraging to notice how these results have reached our stakeholders and are really making an impact. In this context, we can mention that output from the programme has been used in developing the Swedish climate action plan. The programme has also intensified its activities towards the new EU parliament and the EU Commission, driven by the fact that several of the

research topics in Mistra Carbon Exit overlap with the EU Green Deal. For this reason we have provided input to the new EU Commission in the areas of emissions trading, carbon capture and storage and trade.

The way in which the research achievements have been communicated and debated – seminars, workshops, bilateral meetings – with stakeholders has underpinned the success of the programme. This inclusive approach, which was a clear profile in 2019, bolsters expectations for the outcome of the entire programme.



Peter Nygårds,
Chairman of the
programme board

2019 was the springboard and more results are in the pipeline

LARS ZETTERBERG AND FILIP JOHNSON, PROGRAMME DIRECTOR AND VICE PROGRAMME DIRECTOR

Three years into the programme and we are harvesting the results and are able to communicate the fruits of our research. Some examples of this are our three roadmaps – cement, steel and buildings – that showcase the technologies able to deliver a net zero carbon economy by 2045.

Different transportation scenarios have been analysed that provide us with an understanding of the impacts of shared mobility and autonomous vehicles. A first critical analysis of sustainable assessment tools in industry has been developed and pre-published in an international conference. Attitudes about climate leadership have been studied in a set of focus groups. Several studies that examine the potential role of various policy instruments, e.g., emissions trading, public procurement and base materials policies, have been brought to the fore.

A list of all we have achieved with the programme would be too long, but you will find our key deliverables further down in the report and a few are cited immediately below.

We have entered the twenty-twenties, and the coming decade will be critical for climate action, both in Sweden and

internationally. IPCC has shown that global emissions must be capped and set on a downwards trajectory very soon if there is to be any chance of complying with the Paris Agreement.

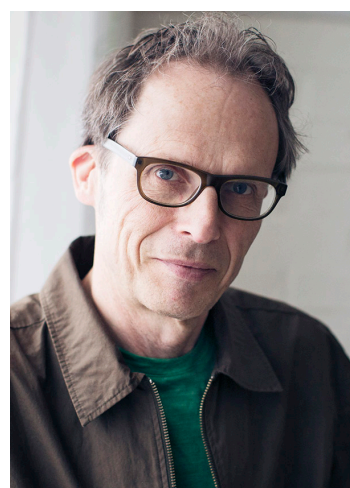
The incoming EU Commission has indicated that it intends to become a leader on the world stage when it comes to climate action, but these intentions must be translated into concrete action.

Industry and authorities in Sweden must ramp up efforts to reduce emissions in the building, transport infrastructure and transportation supply chains. Mistra Climate Exit believes that the programme will be able to play an important role in providing decision support in the transformation of these supply chains. In 2020, we will continue to deliver knowledge about how Sweden can meet the net zero emissions target by 2045, and we will communicate our results to key stakeholders in Sweden and across the world.

We hope that you will find this annual report useful, and that you will follow us in 2020 through our newsletter, website and seminars, and we encourage you to take personal contact with researchers in the programme.



Lars Zetterberg,
IVL Swedish Environmental
Research Institute



Filip Johnson,
Chalmers University
of Technology



Key 2019

Mistra Carbon Exit deliverables

- **Three Roadmaps for infrastructure** have been published: Toktarova, A., Karlsson, I., Rootzén, J., Odenberger, M., 2019. Scenarios and roadmaps exploring different future pathways and developments in the steel and cement-industries and in the buildings and infrastructure supply chains have been developed.

- **Negative emission technologies.** A marginal cost curve for CCS and BECCS has been developed.

- **The electricity system.** Scenario narratives for the North European electricity system including the electrification of the steel industry and passenger vehicles have been created. With these scenarios as a starting point, the impact of electrification from a systems and sectors perspective has been evaluated.

- **Transportation scenarios.** Scenario narratives for future personal car use in Sweden with focus on major uncertainties vis-a-vis the development of connected and autonomous vehicles as well as with shared mobility.

- **Policy dialogue with several Swedish and EU institutions** including Swedish EPA in preparation for Sweden's climate action plan; the Swedish investigation on negative emissions, "Vägvalsutredningen"; the Climate Policy council in preparation for their assessment report; Sweden's Foreign Office on forming a Swedish position for energy investments in Eastern EU; Sweden's permanent representation in Brussels in preparation for a more stringent EU climate target; and the EU Commission prior to the installation of the incoming von der Layen Commission. For these dialogues, a series of papers has been produced:

- o Zetterberg, L., Källmark, L., Möllersten, K. Incentives and financing of Bio-CCS in Sweden. June 2019.

- o Zetterberg, L., Elkerbout, M., The future of the EU Emissions Trading System – Responding to the Green New Deal Proposals. Dec 2019.

- o Christian Flachsland, Michael Pahle, Dallas Burtraw, Ottmar Edenhofer, Milan Elkerbout, Carolyn Fischer, Oliver Tietjen, Lars Zetterberg: "How to avoid history repeating itself: The case for an EU ETS price floor revisited," Climate Policy (Jan 2020).

- o Zetterberg, L., Elkerbout, M. (editors), Göransson, L., Johansson, D., Johnsson, F., Karlsson, I., Rootzén, J., Odenberger, M., Neuhoff, K., Chiapinelli, O., Löfgren, Å., Kadefors, A., Erlandsson, M., Källmark, L., Research in Mistra Carbon Exit relevant to the DG GROW HLG on industrial transformation. June 2019.

- o Neuhoff, K., Chiappinelli, O., Gerres, T., Haussner, M., Ismer, R., May, N., Pirlot, A., and Richstein, J. (2019), "Building blocks for a climate-neutral European industrial sector. Policies to create markets for climate-friendly materials to boost EU global competitiveness and jobs", Climate Strategies Report.

- o Elkerbout, M., Zetterberg, L., Möllersten, K., Johnsson, F., Johansson, D. An integrated strategy for carbon capture and storage and negative emissions in the EU. Policy brief (in draft). IVL Swedish Environmental Research Institute, Box 21060, SE-10031 Stockholm, Sweden.

- **A synthesis report** is under preparation linking the findings from technologies, policy instruments and behaviour into a single report.

- **Green public procurement.** A report concerning green public procurement has been finalised (Kadefors et al, 2019).

- **A transformation fund** together with the banking sector is under development.

- **Understanding attitudes to car sharing.** A full experimental study exploring the attitudes of 1000 car owners in Gothenburg towards car sharing and electrification is ongoing.

- **Climate leadership in firms.** An experiment targeting industrial leaders is under preparation.

- A book - Linnér, B.-O. & Wibeck, V. **Sustainability Transformations. Agents and Drivers across Societies** (Cambridge University Press) has been finalised.

- An **SDG Impact Assessment Tool** has been developed and is available online at www.sdgimpactassessmenttool.org.

- A first **critical analysis of SDG assessment tools** in industry has been completed and a journal paper has been submitted for publication.

About Mistra Carbon Exit

The Mistra Carbon Exit programme addresses and identifies the technical, economic and political challenges that Sweden will encounter when it attempts to reach the net zero greenhouse gas emissions target by 2045. This target will require transformative pathways in virtually all industrial processes and their associated products and services.

Mistra Carbon Exit takes a novel approach in addressing this problem by focusing on opportunities and barriers for mitigating carbon emissions along industry supply chains – from the input of raw materials, through primary and secondary activities, to final products and services demanded by the end user.

In three industrial case studies we assess the buildings, transportation infrastructure and transportation supply chains. These supply chains allow us to identify around 75 per cent of Sweden's carbon dioxide emissions.

The programme examines and identifies pathways and policies that will enable Sweden and Swedish companies to become frontrunners when it comes to rapidly transforming society and industries – providing low carbon products and services while simultaneously addressing market risks. This will make Sweden an important international example for other countries to follow in a holistic perspective that embraces multiple technical, social and policy points of view.

Mistra Carbon Exit is a four-year programme that addresses the technical, policy, economic and market opportunities for different scenarios that will deliver emissions reduction targets by 2045 by focusing on three supply chains: buildings, transportation infrastructure and transportation.

We have divided our efforts into four case studies (energy carriers, buildings and transportation infrastructure, transportation and local arenas), five academic work packages and a communication package. The academic work packages investigate and define transformative pathways, technology assessments along supply chains, changing market institutions and attitudes towards commonly held Swedish leadership principles (which are consensus-based, team-focused and non-hierarchical), policies and governance, and integration and sustainability implications.

The Mistra Carbon Exit consortium embraces a broad representation of researchers and actors: four universities: Chalmers University of Technology, University of Gothenburg, Linköping University and the Royal Institute of Technology (KTH), four research institutes: IVL Swedish Environmental Research Institute, Resources for the Future (RFF), The German Institute for Economic Research (DIW), The Centre for European Policy Studies (CEPS) and 20 non-academic partners.



“Mistra Carbon Exit’s selected supply chains allow us to capture at least 75 per cent of Sweden’s carbon dioxide emissions.”

One plus 16 sustainability dimensions

ANDERS AHLBÄCK, WP 5: INTEGRATION AND SUSTAINABILITY ASSESSMENT

As challenging as it may be to identify pathways to reach net zero carbon emissions, we are still only addressing one dimension of sustainability. What happens when we add 16 more?

Through the launch of the UN 2030 Agenda for Sustainable Development in 2015, actors across the globe were presented with an ambitious framework pinpointing major sustainability challenges of global relevance. These challenges are described as 17 Sustainable Development Goals (SDGs), all agreed upon by the UN member states. While the SDGs do not put forward *new* challenges per se, together they form an integrated and holistic agenda to drive sustainable development on all levels of society. The main implication is that we cannot cherry-pick or play whack-a-mole – that is, create solutions for specific SDGs that might pose problems to the implementation of others. Rather, these 17 dimensions of sustainability need to be addressed as a whole, which indeed poses a great challenge.

The transformative pathways developed in the Mistra Carbon Exit programme will help Swedish stakeholders achieve carbon neutrality by 2045 and, thus, the implementation of SDG 13 *Climate Action*. Given the scope, scale and ambition of the transformations – targeting buildings & infrastructure, transports and energy carriers – there is an urgent need to identify and evaluate trade-offs between *Climate Action* and other SDGs as well as potential synergies. This is the main aim of the SDG impact assessments carried out in the Mistra Carbon Exit programme, focusing on key components of the transformative pathways.

In collaboration with case study leaders, the following study objects for SDG assessments have been defined: (i) carbon neutral cement and concrete, (ii) electric vehicle batteries (EVb) and (iii) renewable energy technologies (RETs), specifically wind power, photovoltaics and bioenergy. The underlying rationale is that they are all *essential* within the scope of Mistra Carbon Exit to reach the goal of carbon neutrality by 2045. The methodological starting point is a structured approach to identify and characterise impacts from the study objects using the SDG Impact Assessment Tool¹. For each case study and each SDG, the context, mechanism,

magnitude and assessment of risks and opportunities in Sweden as well as abroad (spillovers) are assessed.

The assessments are carried out in a series of iterations, in a Delphi-inspired approach, aiming to increase confidence in each step. Case study leaders and associated expertise have during the autumn of 2019 provided initial input to workshops and will later be asked to give second opinions on a refined, reviewed and structured assessment. This spring the focus is to produce a first paper presenting the methodological approach and associated risks and opportunities of wind power linked to the SDGs.



Anders Ahlbäck,
Gothenburg Centre for Sustainable Development, GMV

FOTO: Nina Silow

¹www.sdgimpactassessmenttool.org

Opportunities for carbon pricing and its limits

DALLAS BURTRAW, WP 4: POLICIES AND GOVERNANCE

A pressing question for Sweden is how to achieve the nation's 2045 goal of greenhouse gas neutrality while preserving economic well-being. To achieve this ambitious outcome seems to require that emissions reductions be achieved at minimum cost. The standard strategy for cost reduction coming from economic luminaries is to rely on carbon pricing. However, over recent decades, many readers have taken this to mean that carbon pricing by itself would be policy enough. The Mistra Carbon Exit analysis of marginal cost pricing and multi-level policies has cast this economic advice in a fuller and more proper light.

Indeed, prices are a powerful force in allocating resources in society. Prices influence decisions one makes daily; however, they do not determine outcomes. Habits, social relationships, and physical and human capital also influence outcomes. Even economic relationships limit the effectiveness of prices as a policy instrument because market forces work to undermine carbon prices in jurisdictions that try to implement prices unilaterally.

Mistra Carbon Exit has worked to identify the opportunities for carbon pricing, its limits, and how those limits can be overcome. Some examples include the following:

- Deep decarbonisation requires **innovation and investment**. Carbon pricing can incentivise innovation, but it can also cause investment to occur outside the regulated jurisdiction. Every programme has measures to mitigate against leakage, but these programmes have not been tested with the seriously high prices necessary to drive investment decisions. Programme design must better anticipate how carbon revenues can be used to promote domestic clean investment.
- **Uncertainty** about technology and future regulation raises the hurdle rates for new investment. Infrastructure planning and industry-specific performance standards can help coordinate investment.
- Industrial commodities such as cement and steel are elements of **complicated value chains**. A carbon price that may have only a small effect on the product price can have a large effect on commodities involved in production. Regulatory policy can complement carbon pricing to support the transformation of these industries.
- **Decision making inside complex organisations** involves rules of thumb and metrics of performance that are only indirectly affected by the prices facing the organisation. Regulatory standards may usefully promote a cultural

transformation and innovation effort within the firm that enables a more successful response to carbon pricing.

- Political decisions are heavily influenced by **perceptions of equity**. Prices do not require a specific outcome and provide firms with flexibility, but this can be viewed as a pass for industry, from the perspective of some interested stakeholders. Reasonable rates of progress can be introduced as companion policies to pricing to boost public confidence while preserving flexibility in outcomes.

Mistra Carbon Exit promotes the important conclusion that multi-level policies can be a constructive companion to carbon pricing. Of special interest is the role of **flexible emissions performance standards**, which can be overlaid carbon pricing to achieve more powerful incentives for innovation and investment than can be achieved with a carbon price alone. These standards can be made flexible by allowing firms to sell credits when they overachieve a product specific benchmark. They have the inherent characteristic of keeping carbon credit value in the sector, rewarding firms that are innovators, and suppressing the change in the final product price. We are looking at examples in transportation, industry and electricity from around the world to find lessons that can help Sweden advance towards its climate goals.



Dallas Burtraw,
Resources for the Future

Roadmaps for strategic choices and key actions

IDA KARLSSON AND JOHAN ROOTZÉN, CASE STUDY: BUILDINGS AND TRANSPORTATION INFRASTRUCTURE

Activity within the Buildings and Transport infrastructure case study has continued over the year with regular webinars and representation at key industry workshops and collaborative projects. Yet, most of the focus within the case study has evolved around the development of a set of roadmaps exploring, both quantitatively and qualitatively, different possible trajectories of technological developments in the buildings and transportation infrastructure supply chains, including primary production of steel and cement.

The Mistra Carbon Exit Roadmaps outline material and energy flows associated with different technical and strategic choices and explore interlinkages and interactions across sectors. Thus, by linking short-term and long-term goals with specific technology options, the Mistra Carbon Exit roadmaps describe key decision points and potential synergies, competing goals and lock-in effects.

The results show how strategic choices with respect to process technologies, energy carriers and the availability of biofuels, CCS and carbon neutral electricity may have very different implications on energy use and CO₂ emissions over time. The results also illustrate the importance of intensifying efforts to identify and manage both soft (organisation, knowledge sharing, competence) and hard (technology and costs) barriers and the importance of acting now, and in parallel, on both measures with shorter (e.g., material efficiency and material/fuel substitution measures) and longer lead times (low-CO₂ steel or cement). Deep decarbonisation will require not only technological innovation but also innovations in the policy arena and efforts to develop new ways of cooperating, coordinating and sharing information between actors.

The ambition is that the roadmaps will provide a basis for external communication with stakeholders and policymakers about the strategic choices involved in the Swedish climate transition, and also be used internally for continued analysis in the Mistra Carbon Exit programme.

Similar roadmaps are also under development within Mistra Carbon Exit for Transportation (with an emphasis on the future role of automation, electrification and sharing in the car fleet) and energy carriers (including scenarios exploring different future developments of Swedish and North European electricity systems).

Close collaboration with both public and private stakeholders involved in the Mistra Carbon Exit research programme has been crucial to the development of the roadmaps. The last few years have been a period of collective learning with regard to the challenges and opportunities involved in the climate transition. Still, while there is a relatively broad consensus both in politics and industry that Sweden should be at the forefront of climate action, the details of what this commitment should entail are still under negotiation. We hope that our roadmap can be one of the pieces in the puzzle, pinpointing what is at stake and required from stakeholders, if we are to realise ambitious CO₂ emissions reduction goals in the construction sector and associated supply chains. As we move into a new decade, we look forward to continuing being part of this process of collective learning, and hopefully, collective action. If the 2010s was the decade of discussion, let's make the 2020s the decade of action.



Ida Karlsson,
Chalmers University
of Technology



Johan Rootzén,
University of Gothenburg

Policy design for greening construction supply chains

OLGA CHIAPPINELLI, WP 4: POLICIES AND GOVERNANCE

A successful transition of the construction sector to net-carbon neutrality will most likely require a portfolio of mitigation options. On one hand, enhancing material efficiency and recycling is essential to reduce the demand for primary production of carbon intensive materials and thus helps to alleviate resource constraints. On the other hand, developing and deploying clean production processes will also be necessary, as building and transport infrastructures will likely continue to require significant volumes of currently carbon intensive materials.

Three policy instruments have particular potential to support the portfolio of mitigation options and guide the construction sector towards net-carbon neutrality, namely (i) Carbon pricing, (ii) Green public procurement, and (iii) Carbon-intensity standards for buildings. However, these policies have so far been developed in parallel by different research communities and institutions. Therefore, to date potential conflicts and synergies between instruments – crucial aspects for effective policy design – have been overlooked.

For this reason, at the end of May a workshop was organised in the context of WP 4 with the purpose of bringing together these different communities to discuss the potential of the three policy instruments, as well as experiences in connection with their implementation and the barriers encountered so far, as well as possible solutions to overcome these.

The workshop, held at the Swedish EPA, was arranged as a joint event between Mistra Carbon Exit and the Climate Friendly Materials Platform, led by the German Institute for Economic Research, DIW Berlin and the Climate Strategies research network.

The workshop helped highlight existing barriers, implementation challenges and the potential for interaction as a starting point for the next steps needed for a decarbonisation of the construction sector. A workshop summary of the main insights emerging from the discussions held during the workshop was published. One of the main insights was that standards and procurements are easy to understand in an abstract way, but careful implementation is required to make them effective.

The timely and instructive discussion initiated with the workshop has to be continued. There is interest from the public administration side in Sweden to follow up on such a discussion and possibly establishing its conclusions as an international standard. In addition, experiences on policy implementation at the national level can be helpful for learning from the perspective of EU-level policy making. Therefore, the priority should be bringing the policy faster to national levels, in order to explain in advance some of the more complex issues. Given this objective, there is a plan to continue the discussion (e.g., with the organisation of follow-up workshops) and in parallel develop analytical work on individual instruments, which is already ongoing as part of WP 4 research activities.



Olga Chiappinelli,
DIW Berlin,
German Institute for Economic Research

Consumers making sense of carbon exits

KAJSA-STINA BENULIC, WP 3, POSTDOC, LINKÖPING UNIVERSITY

Achieving the target of net zero greenhouse gas emissions by 2045 implies transformative change at a societal level. In WP 3 we have turned our gaze to Swedish consumers and how they make sense of changes spanning the cultural, social, political, technological, and economical spheres.

What will everyday life look like in net zero emission Sweden? How do we get there? To answer these questions, we have set up focus groups and gathered together consumers of different ages and educational backgrounds, living either in urban areas or in the countryside. With the help of interactive visualisation tools, these consumers formulated visions of net zero emissions Sweden and what their lives would be like then. Additionally, consumers rated and discussed the effectiveness and desirability of specific products and services, for example car-sharing.

The focus group transcripts and visualisations contain visions of behaviour changes in the practical sphere, for example ride-sharing and increased travelling by train, as well as life-style changes, such as staycationing and working fewer hours. The visions also included changes in the political sphere – investments in infrastructure and policy reforms, to name but a few. Similar visions can be found in roadmaps,

future scenarios and pathways but the interactive focus group setup generates the kind of rich material that also allow a deeper sense-making analysis.

Sense-making analysis contributes the kind of insights that can enhance our knowledge about the dynamics and premises of societal transformation, by probing how the visions and the ways these can be achieved are constructed by participating consumers. Initial readings of the transcripts indicate three topics that permeate the consumers' sense-making of net zero emissions in everyday life and societies. The first topic is plausibility, which is used as a premise for transformative change. The second topic is an urban-rural divide where transformative change, both practical and political, is understood as geared towards an urban way of life. The third topic is personal transformation, i.e., shifts in values, and how these may facilitate behaviour and lifestyle changes.

These topics will be further explored during 2020, and compared and contrasted with how representatives of Swedish industry, environmental politics and administration make sense of sustainable futures and the changes needed to achieve these, something which has been touched upon in a previous round of focus groups.



Kajsa-Stina Benulic,
Linköping University

Reaching climate-neutrality in the EU

MILAN ELKERBOUT, RESEARCH FELLOW, IVL SWEDISH ENVIRONMENTAL RESEARCH INSTITUTE AND AT CENTRE FOR EUROPEAN POLICY STUDIES (CEPS)

The European Green Deal was presented in December 2019 as one of the first acts of the Von der Leyen Commission. Although the document is only about 25 pages long, it presents a sprawling – if not always concrete – vision of how to transform the European economy towards climate-neutrality by 2050. Politically, it is the successor to the Energy Union of the Juncker Commission, that also aimed at treating climate, energy and eventually industrial policy in an integrated manner. With the Green Deal, however, the EU wants to move beyond that and bring social policy, taxation, trade, agriculture, finance as well as regular environmental policy into a single political endeavour. If successful, this would represent a transformation of most areas of EU policy – and therefore of the European economy. In that sense, the Green Deal should also be the driver of European growth and competitiveness.

At the same time, the Commission needs to contend with the same constraints as previous administrations: the EU treaties and competences are still the same and crucially, the EU budget (Multiannual Financial Framework) is not getting any larger – especially without the UK's contribution. Much of the success of the Green Deal will therefore depend on individual pieces of legislation – both new and revised. What can we expect in terms of upcoming legislation?

First, the Commission wants to propose a “climate law” that would embed the 2050 climate neutrality (net-zero GHG emissions) objective into legislation. It also wants to increase the emissions reductions target for 2030 to somewhere between 50 and 55 per cent. A higher target means revising many aspects of climate and energy policy – essentially the whole “2030 framework” policies including the EU ETS, Effort Sharing regulation, renewables and energy efficiency directives.

As an alternative way of mitigating carbon leakage risk, a “carbon border tax” is under consideration, which would tie the domains of trade and climate policy closer together. While it will take some time for such a complicated instrument to be designed, the idea has already drawn the ire of the Trump administration. Other proposals include looking at the energy taxation directive again – a controversial but arguably necessary undertaking given the

member states' powers of taxation – but also integration with other EU policy agendas such as on circular economy, a new industrial strategy, “smart sector integration” (think digitalisation), renovating the European building stock, safeguarding biodiversity, “farm to fork” in agriculture, and specific technology strategies for steel, batteries, alternative fuels, and chemicals.

Then there is the financial dimension with a just transition mechanism for regions that lose out from a low-carbon transition, to disclosure for the financial sector, new state aid guidelines and green budgeting practices. If all this seems a lot it is because, well, it is. Reaching climate-neutrality in the EU is a daunting task that can only be carried out if all sectors and all policies point in the same direction.

Mistra Carbon Exit has this year published two policy briefs on the issues of trade and climate policy interaction, and on the EU ETS, to enable stakeholders to arrive at a deeper understanding of the ongoing discussions within the EU.



Milan Elkerbout,
IVL Swedish Environmental Research Institute
and CEPS

MISTRA CARBON EXIT PARTNER

NCC

Reducing our climate impact is of uttermost importance, not only for future generations but also for the construction sector today and tomorrow. If we are to cut back on our climate footprint we need to work together across disciplines. For this reason, being part of Mistra Carbon Exit is for NCC – one of the largest contractors in Sweden – an opportunity not only to learn but also to make things happen.

The need to reduce climate impact will require us to reevaluate construction project priorities and to step up our efforts to meet climate goals. If we are to succeed with this, cooperation and the avoidance of sub-optimisation is vital. The multi-disciplinary approach of Mistra Carbon Exit leverages new knowledge and perspectives, increased understanding and innovative collaboration with other stakeholders.

When we investigate alternative pathways aimed at reducing emissions in the construction sector, it is necessary to consider many technical aspects of the construction process in combination with the technical constraints of the materials used. This is important to ensure not only the durability, safety and long service-lives of the structures and buildings involved but also buildability and safety on construction sites. We are happy to share any expertise we may have in this regard with our partners in the Mistra Carbon Exit programme.

Mistra Carbon Exit is able to contribute with incisive policy and procurement research in an ongoing dialogue with policy makers. This is important to ensure an efficient and transparent regulatory framework, and essential if we are to speed up efforts to mitigate climate impact in the construction sector.

Nilla Olsson,
Leading Expert Concrete, NCC

MISTRA CARBON EXIT PARTNER

Stena Metall Group

Stena Metall Group operates at the centre of the circular economy, recycling and refining discarded products and waste materials that provide society with recycled raw materials. The Mistra Carbon Exit supply chain focus “from base materials to products and services” spurs us to be part of solutions to climate challenge. We are convinced that collaboration is a vital tool in this regard. The Mistra Carbon Exit network of researchers and business partners offers a wide range of opportunities and involves us in concrete experiences and learning.

Mistra Carbon Exit enables us to expand and deepen our knowledge around challenges and possibilities that can be found within construction, infrastructure and transportation supply chains. We want to be a facilitator and materials provider, and we are keen to benefit from the knowledge and advances the programme brings to the fore.

Our operations span many aspects of the circular value chain, Stena Metall Group contributes with knowledge and expertise when it comes to replacing virgin resources with recycled materials – connecting businesses and turning the waste generated by one sector into the raw material needed by another. We supply hands-on experience about what is required and the limitations that must be overcome as we move towards a more circular economy.

Mistra Carbon Exit’s extensive network of dedicated researchers and business operators is well set to create policy and legislation, stimulating fossil free or low-fossil solutions and behaviour.

Christer Forsgren,
*Research and Development Director,
Stena Metall Group*



MISTRA CARBON EXIT PARTNER

Swedish Environmental Protection Agency

The Swedish Environmental Protection Agency has been given the responsibility of providing the Government with “a map and compass” to help navigate in the economic landscape and make it possible to achieve the goal of climate neutrality by 2045. This has given us a unique overview of the climate-change challenge facing Sweden, enabling us to provide key information concerning issues ranging from official statistics to management of the EU ETS system and not least practical experience as to how environmental taxes and environmental grants have worked in practice.

Mistra Carbon Exit has already delivered rich pieces of new knowledge that have helped us improve our analytical capacity. We find it particularly valuable that the research programme covers the entire value chains for the most crucial sectors of the Swedish economy. We hope and believe that the programme will continue to deliver new knowledge about how the transformation can be realistically achieved, with a particular focus on constructive solutions connected to policy-making in the essential shift towards a fossil-free society.

Stefan Nyström,
*Director,
Department for Climate Change and Air Quality, Swedish
Environmental Protection Agency*



About the programme in detail

The Mistra Carbon Exit research programme seeks to identify and analyse the technical, economic and political opportunities and challenges facing Sweden as the country strives to reach the 2045 net zero greenhouse gas emissions target. The programme is designed to push the knowledge envelope and develop strategies that will enable Swedish society and companies to be frontrunners when it comes to offering low or zero-carbon products and services.

The programme consists of four case studies, these studies focus on energy carriers, buildings and transportation infrastructure, transportation and local arenas. In addition, there are five academic work packages designed to pick apart issues relevant to the case studies. These work packages investigate transformative pathways, technology assessment along supply chains, business models and consumption patterns, policies and governance, integration and sustainability.

Programme period: 2017-2021

Budget: SEK 84.1 million

Funding: Mistra is investing SEK 56 million of the total programme budget, with the remainder coming from partner organisations

Programme host:
IVL Swedish Environmental Research Institute

Programme director:
Lars Zetterberg, IVL

Chairman of the programme board:
Peter Nygård

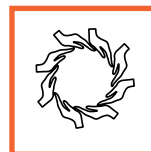
Website: www.mistracarbonexit.com



WORK PACKAGE 1:
Defining transformative pathways



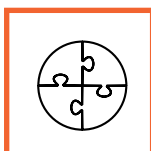
WORK PACKAGE 2:
Technology assessment along supply chains



WORK PACKAGE 3:
Changing market institutions and behaviours towards Swedish leadership



WORK PACKAGE 4:
Policies and governance



WORK PACKAGE 5:
Integration and sustainability assessment

Our key objectives

The proposed Mistra Carbon Exit programme aims to leverage a number of new insights and the key objectives of the programme are:

- **To design transformative pathways for buildings, transport infrastructure and transport supply chains.** Technologies and associated costs across supply chains will be analysed in detail to create a foundation for the design of transformative pathways. This will include developing methods and principles for the cross-sectoral evaluation and design of these pathways.
- **To develop and analyse policy instruments and business models that will enable transformative pathways, while simultaneously mitigating international market risks for Swedish companies and minimising carbon leakage.** Policy instruments and business models will be identified and proposed based on analyses that evaluate politically important issues such as policy stringency, economic efficiency, distributional effects, carbon leakage, and international market risks.
- **To build a world-leading knowledge base on zero-emission products and services and communicate this to academic institutions, industry, research institutes and societal actors.** This knowledge base will reveal crucial opportunities and barriers – as well as potential solutions – for the transformation of buildings, transport infrastructure and transport supply chains that is crucial to meet the Swedish emission reduction target while simultaneously maintaining competitiveness.
- **To develop knowledge on market demand and societal drivers and barriers for carbon efficient products and services.** Demand-side behaviour and attitudes from the public sector, private companies and consumers towards carbon efficient products and services will be investigated, as will implications for procurement policy and best practice.
- **To establish a long-term network connecting academic institutions, industry and governmental organisations.** This will comprise work to evaluate transformative pathways and develop sustainable solutions using real case study data in collaboration with industrial partners within the Mistra Carbon Exit consortium.
- **To engage with national and international stakeholders in communication and dialogue concerning transformative pathways for a zero-emission society.** Mistra Carbon Exit will engage in dialogue with both national and international stakeholders in industry, government, research and NGOs via an ambitious communication plan and interactions with the Sustainable Development Solution Network – Northern Europe (SDSN-NE) framework.

Mistra – Active funding for sustainable development

Research from Mistra is intended to result in a good living environment and promote the development of strong research environments with a bearing on Sweden's future competitiveness.

The aim is that investments should contribute to the development of new products, services and working methods to meet society's environmental challenges, by companies, public stakeholders and other users.

Mistra is investing SEK 56 million of a total program budget of SEK 81.4 million, with the remainder coming from partner organisations.



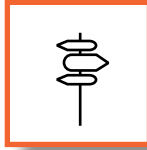
Work packages and case studies

Work is organised under four case studies (CS) and five academic work packages (WP). The case studies enjoy a high level of involvement from our non-academic partners, while the work packages are mainly academic. Each work package involves a raft of different tasks. The case studies are underpinned by the findings of the academic work packages.

Close dialogue and an ongoing information exchange are important facets of cooperation between case studies and work packages. To support this process, we have allocated significant resources to integration and communication activities across the programme.

Work packages

WP 1: DEFINING TRANSFORMATIVE PATHWAYS



The 2045 net zero greenhouse gas emissions target will require transformative pathways across virtually all industrial processes and associated products and services. Our efforts will investigate and define both external and internal scenarios. The external scenarios inform the development of external factors that feed into the internal scenarios. The internal scenarios illustrate the ways in which buildings, transports and industry can be decarbonised.

External scenarios are analysed and defined at Global, EU and Swedish levels. The internal scenarios identify available strategic decisions to leverage the decarbonisation of buildings, transport and industrial supply chains through, e.g., electrification, biofuels, carbon capture and sequestration (CCS), modal shifts, planning and changes in behaviour.

WP 2: TECHNOLOGY ASSESSMENT ALONG SUPPLY CHAINS



The scientific base of WP 2 is the evaluation of technologies along the entire supply chain – from raw materials to final product and/or service provision. This enables us to identify options for mitigating carbon emissions and costing their reduction. An important innovation is the inclusion of a timeline, i.e., how supply chains, including energy carrier deliverables, develop over time. This is particularly relevant for electricity – as pointed out above – this will be increasingly provided by variable sources (wind and solar) which makes it vital to investigate links to other sectors.

WP 3: CHANGING MARKET INSTITUTIONS AND BEHAVIOURS TOWARDS SWEDISH LEADERSHIP



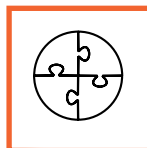
Work in WP 3 departs from the state of art research common in social science, including economics, social psychology, management science and political science, which complement each other to provide a comprehensive picture of market behaviour and response to attitudes and climate policies. The behavioural approach we have adopted specifically draws on behavioural economics and social interaction and recognises that society can shape individual preferences and beliefs – in particular through institutions, social norms and socialisation processes.

WP 4: POLICIES AND GOVERNANCE



Research in WP 4 is firmly grounded in economic theory but goes far beyond simple textbook “homo economicus” models. The methods used in WP 4 span theoretical approaches that utilise economic modelling as well as more empirical work based on econometric methods using register data and data fetched from experimental approaches. Some tasks also include collaborations with case studies. Furthermore, in all tasks care is taken to identify potential overlapping or interaction effects (negative or positive) that may arise from policies targeting activities in multiple sectors.

WP 5: INTEGRATION AND SUSTAINABILITY ASSESSMENT

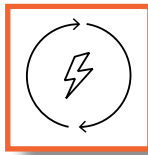


WP 5 will contribute to the project by synthesising results from the different activities in the other work packages and case studies. Since the Mistra Carbon Exit project is informed by scientific research from a number of different disciplines and applies different methods, including modelling, experimentations and case studies, the scientific challenge is to focus on synthesising results and knowledge from a variety of different scientific fields. The professional experience and practical perspectives of different stakeholders must also be taken into account. A transdisciplinary perspective, where different disciplines, together with the knowledge and priorities of stakeholders, contributes to the analysis and the final integration of results.

WP 5 also examines sustainable development – here represented by the sustainable development goals (SDG), and Swedish environmental objectives (SEO). These overarching goals provide a framework that enables the linking of WP 1-4 findings on transformative pathways to a development agenda that subsumes global and regional development challenges.

Case studies

CASE STUDY: ENERGY CARRIERS



This case study takes as point of departure the European electricity generation system modelling package (ELIN and EPOD models), in which different future scenarios of electricity generation can be assessed, allowing different policies on emission reduction, the share of renewable electricity, and energy efficiency measures to be addressed. The case study will focus on and assess the use of electricity and biomass derived fuels along buildings, transportation infrastructure and transportation supply chains. This will be carried out in dialogue with industrial partners, including Energiforsk and associated networks within the energy industry (especially the network established for the North European Power Perspective project).

CASE STUDY: BUILDINGS AND TRANSPORTATION INFRASTRUCTURE



These two case studies are based on one (or several) ongoing building and infrastructure construction projects that provide reference points for how material, energy and transport and mobility services can be used in the construction process, including the way in which construction materials are produced and supplied. The mapping and description of the energy, material and value flows involved provides the basis for an investigation into how supply and value chains can be transformed in future, similar, building projects while simultaneously maintaining competitiveness in carbon restricted markets. The formulation of the transportation case study will be carried out in close cooperation with the transportation and energy carrier case studies, since these will share scenarios on the future pathways of the transportation and energy system towards zero emissions and increased use of renewable energy supply.

CASE STUDY: TRANSPORTATION



There are different potential energy supply options available to leverage net zero emissions in the transport sector (primarily biofuels, electrification and hydrogen-based fuels), however each of these options runs up against different challenges and constraints. In addition to a growing interest in various low-carbon dioxide energy propulsion options, the transport sector is impacted by trends such as digitalisation, servitisation, and automation that can radically transform

the way in which we transport people and goods. A key challenge is to steer this development towards high energy efficiency and low supply chain carbon dioxide emissions. It is important to evaluate the impact of alternative low-carbon dioxide energy propulsion options, autonomous vehicles and the increased use of intermodal urban transport, on the transformation of the transport supply chain towards net zero carbon dioxide emissions.

CASE STUDY: LOCAL ARENAS



In Sweden, regions have often had more ambitious climate targets than the national target and have been willing to move faster (for instance the towns of Uppsala, Stockholm and Växjö, as well as the regions of Västra Götaland and Skåne aim at being fossil free by 2030). This trend can also be seen across the rest of Europe, as well as in the US, where the state of California has a long record of being a frontrunner in environmental policies.

The aim of the Mistra Carbon Exit local arena project is to:

- Use the local area to test transformative solutions and identify opportunities and barriers from both technological and policy perspectives.
- Analyse whether national technology and policies solutions are compatible with local targets and actions. For instance: power availability, national transport solutions

and standards that are decisive for local initiatives, and the climate footprints of steel and cement used in housing. What local policies are within the control of the municipality?

- Try to determine the possibly value of municipalities acting as frontrunners in the transformation process, with focus on buildings, transportation and transportation infrastructure, including the possibility to boost renewable technologies such as wind power and the use of biomass.
- To understand if and how dialogue and cooperation between regional and national levels can be improved.
- To provide local stakeholders with science-based advice on how to implement solutions to leverage local prioritised actions.



Key 2019 deliverables at programme level

Key scientific achievements

- A report on scenarios and roadmaps exploring different future pathways and developments in the steel and cement-industries as well as the supply chains for buildings and infrastructure (WP 1, WP 2, Case Study: Buildings and Transport Infrastructure).
- A book *Sustainability Transformations. Agents and Drivers across Societies* (WP 3).
- The publication "Incentives and financing of Bio-CCS in Sweden" (Incitament och finansiering av Bio-CCS i Sverige) (WP 3).
- An article "How to avoid history repeating itself: The case for an EU ETS price floor revisited" (WP 4).
- A final report and executive summary of green public procurement in the Impres project (WP 4).
- Scenario narratives for future personal car use in Sweden with focus on capturing major uncertainty in the development of connected and autonomous vehicles as well as shared mobility (Case Study: Transportation).
- Scenario narratives for North European electricity systems including electrification of the steel industry and the passenger sector. With these scenarios as starting points, the impact of electrification from a systems and sectors perspective was evaluated. Costs and benefits of electrification options offering flexibility to the electricity system were assessed (Energy Case Study).
- A first critical analysis of SDG assessment tools in industry completed and a journal paper submitted for publication (WP 5).
- A methodology to link the findings from the different academic disciplines in the programme – technologies, policy instruments, behaviour and sustainability – presented in a synthesis report (WP 5).
- A SDG Impact Assessment Tool, available at www.sdgimpactassessmenttool.org (WP 5).
- A full experimental study targeting the introduction of 1000 car owners for car sharing and electrification in Gothenburg (WP 3).

Key administrative results

- The programme board met four times in 2019. The board consists of Peter Nygårds, Chair for the Foundation of Stiftelsen IVL, Birgitta Resvik, Sameko, Erik Eriksson, Formas, Stefan Nyström, Naturvårdsverket, Anna Denell, Vasakronan and Kristina Sundin Jonsson, Municipality of Skellefteå. Kristina joined the board in 2019.
- Five management group meetings were held.
- A programme assistant was introduced, tasked with supporting the programme director in various areas.



Key meetings, seminars and international scientific conferences

Meeting our target groups on a regular basis through seminars, workshops and bilateral meetings is essential to the programme. These meetings serve multiple purposes, such as sharing and discussing research results, understanding our stakeholders' priorities, connecting our researchers across the sub-projects and building a community and a platform around central Mistra Carbon Exit topics. Some of these are presented below:

- In January the programme organised a seminar about the outcome of COP 24 in Katowice.
- In February Frances Sprei, Lisbeth Dahllöf and Mark Sanctuary participated at the CEPS Ideas Labs conference in Brussels to discuss mobility, batteries and trade issues.
- In April Johan Rootzén participated in a reference meeting at the Swedish Transport Administration, discussing greenhouse gas emissions and energy consumption in infrastructure projects.
- In May DIW and IVL organised a workshop on Policy Design for Greening construction supply chains in Stockholm.
- In June, the programme in collaboration with Mistra and the Swedish representation in Brussels, organised the seminar "Reaching net-zero emissions in the EU by 2050 – opportunities and potential in the context of partnerships between academia, industry and the public sector".
- In June, CEPS arranged the Low Carbon Economy Forum in Brussels where Mistra Carbon Exit representatives were among the speakers. The theme was Industrial implications of EU and global climate change policy.
- In September nearly all Mistra Carbon Exit partners, totalling 43 participants from 25 different organizations, came together at our programme conference in Stockholm, Sweden.
- In October, Thomas Sterner held a speech at the Ministry of Foreign Affairs on how to reach the Paris agreement: concrete proposals for action, countries, companies and individuals.
- In October the programme organised a lunch seminar in Stockholm dedicated to Bioenergy with Carbon Capture and Storage – opportunities and challenges.
- In November the programme participated in the seminar "Coordinating the next wave of EU climate policies", organised by Mercator Research Institute on Global Commons and Climate Change and the Potsdam Institute.

Key communication and media exposure

To increase visibility and communicate our results to a broader audience, Mistra Carbon Exit researchers have played an active part in the public climate discourse. Mistra Carbon Exit and its researchers have been mentioned in over 45 media appearances.

We have also been successful in publishing opinion pieces in major Swedish newspapers:

- "Osäkerhet om CCS-teknikens kostnader ökar behovet av strategi". Opinion piece, DN, Filip Johnsson, Jan Kjärstad and Fredrik Normann.
- "Koldioxidlagring kan enkelt halvera utsläppen i Sverige". Opinion piece, DN, Filip Johnsson, Jan Kjärstad and Fredrik Normann.
- "Orealistiskt tro att FN kan få igenom en effektiv global koldioxidskatt". Opinion piece, DN, Filip Johnsson and Lars Zetterberg.
- "Ineffektivt att ge stöd för att annullera utsläppsrätter". Opinion piece, DN, Lars Zetterberg, Filip Johnsson and Svante Axelsson.

The programme web site has regularly posted news and publications. A full-scale version of the website is available in English: www.mistracarbonexit.com.

In 2019, the programme has published four newsletters.

Organisation

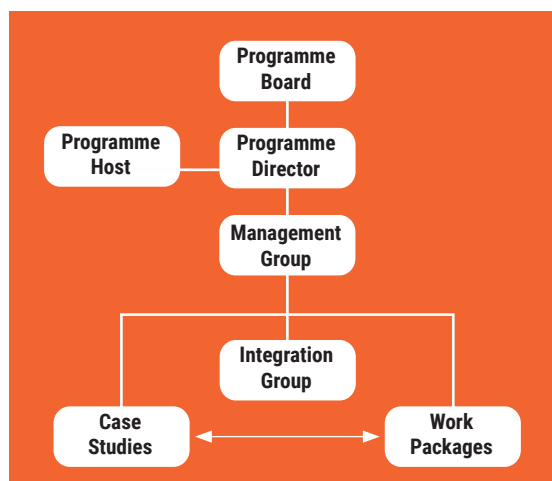
PROGRAMME BOARD

Peter Nygårds (Chairman)
 Birgitta Resvik, SAMEKO Management
 Erik Eriksson, Formas
 Stefan Nyström, Swedish Environmental Protection Agency
 Anna Denell, Vasakronan
 Kristina Sundin Jonsson, Skellefteå municipality

MANAGEMENT GROUP

Lars Zetterberg, Programme director, IVL Swedish Environmental Research Institute
 Filip Johnsson, Chalmers University of Technology
 Magnus Hennlock, IVL Swedish Environmental Research Institute
 Daniel Johansson, Chalmers University of Technology
 Anna Kadefors, Royal Institute of Technology (KTH)
 Lovisa Källmark, IVL Swedish Environmental Research Institute
 Åsa Löfgren, University of Gothenburg
 Jan Pettersson, Gotenburg Centre for Sustainable Development
 Victoria Wibeck, Linköping University
 Sonia Yeh, Chalmers University of Technology
 Jessica Kriström, IVL Swedish Environmental Research Institute (until Feb 2020)

The programme is managed according to the following structure:



PARTICIPANTS

Academic partners

IVL Swedish Environmental Research Institute
 Chalmers University of Technology
 University of Gothenburg
 Linköping University
 Royal Institute of Technology (KTH)
 Resources for the Future (RFF)
 The German Institute for Economic Research (DIW Berlin)
 Centre for European Policy Studies (CEPS)

Non-academic partners

A-betong
 Cementa
 Danske bank
 Energiforsk
 Fores
 Fortum
 Göteborg Energi
 JM
 NCC
 Outokumpu
 Peab
 Region Västra Götaland
 Sacramento Metropolitan Air Quality management
 Skanska
 Stena Metall
 Swedish Environmental Protection Agency
 Swedish Transport Administration
 The Haga Initiative
 Thomas Betong
 Uppsala klimatprotokoll
 Voestalpine
 Volvo Cars
 Volvo CE

Contact

**WORK PACKAGE 1:
DEFINING TRANSFORMATIVE PATHWAYS**

Sonia Yeh,
Chalmers University of Technology,
sonia.yeh@chalmers.se

**WORK PACKAGE 2:
TECHNOLOGY ASSESSMENT
ALONG SUPPLY CHAINS**

Filip Johnsson,
Chalmers University of Technology,
filip.johnsson@chalmers.se

**WORK PACKAGE 3:
CHANGING MARKET INSTITUTIONS AND BEHAVIOURS
TOWARDS SWEDISH LEADERSHIP**

Magnus Hennlock,
IVL Swedish Environmental Research Institute,
magnus.hennlock@ivl.se

**WORK PACKAGE 4:
POLICIES AND GOVERNANCE**

Åsa Löfgren,
University of Gothenburg,
asa.lofgren@economics.gu.se

**WORK PACKAGE 5:
INTEGRATION
AND SUSTAINABILITY ASSESSMENT**

Lars Zetterberg,
IVL Swedish Environmental Research Institute,
lars.zetterberg@ivl.se

Filip Johnsson, Chalmers University of Technology,
filip.johnsson@chalmers.se

**CASE STUDY:
ENERGY CARRIERS**

Lisa Göransson,
Chalmers University of Technology,
lisa.goransson@chalmers.se

**CASE STUDY:
BUILDINGS AND
TRANSPORTATION INFRASTRUCTURE**

Johan Rootzén,
University of Gothenburg,
johan.rootzen@economics.gu.se

**CASE STUDY:
TRANSPORTATION**

Daniel Johansson,
Chalmers University of Technology,
daniel.johansson@chalmers.se

**CASE STUDY:
LOCAL ARENAS**

Stina Stenquist,
IVL Swedish Environmental Research Institute,
stina.stenquist@ivl.se

PROGRAMME MANAGER

Lars Zetterberg,
IVL Swedish Environmental Research Institute,
lars.zetterberg@ivl.se

VICE PROGRAMME MANAGER

Filip Johnsson,
Chalmers University of Technology,
filip.johnsson@chalmers.se

PROGRAMME ASSISTANT

Lovisa Källmark,
IVL Swedish Environmental Research Institute,
lovisa.kallmark@ivl.se

PRESS

Helena Larsson,
IVL Swedish Environmental Research Institute,
helena.larsson@ivl.se

WEBSITE

www.mistracarbonexit.com

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www.mistracarbonexit.com