Annual Report | 2021

MISTRA
CARBON
EXIT

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Contents

Looking back at 2021 and looking forward

The Year 2021 was the first year of the second phase of Mistra Carbon Exit, which will run for four years, from April 1, 2021 to 31st of March 2025. Strengthened by the positive feedback from our end-users and the decision by Mistra to fund a second phase, we are very glad and excited to continue this program with our research colleagues and partners in industry and municipalities.

In the second phase we continue 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.

But there will also be new features in Phase 2:

Strengthening collaboration. In Phase 2 we will launch a set of implementation projects, aiming at applying our research results more directly into the operations of our industrial partners. We will create opportunities for collaborating across work packages and institutions through a set of cross-disciplinary research seminars and joint projects.

New research areas have emerged, for instance, related to the "Fit for fifty-five" climate package proposed by the European Commission in 2021. We will closely monitor and analyze this proposal to provide decision support to the Swedish government and its agencies. Another area receiving attention is negative emissions by means of Carbon Capture and Storage from biogenic emission sources (bio-CCS). Sweden has favorable conditions for producing Bio-CCS, but there are concerns related to large scale implementation of Bio-CCS. We will investigate how to establish sound markets for negative emissions in close cooperation with Swedish policy makers.

PhDs. In addition to our 3 PhDs from Phase 1, we have recruited two new PhD-students. Qiyu "Aaron" Liu will expand our work on the transformation of the Swedish infrastructure and Cecilia Hult will focus on climate transition in the transportation sector. For more detailed presentations of our five PhDs – please see pages 20-21.

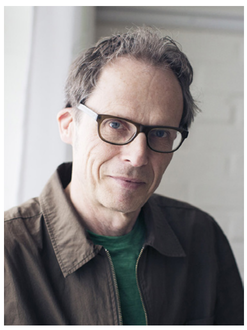
Effects of the pandemic. As in 2020, the pandemic continued to affect us in 2021. Some experiments involving physical participation needed to be postponed, but apart from that, most projects continued as planned. The program conference ("the Mistra Carbon Exit Week"), held in March 2021, was also organized digitally, and allowed us to invite and engage more people than had it been a physical meeting. The conference gathered over 400 participants which would hardly have been the case if it had been a physical meeting. We have taken these experiences with us for our future planning.

Meetings. In 2021, all our seminars, board and management meetings were digital which allowed us to save time and reduce the climate impact from travels. However, digital meetings cannot replace all physical meetings. Such will of course take place when we find them appropriate and effective and when the pandemic allows. In 2022, we particularly look forward to the first physical conference in over two years, which will be held in Nynäshamn on June 1 and 2, 2022.

Changing world. Although the Russian attack on Ukraine is still unfolding and the full effects of it is yet to be understood, it is clear that the war will have an impact on climate transition. The war will have consequences on energy supply in the EU and Sweden, on the supply of critical minerals, on EU policies, on agriculture and on international trade. Our activities in 2022 will include assessments of consequences on Swedish industry from the war. Thus, we hope to be able to assess some of what is proposed in the recent communication from the EU commission "REPowerEU: Joint European Action for more affordable, secure and sustainable energy".

Year 2021 was a year of harvest when we compiled our most important results in the publication "Accelerating the Climate Transition – Key Messages from Mistra Carbon Exit", which presents messages from the program drawn from the first four years. This annual report gives some further examples of our activities in 2021

Lars Zetterberg and Filip Johnsson, April 2022



2. Mistra Carbon Exit in short

About Mistra Carbon Exit

The Mistra Carbon Exit program 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 challenge 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.

The program gathers key Swedish industries, covering the supply chains of buildings, transportation infrastructure and transportation, which allow the capture of at least 75 percent of Sweden's CO_2 emissions. Mistra Carbon Exit was approved for funding by Mistra in December 2016 and started in April 2017. In December 2021 Mistra approved a second phase of the program.

In Phase 1 we identified technical pathways, including a first assessment of opportunities and barriers for their implementation. We also identified and analyzed a set of policy instruments that can trigger these transformative changes, and we started to understand the importance of attitudes and behavior for a successful transition of the supply chains investigated.

In Phase 2 we will focus on key areas related to technologies, governance, behaviors, and policies. 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.

The Mistra Carbon Exit consortium includes a broad representation of researchers and actors: four universities:, including 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 (program 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.

3. Some examples from our research

Hydrogen-mediated direct reduction of steel and the electricity system – a win-win combination

ALLA TOKTAROVA, IDA KARLSSON, LISA GÖRANSSON,
JOHAN ROOTZÉN, MIKAEL ODENBERGER, AND FILIP JOHNSSON

The European steel industry must achieve deep reductions in CO_2 emissions to meet the targets set out in the Paris Agreement. Options for reducing CO_2 emissions include electrification, carbon capture and storage (CCS), and the use of biomass. The plummeting cost of renewable electricity makes expanded electrification an attractive option for eliminating the current dependence of the steel industry on coal.

In Mistra Carbon Exit, we have investigated how electrification of the steel industry using a hydrogen-mediated direct reduction steelmaking process can interact with the electricity system towards achieving zero CO_2 emissions from both the steel industry and electricity sector.

Techno-economic pathways to assess electrification of the steel industry

The concept of techno-economic pathways is used to investigate the potential implementation of CO_2 abatement measures over time, towards the goal of zero-emissions steel production in Sweden. Two different techno-economic optimization models are used. The first model investigates the impacts of electricity price variations on investments and the operation of steel production. The second model is applied to study the interaction between an electrified steel industry and the future electricity system of northern Europe.

Sweden can help to decarbonize the European steel industry

The results reveal that for Sweden, it will be feasible to reach close-to-zero CO_2 emissions from steel production by Year 2045 using electrification via a hydrogen direct reduction process. We also show that increased production of hot briquetted iron (HBI) pellets could lead to decarbonization of the steel industry outside Sweden, assuming that the exported HBI will be converted via an electric arc furnace (EAF) and that the receiving country has a decarbonized electricity generation system.

The results also indicate that the cost-optimal design of the steelmaking process is strongly dependent upon the electricity system composition. It is found to be cost-efficient to invest in overcapacity for steel production units [electrolyzer, direct reduction shaft (DR shaft) furnace and EAF] and in storage units for hydrogen and HBI, so as to allow the operation of the steel production capacity to follow the variations in electricity price.

Electrification of the European steel industry will increase electricity demand

The modeling shows that an electrified steel industry could increase the electricity demand of northern Europe by around 180 TWh (i.e., 11 percent), and that the geographic placement of the electrified steel production capacity might differ from the current allocation of steel plants. Certain factors, such as the availability of low-cost electricity generation and access to iron ore, significantly influence the allocation of electrified steel plants. The modeling results show that the additional electricity demand from an electrified steel industry can be met primarily by increasing the wind and solar power outputs.

Achieving a transition of the steel industry as described above will obviously present major challenges for society. There will be strong pressure on the transition of the electricity supply system to include flexibility on the demand side and the application of hydrogen storage systems.

Literature

A. Toktarova, I. Karlsson, J. Rootzén, L. Göransson, M. Odenberger and F. Johnsson (2020). "Pathways for low-carbon transition of the steel industry—a Swedish case study". Energies, 13(15), 3840. DOI: 10.3390/en13153840

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Swedish phase out of internal combustion engines – enabling decarbonization or relocating emissions to battery manufacturing?

JOHANNES MORFELDT AND DANIEL JOHANSSON

Phasing out internal combustion engines for sales of new cars results in net benefits for the decarbonization of Swedish passenger car travel, despite the high CO_2 intensity of battery manufacturing.

Electrification of passenger cars is one of the main strategies for decarbonizing transportation. To promote and accelerate such a pathway, several countries and companies are considering to ban or phase out internal combustion engines in sales of new cars.

A Swedish ban on internal combustion engines in new cars for sale presents the possibility to enable long-term decarbonization and zero tailpipe emissions by mid-century. The main alternative considered in Sweden is to increase the use of biofuels. Biofuel use is, however, largely constrained by a limited supply of sustainably produced bioenergy and demands for biomass in other sectors.

The actual climate benefit of biofuel use is largely determined by the type of biofuel used, which is regulated in Swedish biofuel policy so as to promote biofuels with low lifecycle greenhouse gas emissions. Further research is needed to clarify how the increased use of different types of biofuels will influence the carbon cycle for the coming decades and the related levels of warming.

The full effect of a ban becomes apparent 20 years later

In order to analyze consequences of different pathways for the future Swedish passenger car transport system a model that takes into account different demand patterns, vehicle stock turnover as well as supply chain emissions for different energy carriers, materials and batteries have been developed. The model can be used to analyze carbon footprints and material flow impacts of different pathways with respect to, for example, car and ride sharing, autonomous vehicles, electrification etc. So far in Mistra Carbon Exit the analysis have been focused on carbon footprint consequences of a ban of the internal combustion engine in new passenger cars.

Using this model, our analysis of the carbon footprints of strategies to achieve zero tailpipe emissions of CO_2 from cars in Sweden reveals that approximately 20 years elapses after the introduction of a ban on internal combustion engines before the full effect is observed in terms of reaching near-zero tailpipe emissions. This is a consequence of the fact that the average passenger car lifetime is about 17 years, which means that cars with internal combustion engines will be present in the system at least until Year 2050. Consequently, the introduction of a ban of internal combustion engines for sales of new cars from Year 2030 will, if implemented in isolation from other policies, not be sufficient to ensure zero tailpipe emissions of $CO_2$from passenger cars by Year 2045. Various types of biofuels are needed to enable a decarbonization of car passenger transport by Year 2045. However, the levels of biofuels are expected to be lower than what will be needed to meet the climate target for the Swedish transport sector by Year 2030.

The analyses show that the accrued carbon benefits of a ban are substantial. The carbon footprint of Swedish passenger car travel (tailpipe and fuel- and vehicle-related emissions, including CO_2emissions from battery production) is significantly reduced when implementing a ban, since emissions related to the electricity used for charging are low in Sweden. In this case, the low emissions during the use-phase of an electric car compensate for the currently CO_2-intensive battery manufacturing. However, there is a risk that this policy-driven phaseout of internal combustion

engines will result in increased emissions outside Sweden's borders, as a consequence of the increased demand for batteries and its manufacturing-related emissions.

Full carbon footprint regulations may be needed

The potential for reducing CO_2-emissions linked to battery manufacturing is significant. We estimate that for the global manufacturing industry, the average emissions per produced kWh of battery capacity can be reduced to one-third by Year 2050 if the industries decarbonize their production systems in line with the levels necessary to reach the temperature targets of the Paris Agreement. However, these potentials may not be realized if the manufacturing sites are located in countries with less-ambitious climate policies and targets.

Policy interventions that contribute to reducing carbon leakage and incentivizing emissions reductions in manufacturing processes may, therefore, be warranted. Regulation of the full carbon footprint of new cars and sustainable batteries (in terms of both their environmental and social aspects) are currently being discussed within the European Union.

Furthermore, concerns have been raised regarding the mining of materials used in batteries, as this creates substantial social and environmental problems in the mining country. Future research should focus on measures to reduce the demand for virgin battery materials, including car- and ride-sharing, battery downsizing in response to new charging options (such as electric roads), and battery recycling.

Literature

Morfeldt, J., Davidsson Kurland, S., Johansson, D.J.A. (2021). "Carbon footprint impacts of banning cars with internal combustion engines". Transportation Research Part D: Transport and Environment 95, 102807.

Green recovery: What drives firms towards climate action?

CECILIA ENBERG

The Green Recovery Package issued by the Government of Sweden as a response to the economic downturn following the COVID-19 pandemic, is designed to cut greenhouse gas emissions while simultaneously boosting economic recovery. However, if not appropriately used, there is a risk that the recovery package will exhaust available state funds for climate transition for a long time to come while not pushing firms away from their business-as-usual mindset.

In the study that we conducted within the Mistra Carbon Exit project, we found that many firms have targets for net-zero greenhouse gas emissions by Year 2045. Moreover, their heads of sustainability agree that efforts aimed at transition make sense from a business perspective. Some firms also suggest that in recent years the rationale for conducting climate work has shifted from a willingness to 'do good' to one that is more concerned with business and profitability. Despite this, they ask for policies that incentivize them to take further action, and that spur those firms that do little or nothing to shape up.

The important question that arises is: Do green recovery packages do that?

Green Recovery Package of low importance?

Our respondents suggested that most of the investments included in the Green Recovery Package were of low importance to their firm's sustainability strategies or priorities. Moreover, they were considered marginal in size, particularly by firms at the beginning of the supply chain (e.g., basic material producers), as these firms need to make large investments, converting their production processes to become electricity powered. These firms asked for investment support and help to reduce the financial risks involved [1]. They also called for public investments to enhance the capacity of the electricity grid.

Difficulties in implementing circular flows

Many of the firms in our study experienced difficulties in implementing circular flows of materials. These difficulties were related to legislation, as many of the used materials are classified as waste, rather than products, and are not allowed to be used in circular flows. Thus, firms asked for changes in the legislation. An investment aimed at increasing the pace of transition to a circular economy was the only one that a majority of our respondents thought would have an impact on the strategies and priorities of the firms, as it both supports steps already taken and could contribute to initiating new activities. This investment is directed at changing legislation and providing guidance, rather than financial support.

In general, a large majority of firms included in our study preferred policies that focus on legislation, e.g., the setting of tougher standards, over policies that focus on financial support.

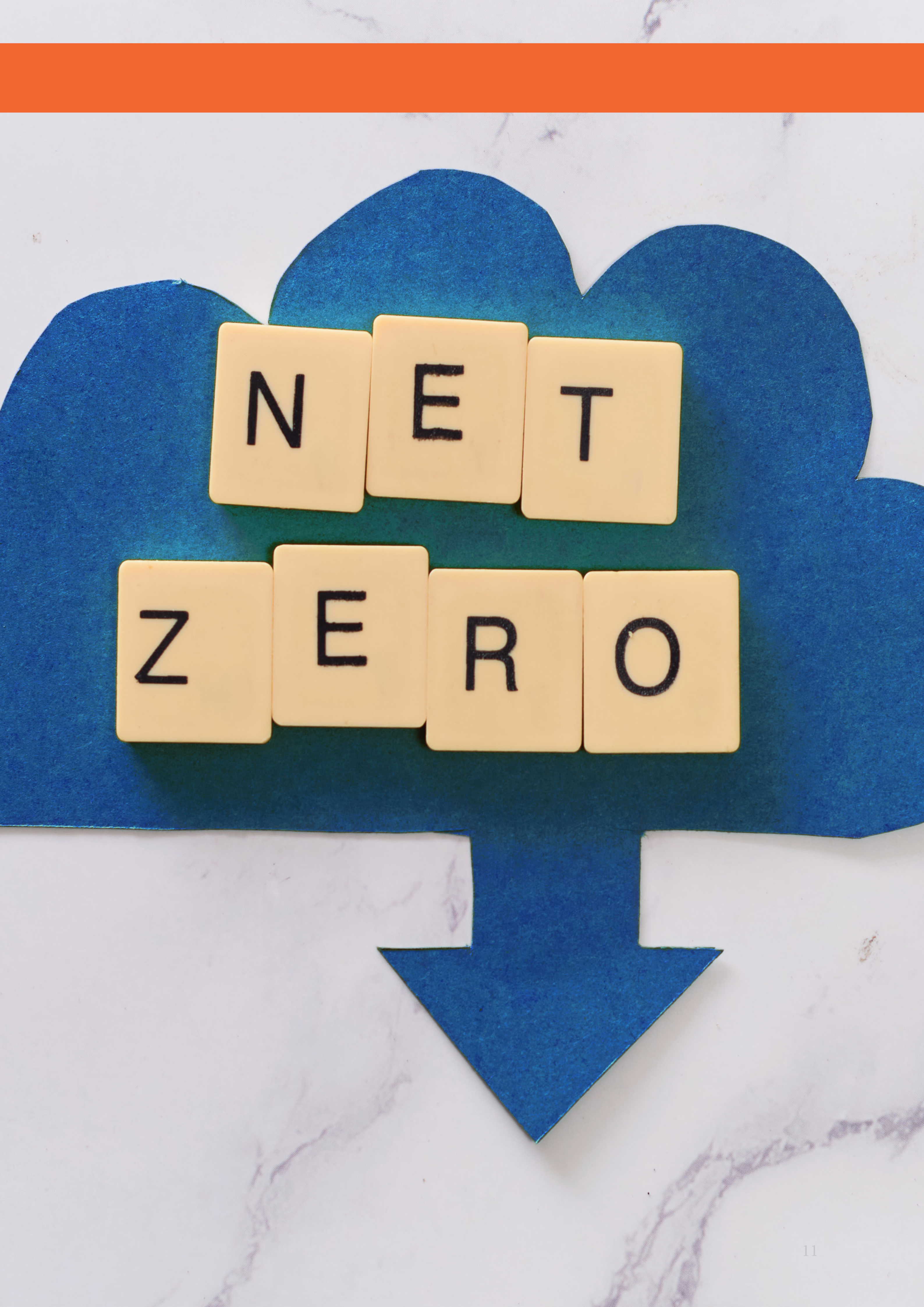
A possible game-changer?

We conclude that updated legislation is a possible game-changer, which could help create markets for climate-friendly products in ways that make business more difficult for firms that are not on track with reform and provide incentives for those that are onboard. In this context, our respondents suggested that public organizations should use their purchasing power to choose climate-friendly alternatives. Indeed, almost 90 percent of respondents to our survey asked for green public procurement, making it the most-requested policy. Incidentally, green public procurement is not a policy that is included in the government's Green Recovery Package.

Our respondents emphasized the necessity of a supply-chain perspective when implementing policies, including the investments of the Green Recovery Package. Such a perspective would enable a system approach in which the most important pressures, mitigation actions and key actors could be identified.

Moreover, a system approach would enable the implementation of policies along the supply chain that are not in conflict with each other – something that has been suggested to be the case today. It is also essential to understand that the climate targets set by firms in different parts of the supply chain are inter-related and that they can be reached more quickly if policies incentivize joint initiatives.

[1] Credit guarantees for investments in green technologies have been issued by the government but not as part of the recovery packages. Moreover, it is unclear whether they cover the kinds of investments needed by these firms.


NET
ZERO

Bridging the policy gap to materialize deep decarbonization in the basic materials industry

Å LÖFGREN, J ROOTZÉN

Direct emissions from industries currently account for almost one-quarter of total global CO_2 emissions; production of steel and cement account for roughly half of these emissions. This research project aims to inform policy makers about the need to look beyond pricing mechanisms - extending the policy toolbox to overcome the barriers to unlock innovation and investments to reduce CO_2 emissions to zero in these sectors.

A basic materials producer that has to decide whether to invest in carbon mitigating technologies is subject primarily to four categories of barriers— market, technology, regulatory, and coordination barriers. The barriers and risks within each of these four categories largely determine the investment (innovation) decision. Table 1 summarizes the key barriers and risks attributed to each of the categories as identified in the sustainability transitions literature. Most importantly, the barriers in each category share properties that influence the adequate policy response.

Market barriers. As long as firms employing established fossil fuel–based technologies are not required to internalize carbon costs, actors attempting to introduce new low-CO_2 production technology with higher production costs face a market risk. Policies that can mitigate and overcome these types of risks are for example price instruments. A carbon price has a large potential to mitigate both the market and regulatory barriers through leveling the playing field between products with high versus low carbon content. However, the efficiency of a carbon price hinges critically on the scope and level of the price.

Technology barriers. Technology barriers involve the complexity and risks associated with development of new clean technologies, including the need to demonstrate feasibility, technical performance, and commercial viability. Policies that can mitigate and overcome these types of risks are for example technology and industry support. Funding of R&D and demonstration projects aimed at mitigating the technology risk is quite common in Sweden and the EU. But support tends to be directed primarily toward incremental investments in technologies that are close to commercialization or are in the early pilot or demo stage. Hence, there is still a need for support of high-risk technology development, scaling up from pilot to full commercial scale, the part of the innovation ladder often referred to as the "valley of death".

Regulatory barriers. Regulatory barriers reflect the risks and challenges associated with differences and changes in the regulatory environment and changes (or lack thereof) in regulatory structures. Policies designed to handle competition between industries in non-regulated and regulated jurisdictions (such as a carbon border adjustment mechanism or tradable performance standards), as well as global agreements aiming to increase scope and stability of policies play an important role to mitigate these types of barriers.

Coordination barriers. While the three above-mentioned risks are quite well known, and the literature discusses a plethora of policy responses, less attention has been given to the importance of handling what we refer to as "coordination risk". Successful deployment of low-CO_2 production processes in most cases require, in parallel, planning and deployment of complementary infrastructures (zero emissions electricity supply, electricity grid expansion, hydrogen storage, and CCS infrastructure). For example, unless the challenge of agreeing on how to handle transport and storage of CO_2 is met, capturing carbon at an industrial point source will be pointless. To overcome these barriers initiatives such as buyers' coalitions, transformation funds, joint ventures, and climate clubs could play important roles. In addition, measures to overcome compartmentalization within different levels of governance, across sectors as well as among actors involved in the supply chain for key basic materials are also necessary to mitigate coordination barriers.

Table 1. Key barriers and market failures in each category. Adapated from Löfgren and Rootzén (2021).

Category	Barriers and risks
Market barriers	Demand and price sensitivity for low-CO2 materials
	Competition in the market, including substitution of other materials
	Exposure to exogenous change due to long planning horizons and lead times
Technology barriers	Uncertainties regarding technical performance, upscaling, and commercial viability
	Nonstandard designs limiting learning effects
	Capacity building and R&D competence
	Long investment cycles
Regulatory barriers	Stringency, scope and credibility of climate policy and medium- and long-term climate targets
	Design and function of specific policy instruments
	Forward thinking in adjacent legislation (e.g., permitting)
Coordination barriers	Timely deployment of support infrastructure (e.g., zero emissions electricity supply, CCS infrastructure)
	Cross–supply chain coordination (e.g., adaptation among specialized suppliers of raw materials and process equipment, as well as end users and customers)
	International coordination (e.g., CO2 transportation, electricity transmission)
	Mobilizing and matching financing

Cite: Löfgren, Å., & Rootzén, J. (2021). Brick by brick: Governing industry decarbonization in the face of uncertainty and risk. Environmental Innovation and Societal Transitions, 40(July), 189–202. https://doi.org/10.1016/j.eist.2021.07.002

Climate mitigation and sustainability – a game of whack-a-mole?

ANDERS AHLBÄCK, MARTIN ERIKSSON, AND EDVIN NORDELL

Transforming Swedish industry to achieve net-zero emissions of greenhouse gases entails opportunities and risks for other sustainability objectives, as described by the Sustainable Development Goals (SDGs). Moving forward, holistic perspectives, transparency and supply chain coalitions will be key factors in avoiding the creation of new problems when solving the climate challenge, like a game of whack-a-mole.

As more attention is devoted to limiting global warming, finding cohesion between the Paris Agreement and the UN 2030 Agenda for Sustainable Development will be a major challenge. Reaching net-zero emissions of greenhouse gases in Sweden by Year 2045 will require new practices, policy instruments and technologies. In technology terms, the transformation is heavily dependent upon the expanded use of renewables and electrification, as well as the introduction of new raw materials, production processes and carbon capture and storage (CCS).

Exclusively addressing the climate issue will most likely introduce risks and opportunities for other SDGs in Sweden and elsewhere. Therefore, we have assessed the additional impacts from the transformative key technologies of wind, solar and bio power, electric vehicle batteries (EVB), climate-neutral concrete and CCS, all of which need to be considered at an early stage. Moreover, assessments need to be conducted that consider the implications across the entire supply chain.

Table 1. Identified SDG risks and opportunities expressed as being positive (P) or negative (N) or having no impact (-), as well as the knowledge gaps (?) for key technologies in the Mistra Carbon Exit pathways. Note that there are several cases with more than one impact category for the same SDG from each key technology.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Wind	-	-	P/N/N	-	-	N	P	P	P	P/N/N	P/P	P/N/?	P	P/N/?	N/N/?	N	P
Solar	-	-	?	-	-	N/N	P	P	P	-	P	P/N	P	-	?	-	-
Biomass	-	N	N	-	-	N	P/N	P	P	-	?	P	P	N	N/P	-	-
CCS	-	-	-	-	-	-	P/?	P/N	P/?	-	P	N	P	N/N	N	-	P
Concrete	-	-	-	-	-	P/N	P	P	P/P/?	-	P	P/N	P	N/N	N/?	-	-
EVB	-	-	P/N	-	-	N	P/?	P/N	P/ P	?/?	P	?/?	P	P/?	N	N	?

Large-scale expansion of new technologies comes with risks

The SDG impact assessments carried out within the Mistra Carbon Exit program (see Table 1) show that large-scale expansion of key technologies may lead to environmental concerns for aquatic and land-based ecosystems (SDG 6 "Clean Water and Sanitation", SDG 14 "Life Below Water", and SDG 15 "Life on Land") in terms of reduced biodiversity and the degradation and contamination of ecosystems. Moreover, extractions of raw materials for use in the production of wind turbines, solar cells and EVB also entail risks to human health (SDG 3 "Good Health and Well-being").

Increased pressure on reuse and recycling

Further risks to human health are apparent downstream of the supply chains. These include air pollution from the combustion of biomass and noise pollution from wind power. In addition, there are few established systems to handle large volumes of disposed wind turbines, lithium-ion batteries and photovoltaic cells, which might exert a negative impact on SDG 12 "Responsible Consumption and Production". Thus, as usage continues to grow, there will be increased pressure on the capabilities to reuse and/or recycle raw materials and components.

Climate mitigation brings opportunities

Undoubtedly, the transformation will confer opportunities and benefits on Swedish Society and stakeholders around the world. Most notable will be: the creation of new jobs and economic growth (SDG 8 "Decent Work and Economic Growth"); innovation opportunities for industry at both component and system levels (SDG 9 "Industry, Infrastructure and Innovation"); and greater accessibility to clean and renewable energy (SDG 7 "Affordable and Clean Energy").

Managing trade-offs towards a sustainable climate mitigation

To stimulate opportunities and minimize the risks associated with reaching net-zero emissions of greenhouse gases in Sweden, actors across the supply chains will need to find new ways to collaborate, both nationally and globally. There is a need to monitor the sustainability performance of supply chains, both continuously and transparently, to identify trade-offs among the SDGs. Taking responsibility across supply chains and beyond national borders while adopting a holistic perspective will be crucial to handling trade-offs and minimizing negative impacts, towards the goal of sustainable climate mitigation. These perspectives are pivotal to avoid playing whack-a-mole with sustainability.

Successful implementation of abatement measures in the construction sector

MARCUS ERIKSSON AND STEFAN UPPENBERG

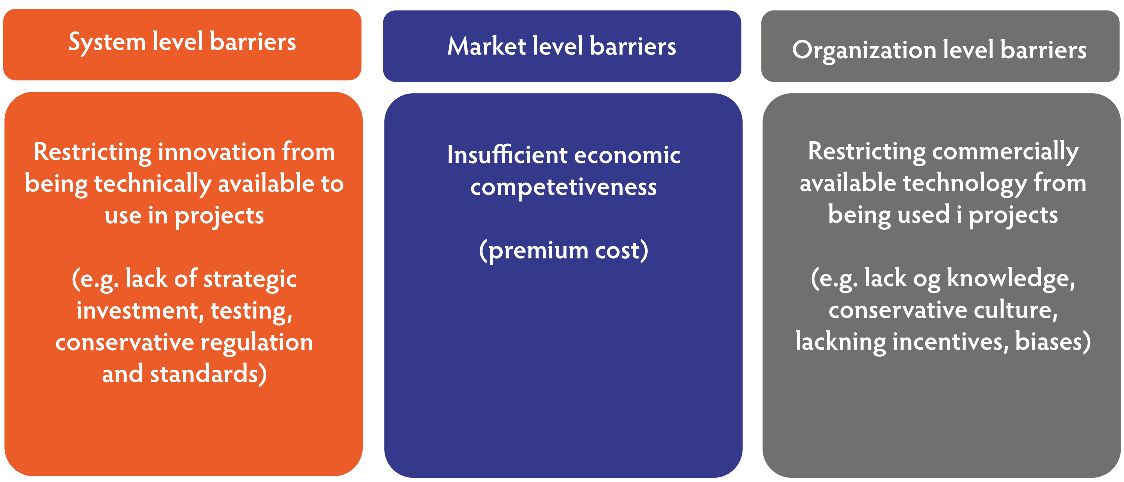
Based on an assessment of the different technical measures needed to decarbonize the building and construction sector, we identify barriers on the levels of the system, market and organization. This three-level barrier structure calls for a holistic approach to finding solutions and orienting construction projects on a trajectory towards climate neutrality.

We have analyzed the barriers that need to be overcome to implement successfully the technical abatement measures identified by Karlsson and colleagues (2020) as part of the Mistra Carbon Exit Programme. The aim was to use the barrier assessment as a starting point for formulating solutions and policies towards an efficient transition of the building and construction sector, although here we focus on the construction sector.

The barriers to abatement can be broadly characterized as obstacles that occur at the system level, market level, and organization level (Figure 2). This categorization is based on where in the construction process the barriers occur and at what level they can be solved. Typically, system-level barriers and market-level barriers need to be overcome for an abatement measure to become available for use in projects, after which organization-level barriers become relevant.

System level

It is clear that certain abatement measures need to occur in conjunction with significant developments before they become available on the market and, subsequently, available to use in construction projects. These developments include further investments in research and development, further testing and validation of the technical capabilities of an innovation, and steps to ensure that the innovation is compatible with the applicable legislation and is included in the relevant technical standards.



Market level

Once an abatement measure becomes technically available, the level of economic competitiveness needs to be such that there are incentives to choose the low-carbon solution.

This is particularly important for the innovation to penetrate the market and become the default choice. The absence of economic competitiveness is a market barrier, and is governed by factors such as supply, demand, and economic policy.

Organization level

Whether or not available and viable abatement measures are eventually implemented depends on decisions made by the construction project stakeholders – the clients, designers, contractors and suppliers. Regardless of economic competitiveness, someone, at some point, needs to decide to use a less-carbon-intensive product, material or process in place of the conventional solution. The factors that influence the choices and decisions of individual designers, engineers or planners include the workplace culture, norms, expectations, and incentives for the person or team. The barriers within this category can exist within organizations, as well as within specific project groups, which do not always align with each other.

Three of the most-important organization level barriers identified were: lack of reliable reference cases; lack of incentives for project managers to try new solutions; and lack of knowledge regarding the properties and cost reduction potentials of low-carbon materials.

Holistic approach

The abovementioned barriers call for a holistic approach to work out how available mitigation measures can best be implemented over time. An example is the introduction of calcinated clays as a large-scale alternative to Portland cement: on the system level, cement standards have to be adapted to allow the use of such binders; on the market level, the possibility to obtain permits for clay mining has to be enabled; and on the organization level, designers, contractors and suppliers have to learn about the properties of the materials and how to adapt their design parameters and construction methods.

Literature

Karlsson, I; Rootzén, J; Toktarova, A; Odenberger, M; Johnsson, F; and Göransson, L. 2020. Roadmap for Decarbonization of the Building and Construction Industry— A Supply Chain Analysis Including Primary Production of Steel and Cement Production of Steel and Cement," Energies, vol. 13, no. 16, p. 4136.

Eriksson, M., Uppenberg, S., Barriers to Carbon Abatement in the Construction Sector – A Case Study within the Mistra Carbon Exit Programme, Report, WSP, 2021-03-26.

4.Developing links across work packages and disciplines

The Mistra Carbon Exit Sociogram provides an overview of the ties between individual researcher and research groups and of cross-disciplinary and cross-sectoral collaborations in the program.

The Mistra Carbon Exit consortium includes a broad representation of actors within industry, authorities and civil society including researchers from 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.

The program is organised in four academic work packages:

- WP1, *Technology assessments for buildings, transport infrastructure and energy*
- WP2, *Technology assessments for transportation*
- WP3, *Governance and policy process*
- WP4, *Policy design options*
- 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.

1

Climate Alliances/Collective action
What would it take to produce the first series of zero carbon footprint vehicles?
A Ahlbäck, D Johansson, J Morfeldt, J Rootzén (GMV, CTH, IVL)
Polestar, Volvo CE, Volvo Cars

2

BETCRETE 2.0
Aimed at contributing to decarbonizing the cement and concrete value chain
F Johnsson, I Karlsson, S Uppenberg, J Rootzén (CTH, WSP, IVL)
NCC, ByggVesta, WSP and several other partners (Lead by RISE)

3

Consumption based GHG emission scenarios
Basis for discussing Sweden's future climate policy, in general, and consumption-based climate targets, in particular
J Morfeldt, D Johansson, C Hult, I Karlsson, AQ Liu, J Rootzén (CTH, IVL)
The Swedish Cross-Party Committee on Environmental Objectives (Lead by Mistra Sustainable Consumption)

4

Local Arenas
Opportunities and challenges involved in reducing the climate impact in municipal building and infrastructure construction.
A Övereng, I Karlsson, J Rootzén (CTH, IVL)
Skellefteå kommun

5

Design for Green recovery
Assessments of organizations' sustainability work today and their attitudes toward the green recovery packages
C Enberg, F Johnsson, L Zetterberg (LiU, CTH, IVL)
Skanska, NCC and several other partners

6

Behavioural Science Lab for Policy Effects
State-of-the-art research exploring market actors' behavioral changes in response to specific climate policies.
M Hennlock, V Wibeck (LiU, IVL)
Skanska, NCC and several other partners

7

Clean Materials Platform
Analyses the transformation of basic material production and use to achieve carbon neutrality by 2050
K Neuhoff, O Chiappinelli, L Zetterberg (DIW, IVL)
Swedish EPA

8

Green Deal
Assessments of the EU Commissions' Green deal proposals to reform the EU emissions trading system (ETS), introduction of carbon border adjustments and the development of an ETS for transport and heating
L Zetterberg, M Elkerbout, K Neuhoff (IVL, DIW, CEPS)
Swedish EPA, Government Offices of Sweden

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Material use and public procurement
Mapping material flows and climate impact from transport infrastructures and the role of climate procurement requirements
AQ Liu, A Kadefors, I Karlsson, F Johnsson, J Rootzén (CTH, KTH, IVL)
Swedish Transport Administration,

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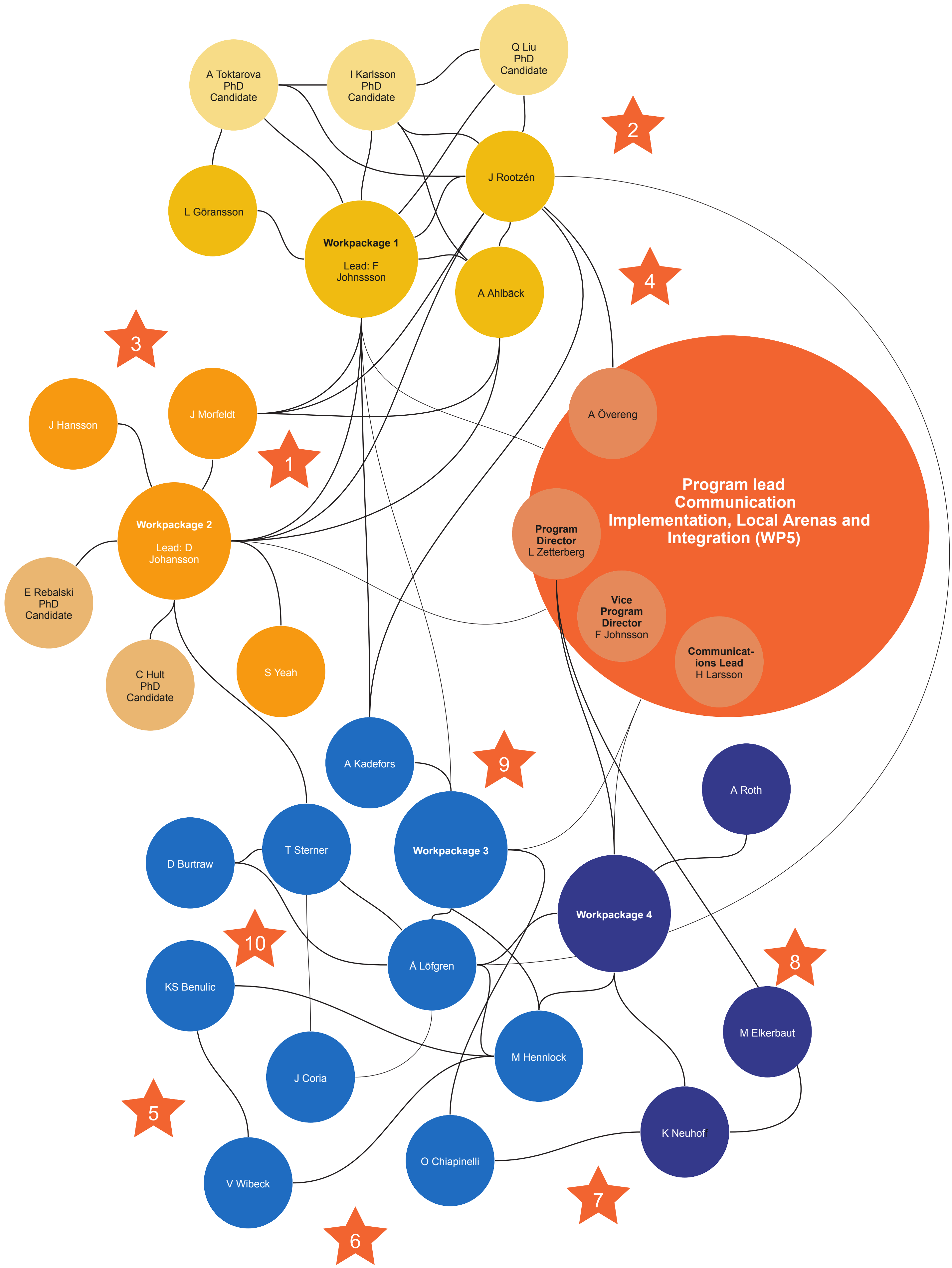
Tradable performance standards
Exploring the role of tradable performance standards as building blocks for carbon pricing.
Å Löfgren, D Burtraw, S Yeah (GU, RFF, CTH)
Government Offices of Sweden


A Toktarova
PhD
Candidate
I Karlsson
PhD
Candidate
Q Liu
PhD
Candidate
2
L Göransson
J Rootzén
Workpackage 1
Lead: F
Johnssson
A Ahlbäck
4
3
J Hansson
J Morfeldt
A Övereng
1
Program lead
Communication
Implementation, Local Arenas and
Integration (WP5)
Workpackage 2
Lead: D
Johansson
Program
Director
L Zetterberg
E Rebalski
PhD
Candidate
Vice
Program
Director
F Johnsson
Communicat-
ions Lead
H Larsson
C Hult
PhD
Candidate
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A Kadefors
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A Roth
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D Burtraw
Workpackage 3
Workpackage 4
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Å Löfgren
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KS Benulic
M Elkerbaut
M Hennlock
J Coria
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K Neuhoff
O Chiapinelli
V Wibeck
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5. Our PhD:s

Cecilia Hult joined Mistra Carbon Exit as an industrial PhD student as the programme entered the second phase in May 2021. Cecilia works at IVL Swedish Environmental Research Institute and will carry out her PhD at the division of Physical Resource Theory at Chalmers University of Technology. Her research within Mistra Carbon Exit will focus on the interaction between technology and behaviour in the transport sector.

"After working with transport emissions for years at IVL, I'm excited to look at transport from a systems perspective", says Cecilia. The latest report from IPCC Working group III tells us that demand-side options together with electric vehicles can reduce transport emissions in developed countries. I believe it is very important to study how technical innovations such as electric vehicles will impact the transport system and how we travel.

During her time at IVL, she has worked with transport air pollutants and mobility issues, and there are many potential co-benefits with the decarbonization of transport and other sustainable development goals. "Finally, I'm also looking forward to return to my alma mater". Cecilia has a master's degree in Engineering Physics and Complex Adaptive Systems.

Ida Karlsson has recently initiated a study aimed towards analysis of cost implications of carbon abatement from a value chain perspective.

Emanating from my Licentiate Thesis, which formed a sort of encyclopedia of carbon abatement measures with associated reduction potentials for the construction industry, I concluded that to realize the maximum reduction potential, there is a need for extensive collaboration along the whole value chain. For this study, I will gather and analyze data on a practical building case currently in the early design stage, in collaboration with several organizations active along the building construction value chain.

Based on previous work within Mistra Carbon Exit together with the case data, I will propose a framework for analysis of the supply chain and end-user abatement cost implications – taking into account costs linked to material substitution and material efficiency measures. It is my hope that this will provide evidence-based motivation for relevant actors to accelerate cooperation towards greater implementation of these types of abatement measures. It is indeed the partnerships between academia, industry partners and governmental organization that I find so encouraging about being part of Mistra Carbon Exit.

We now see clear examples of how partnerships are moving the entire playing field forward. While the climate transition is still moving too slowly, I see the momentum growing, ambition turning into action on the ground and targets being strengthened or moved forward.

It really does feel like over a short space of time, we have moved from talking and planning the transition to being in the midst of it. We might not see the results just yet, but I am eager to see what the next few years will bring.

Qiyu 'Aaron' Liu joined phase 2 of the Mistra Carbon Exit as a PhD student in October 2021. Aaron grew up in China and he completed a master's degree in Industrial Ecology at The University of Sydney in Australia before moving to Sweden.

His research will focus on quantifying the embodied emissions in the Swedish built environment using a combination of Material-flow analysis and scenario-based modeling. This research aims to combine previous work done by fellow Mistra Carbon Exit PhD student Ida Karlsson with a national scale bottom-up model to simulate how the Swedish construction sector could aim to achieve net zero embodied emissions by the year 2045.

Aaron is a strong believer in utilization of academic research, especially in sustainability related areas. Mistra Carbon Exit phase 2 offers a unique opportunity to work with stakeholders and government agencies to make a real impact on society.

Ella Rebalski joined Mistra Carbon Exit as a PhD student in February 2018, where she studies how automated vehicles (AVs) will affect carbon dioxide emissions in Sweden.

Originally from Vancouver, Canada, Ella completed a master's degree in environmental management and policy at Lund University before moving to Gothenburg. Prior to joining Mistra Carbon Exit, she was a researcher at RISE, working with electromobility, AV regulation, and mobility as a service. As a transportation researcher, Ella was drawn to the project out of excitement for AVs, coupled with an awareness that they will soon transform the way we travel and move in society. She is currently working on two studies, one that uses an economic, quantitative method to model increased travel demand, and one that uses qualitative interview data to examine the various forces that could influence the introduction of AVs.

Ella finds that the cross-pollination of ideas from engineering and the social sciences has helped to make her research more applicable to the real-world context, and to understand how everyday habits aggregate into societal transitions that affect carbon dioxide emissions at a larger scale. She is looking forward to further collaboration and fruitful discussions with other researchers in Mistra Carbon Exit.

Alla Toktarova joined Mistra Carbon Exit as a PhD student in February 2018, where she studies the decarbonization of energy-intensive industries and its impacts. She said that timely research questions which are investigated within the Mistra Carbon Exit programme are of interest to both, the scientific community and to stakeholders that are involved in the transition of the energy - and carbon-intensive industries to climate neutrality.

The findings of the case studies in her work provide insights into the designs and operations of decarbonized industries, the developed models can be utilized to study industries transition scenarios for different regions of Europe. The involvement in the Mistra Carbon Exit programme allows to have dialogue and get direct feedback on the research results from different stakeholders such as the Voestalpine and from other companies such as Vattenfall AB.

Another valuable aspect of being in the program is that communication with other stakeholders involved in the programme allows for assessing solutions for reducing the present Swedish GHG emissions to net-zero emissions from different angles and filling knowledge gaps in a time efficient way.

Byggvesta

“The building sector accounts for almost 40% of the global climate emissions which is why we need a fast transformation. The knowledge that today’s choices will lay foundation for generated emissions from our buildings for decades, in combination with requirements from stake holders, makes the climate action an existential matter.”

ByggVesta has over the years built up a fast-paced and easy-to-operate project organization at all stages. Among other, we are always searching for new materials and products and we use digital tools to climate optimize our buildings from very early stages. We strive to not only change the industry but the world, which is only possible by working together across disciplines, companies, and sectors.

We have the privilege of surrounding ourselves with partners and co-builders who love challenges, to challenge us, and together we challenge today’s building standards. Through cooperation, we have been able to make sure that there will be climate-neutral concrete on the market by 2030. We have also contributed to development of a new type of concrete, Agribetong, where part of the cement is replaced with grain ash. And we work hard with optimization of all our processes through a committed project organization.

Collaboration and knowledge exchange is one of our most important instruments in the transition to a climate-smart building sector. By taking a broader approach of the climate change with stakeholders across industry boarders, as we do in Mistra Carbon Exit, we seek to contribute to knowledge exchange, explore new constructive solutions, and find synergy effects to speed up the transition. Also, there is a higher power in joint actions when the regulatory framework and policies are to be changed. In total, this is a way to accelerate our journey towards a sustainable world.”

Alicia Åhlfeldt,
Hållbarhetsstrateg Byggvesta

JM

The climate crisis requires a transformation. Climate-affecting emissions must be reduced. New methods and technologies increase the chances of success.

JM is a partner of Mistra Carbon Exit because we get new knowledge and perspectives, increased understanding and innovative collaboration with other companies, scientists, policy makers and stakeholders. The need to reduce climate impact will require us to work together across disciplines.

JM has a climate target to reduce emissions to close to zero by 2030. On our way to the target we are focusing on efforts to reduce the climate impact that arises in the construction process and efforts to ensure that those who move into JMs homes have the conditions to live as sustainably as possible in their homes.

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 limitations of the materials used. During 2021 we had two carbon reducing test projects ongoing, fossil free construction site and low carbon concrete.

We are happy to share our experience from our climate projects with our partners in the Mistra Carbon Exit program and together find the right solutions to reduce the climate impact

Maria Sandell.
Hållbarhetschef JM

Energiforsk

Almost everything we do at Energiforsk is about reducing greenhouse gas emissions. Energiforsk support companies in the energy sector with knowledge they need to be successful in the ongoing transformation of the economy to become more sustainable. Climate action is, by far, the most important driver for that transformation and Energiforsk.

Working closely with the academic community is imperative to Energiforsk. Our mission is not only to identify pressing issues facing companies, but also to work with the brightest people that can help solving those problems. Mistra Carbon Exit is well positioned in the intersection of industry priorities and applied research, which enables dynamic discussions to take place and innovative solutions to emerge.

Russia's invasion of Ukraine has further underscored the need to make the transformation away from fossil fuels very quickly. We cannot wait for all questions to be fully answered before taking action, and important decisions must be made under significant uncertainty. This means we need research on how a low carbon energy system can be developed and operated to be relevant while that same system is being built.

Energiforsk work with the major players making big investments in energy infrastructure in the north European energy sector Mistra Carbon Exit is and will remain an important research and innovation platform for us.

Markus Wråke,
CEO Energiforsk

7. Key deliverables 2021

Key scientific achievements in 2021 include:

• Recruitment of two PhD students: Qi Yu Liu (called "Aaron") at Chalmers ET and Cecilia Hult, at IVL and Chalmers FRT. In total MCE now has 5 PhD-students.

• Recruitment of Johannes Morfeldt as a researcher at Chalmers FRT, September 14, 2021

• Licentiate degree: Ella Rebalski, "Are We There Yet? Combining qualitative and quantitative methods to study the introduction of CAVs in Sweden, and potential travel demand effects", licentiate seminar 2021-03-31

• Licentiate degree: Alla Toktarova, "The low carbon steel industry – Interactions between hydrogen direct reduction of steel and the electricity system", licentiate seminar June 9, 2021.

• Being the first year of the second phase of the programme, our focus has been starting up the research tasks and most of these have started. Some highlights include:

o Task 1.2 (Material use in the low-carbon transition): Work has been initiated as basis for a first proposal for structure and content of a formalized bottom-up model assessing material flows and related GHG emissions along the supply chain related to building and infrastructure construction in Sweden. The work expands the Phase 1 work carried out by Ida Karlsson, aiming at a national material balance with associated CO_2 emissions.

o Task 1.3. (Sectoral collaboration - system and sector perspectives): A research paper on 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.

o Task 1.5 (buildings and transport infrastructure in Uppsala): Reports published on barriers and opportunities for the transition to climate neutral buildings in municipalities

o Task 1.7 (Supply chain-specific sustainability indicators for stakeholder engagement and transparency): Cooperation initiated with electric car manufacturer Polestar for upcoming SDG analysis of relevant supply chains.

o Task 2.1 (Integrated modeling of travel and supply-chain consequences of different policies, consumer behaviors, and technologies): Publication: Carbon footprint impacts of banning cars with internal combustion engines.

o Tasks 2.1 and 1.2 (Synthesis): Report 'Consumption based GHG scenarios for Sweden' (Konsumtionsbaserade scenarier för Sverige) on behalf of the Swedish Cross-Party Committee on Environmental Objectives.

o Task 3.3 (The value of being a frontrunner): Finalized a survey experiment among seven EU countries (Austria, Germany, Sweden, Finland, France, Poland, Spain)

o Task 3.6 (Governance, capabilities and incentives to enhance climate-friendly public procurement in the construction sector): As a part of the pre-study to map the emerging learning landscape we follow the work of the National Agency for Public Procurement on developing and launching procurement requirements for carbon reduction in the construction sector. This will inform the design of the main study, starting in 2022.

o Task 3.8 (Quantitative assessment of the effect of public procurement): Discussion paper on economic assessment of policy needs for acceleration of green public procurement adoption. Literature review completed- analysis will be implemented at the beginning of 2022.

o Task 3.10 (Post-COVID-19 – design for Green recovery): Design for Green recovery Interviews and surveys with businesses have been conducted. Policy report published in Nov 2021.

o Task 3.11. The financial sector: Manuscript draft finalized "If Money Talks, What is the Banking Industry Saying about Climate Change?".

o Task 4.5 (Analytical assessment of policy packages for industrial decarbonization): Policy report - policy packages for industrial decarbonization.

o Task 4.6: (Policy packages and risk in hard-to-abate sectors): Publication: "Brick by brick: Governing industry decarbonization in the face of uncertainty and risk".

o Task 4.7: (Trade and climate policy: Border Carbon Adjustments and alternatives): paper on "Intensity-based rebating" as an alternative policy for addressing industrial emissions and carbon leakage.

o Task 4.8 (Designing policies for negative emissions): A paper "Incentivizing BECCS—A Swedish Case Study" has been published.

6. Key communication in 2021

Messages

In 2021 the program management and the communication management have produced the so-called Key Messages publication, which presents key messages from the program drawn from the first four years.

Seminars and outreach activities in 2021

Meeting our target groups on a regular basis through seminars, workshops and bilateral meetings is central for 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 the topics of Mistra Carbon Exit.

Our main event in 2021 was the *Mistra Carbon Exit Week*, which consisted of four breakfast webinars that were broadcasted live (and recorded) from a fully equipped professional studio at University of Gothenburg. The webinars covered the following themes: Buildings, Infrastructure, Transportation and Taking lead in the climate transition. The webinars gathered over 400 unique participants.

9. List of publications

WP 1. Technology assessments for buildings, transport infrastructure and energy

- Nilsson, J., Nilsson, J., Martin, M. Hållbarhetsanalys av utvecklingsvägen 'starka sektorskopplingar' för att uppnå ett hundraprocent förnybart elsystem. Mistra Carbon Exit, 2021
- Stenquist, S., Övereng, A. Möjligheter och hinder i omställningen till klimatneutrala byggprocesser i Uppsala kommun. Mistra Carbon Exit, 2021.
- Stenquist, S., Övereng, A. Kommuners möjlighet att arbeta mot nettonollutsläpp av växthusgaser med hjälp av detaljplaner. Mistra Carbon Exit, 2021

WP 2. Technology assessment, transportation

- Morfeldt J., Davidsson Kurland S., Johansson D.J.A, 2021, Carbon footprint impacts of banning cars with internal combustion engines, Transportation Research Part D: Transport and Environment, Volume 95, https://doi.org/10.1016/j.trd.2021.102807.
- Yeh S., Burtraw D., Sterner T., Greene D., 2021, Tradable performance standards in the transportation sector, Energy Economics, Volume 102, https://doi.org/10.1016/j.eneco.2021.105490
- Larsson J., Morfeldt J., Johansson D., Rootzén J., Hult C., Åkerman J., Hedenus F., Sprei F., Nässén J., 2021 Konsumtionsbaserade scenarier för Sverige - underlag för diskussioner om nya klimatmål. Rapport - Chalmers tekniska högskola, https://research.chalmers.se/publication/526528

WP 3. Governance and policy process

- Benulic, K. S., Kropf, M., Linnér, B. O., & Wibeck, V. (2021). The meaning of leadership in polycentric climate action. Environmental Politics, 1-21.
- Enberg, C.; Ahlbäck, A; Nordell, E, 2021, Green recovery packages – a boost for environmental and climate work in the Swedish construction and building industry? CSPR Report No 2021:01, Centre for Climate Science and Policy Research, Norrköping, Sweden.

WP 4. Policy design options

- Chiappinelli, O., Gerres, T., Neuhoff, K., Lettow, F., de Coninck, H., Felsmann, B., Joltreau, E., Khandekar, G., Linares, P., Richstein, J., Śniegocki, A., Stede, J., Wyns, T., Zandt, C., Zetterberg, L.: A green COVID-19 recovery of the EU basic materials sector: identifying potentials, barriers and policy solutions. Accepted for publication in Climate Policy Journal.link https://www.tandfonline.com/doi/full/10.1080/14693062.2021.1922340
- Johansson, M., D. Langlet, O. Larsson, Å. Löfgren, N. Harring, S. C. Jagers. 2021. "A Risk framework for optimising policies for deep decarbonisation technologies", Energy Research & Social Science, 82, 102297.
- Löfgren, Å., J. Rootzén. 2021. Brick by brick: Governing industry decarbonization in the face of uncertainty and risk, Environmental Innovation and Societal Transitions, 40, 189-202.
- Zetterberg L, Johnsson F and Möllersten K (2021) Incentivizing BECCS—A Swedish Case Study. Front. Clim. 3:685227. doi: 10.3389/fclim.2021.685227.Neuhoff, K., Chiappinelli, O., Kröger, M., Lettow, F., Richstein, J., Schütze, F., Stede, J., Sun, X. Green Deal for industry: a clear policy framework is more important than funding, DIW Weekly Report, 10/2021
- Löfgren, Å., Burtraw, D., Sterner, T., Zetterberg, L.: Phasing out fossil fuel in the Swedish transport sector: reflections on the potential role of fuel standards and emissions trading. April 2021. Policy brief available on www.mistracarbonexit.com.

10. The program in detail

Background

This research programme was formulated in response to Mistra's research call "Transformative changes in society to achieve challenging climate goals". In response to this a consortium was formed during spring 2016 and a proposal was written by lead authors (Lars Zetterberg, IVL together with Filip Johnsson and Daniel Johansson at Chalmers). The proposal was approved by Mistra on December 9, 2016 (Mistra protocol DIA 2016/12). In 2020, Mistra invited the consortium to submit a proposal for a second Phase of the programme, covering four years. This proposal was evaluated by an external evaluation committee who also evaluated the first four years of the programme. In December 2020, the proposal was approved by Mistra. On April 1st, 2021 the second Phase of Mistra Carbon Exit started.

The Scope of the Programme

The Mistra Carbon Exit programme (Phase 2) is a multidisciplinary research program that addresses and identifies the technical, economic and political challenges for Sweden to reach the target of net zero greenhouse gas emissions by 2045. This target will require transformative pathways with respect to virtually all industrial processes and their associated products and services. Mistra Carbon Exit takes a novel approach to address this problem through a supply chain perspective, from the input of raw materials, over primary and secondary activities, to final products and services demanded by the end user. The programme covers the supply chains buildings, transportation infrastructure and transportation. These selected supply chains allow us to capture at least 75 percent[1] of Sweden's CO_2 emissions. The program has a substantial component of implementation, working closely to companies, authorities and non-governmental organizations.

Programme Participants

The Mistra Carbon Exit consortium includes a broad representation of researchers and actors: four universities: Chalmers, University of Gothenburg, Linköping University and the Royal Institute of Technology (KTH), three research institutes: IVL Swedish Environmental Research Institute, Resources for the Future (RFF) and The German Institute for Economic Research (DIW), The Centre for European Policy Studies (CEPS) and 23 companies, authorities and non-governmental organizations.

Our partners in Phase 2 include Volvo Cars, Volvo Construction equipment, Cementa, Thomas Betong, PEAB, JM, NCC, Skanska, Byggvesta AB, Skandia Fastigheter, Riksbyggen, Vasakronan, Transport Administration (Trafikverket), Outokumpu, Fortum Sverige, Energiforsk, Danske Bank, VGR (West Sweden Region), Hagainitiativet, FORES, Voestalpine,. Swedish Swedish Environmental Protection Agency (Naturvårdsverket) and Sweco.

[1]This is an approximate value, based on the production-based emissions within the Swedish borders.

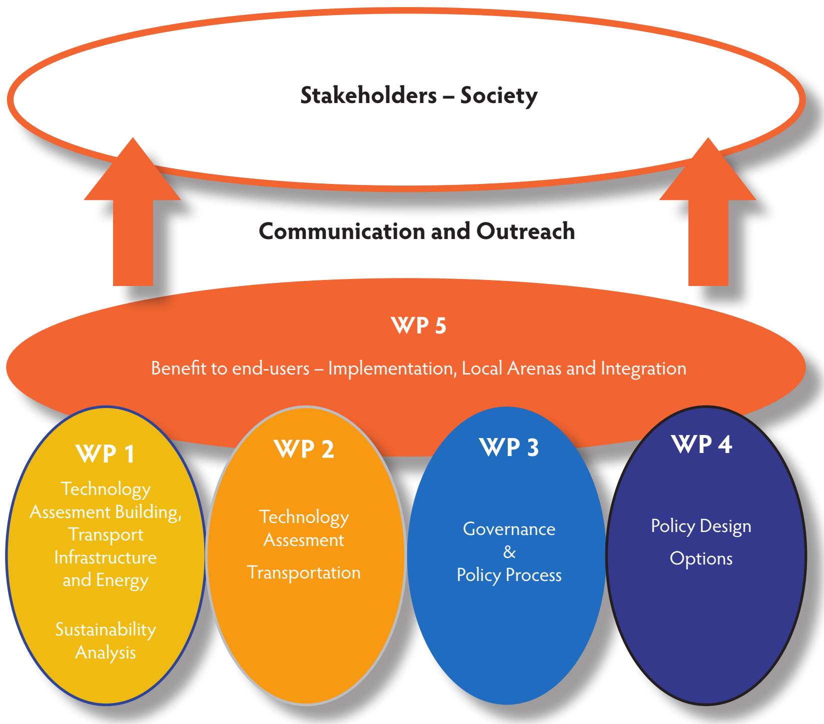
Specific aims of Mistra carbon Exit (Phase 2)

- 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. 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.
- 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; and
- To continue to ensure broad communication of the programme results, including scientific dissemination and public and stakeholder outreach.

Program structure and organization

The work is divided into four work packages plus an implementation package (WP5) and a communication package. The academic work packages investigate and define transformative pathways, technology assessments along supply chains, changing market institutions and behaviors towards Swedish Leadership, policies and governance, and integration and sustainability implications.

The Programme Board has overall responsibility for the programme and is appointed by the programme host (IVL) in consultation with Mistra. IVL Swedish Environmental Research Institute acts 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. 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 Management Group consists 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 is 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 also provides the Programme Director with input for the board meetings.



Program Board

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Stefan Nyström,
Head of Climate Unit,
Swedish Environmental
Agency

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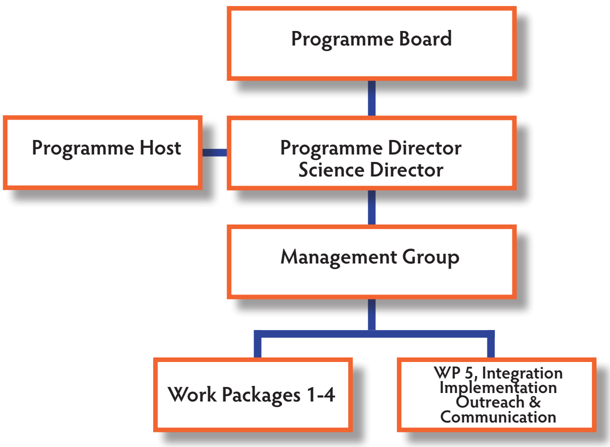

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