Policy priorities for mobilizing investment in Swedish green industrial transitions

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Executive summary

In its latest assessment reports, the Intergovernmental Panel on Climate Change stresses that there is a rapidly closing window of opportunity for global action to prevent and adapt to climate change and that mitigation and adaptation is needed now. The Swedish Climate Policy Council has stated that a transition has been initiated in Sweden, and national emissions have been cut by about 35% since 1990. Still an acceleration of this transition is needed to reach the national target of net-zero emissions by 2045. Industry is responsible for about a third of Sweden's greenhouse gas emissions, and investments in deep emissions cuts in this sector are key for reaching the national target. This involves investments in innovative technologies that enable increased efficiency in the use of materials and energy, increased circularity, and fuel and feedstock switches. For most industrial sectors several pathways are being implemented, although there remain large uncertainties and risks associated with the options they are pursuing.

The implementation of new technologies will often increase both capital needs and operating costs and there might be periods of elevated working capital as investments in new technologies have to overlap old production processes while verifying new solutions. Moreover, industrial sites have long lifetimes and long investment cycles. As a result, investments in technological and production changes that bring deep emissions cuts in heavy industry risk older assets having to be written off prematurely. Details are scarce on the extent to which capital investment entails a challenge for industrial transition and if so how to handle these challenges.

The aim of this report is to better understand the key challenges for investments in technological and production changes that bring deep emissions cuts in heavy industry in Sweden. We investigate this matter from the perspective of both industry actors and actors from the financial sector. Our key research questions are:

- Is the size of the capital investments needed for green industrial production a significant challenge for bringing about these transitions in Sweden?
- What are the most important challenges for actors' willingness to invest in deep green industrial transitions and investors' willingness to provide financing for those investments?
- What policies do industrial and financial actors think can best support the willingness to invest in and provide financing for deep green industrial transitions in Sweden?

The report focuses on Sweden and the heavy industries that account for the largest share of greenhouse gas emissions: iron and steel, cement, refining and chemicals. We also include the pulp and paper industry in this study given that it is a large industrial point source of biogenic CO_2 emissions (through the combustion of bio-fuels) and has the potential to contribute to meeting the national net-zero target with so-called "negative emissions". The study focuses on technological alternatives that can lead to radical reductions of direct emissions. This means that incremental energy efficiency measures and reduced demand, although important, are not considered. Our results are based on interviews with representatives from key industrial firms and financial firms and institutions.

Our main results and recommendations:

1. **Neither the scale of investments nor access to financing are significant obstacles to deep green industrial transformation.** Our key finding is that neither the scale of capital investments in deep green industrial transition nor access to financing to make these investments are perceived to be significant obstacles by industry or financial actors. The scale of investments is large and for many industrial actors there are needs for direct support for early-stage development of new technologies and production processes. However, given a viable business case for green industrial products, capital requirements and access to finance do not appear to be critical obstructions once companies are prepared for commercial level deployments. Instead, our interviewees emphasized issues related to creating market demand

and infrastructure and permitting processes as most important for enabling investments in deep green industrial transitions.

2. **Loan guarantees are an appropriate method of risk sharing for commercial-scale investments in deep green industrial transitions.** According to our results, industry and financial actors find that existing direct financial support mechanisms and government credit guarantees are appropriate support and risk sharing tools. Our results do not point to any specific and new financing support mechanisms that industry and financial actors would like government to put in place. However, respondents did indicate that the scale of government support, both direct financial support and financial risk sharing, may need to be ramped up as industrial decarbonization pathways move from early stages to demonstration and commercial deployment.

3. **Policies for improving the terms of financing will not likely play a large role in mobilizing the willingness to invest in deep green industrial transitions.** Industrial and financial actors stated that securing financing for green industrial transitions will likely not be a challenge when the business case for making these investments is in place. Improving the terms of financing was not prioritized among our respondents as a key lever for improving business cases. Favourable financing terms certainly contribute, but our respondents pointed to issues of market demand, direct financial support for early development, infrastructure and permitting policies as much more important. As such, decision-makers should focus on these areas for the largest effects.

   Importantly, our respondents' comparatively minor concerns regarding financing should be understood in the context of the early stage of development of deep green industrial transition. As many of the major investment decisions have yet to be made, our results may not reflect challenges that could occur at the point of commercial deployment. Moreover, it is very difficult to predict how financial markets will develop over the long timeframes over which investments in deep green industrial transitions are needed. As such it is still too early to make a judgement on the extent to which policy efforts could be needed to mobilize financing towards these transitions.

4. **If needs for new financing solutions become apparent over time, public authorities will likely need to take a leadership role and set in motion proposals and dialogue with relevant private actors.** We did not find developed ideas among industry or financial actor respondents for new financing solutions for green industrial transitions. This reflects both the perspective that financing is not a major obstacle and the early stage of development and deployment in some sectors. Because our results did not find forward-looking strategies in this area, decision-makers can contribute to green industrial transitions by tasking public authorities with investigating potential needs, gaps and innovative financing solutions for green industry transitions for future stages of deployment when capital requirements can become very high.

5. **Policymakers should focus on market formation efforts. Particularly important are efforts at the European Union level to ensure that carbon price signals are high enough to create business cases for green industrial products and that efforts to prevent carbon leakage maintain fair competition.** Our results show that the key policy space for mobilizing investments into green industry is in supporting market formation and demand for green industrial products. As confidence in technological solutions advances, more attention is focused on how the increased costs of green production can be transferred to end consumers. The most desired market generation policies from both industry and finance are general policies like carbon taxes combined with measures to protect the competitiveness of industries, for example a carbon border adjustment mechanism (CBAM).

6. **The methods for and extent of demand-generating policies should be considered sector by sector as there may be divergence on the degree to which general policies and bottom-up approaches achieve the desired pace of change in different sectors.** In addition to general market formation efforts, some actors emphasized demand generation policies directed at specific sectors, motivated by the different prerequisites for transition in those sectors. For example, public procurement policies for green industrial products were put forward as important for the cement sector especially. Another example, particularly important for the refining sector, are the policies requiring the blending of biofuels into petrol and diesel, which are already being implemented.

7. **Both investors and policymakers should continue to push for companies to deliver transparency and target setting with respect to their scope 3 emissions.** Working with value chains to create demand for green industrial products can accelerate the pace of transitions as has been proven in the case of green steel production in Sweden. Repeating this dynamic in other emissions-intensive industrial sectors is crucial. Our respondents emphasize that setting targets for emissions reduction and transparent reporting about progress towards these targets are important to stimulate transition not only of individual firms but also of whole value chains.

8. **Government should continue with its existing financial support mechanism, reviewing financing needs periodically, and work to ensure that Swedish industry is able to access support measures at the EU level.** Although our respondents indicated that access to financing for commercial deployment (assuming good market demand indications) is good, public funding is still needed to incentivize and accelerate the pace of investment in deep green industrial transitions. Getting to commercial readiness involves risky investments in research and development, piloting and demonstration. Our respondents are largely satisfied with the levels of national and EU direct support for research and development, particularly the national programme, Industriklivet. For commercialization and first-of-a-kind full-scale facilities, industry interviewees underlined the need to continue direct support at demonstration and commercialization stages and emphasized the importance of risk sharing between public and private actors.

9. **The Swedish government should pay attention to how public support for industrial transitions may impact fair competition.** As many countries strive to stimulate deep green industrial transitions, several industry respondents stressed that national direct support should be formed so that it does not undermine fair competition. The degree to which public support for green industrial transitions in the EU could undermine effective competition and innovation is an important area for researchers to investigate and policymakers to pay attention to. Our results suggest that more attention needs to be paid to how governments can best combine the need to bring about rapid and deep industrial transitions with maintaining competitive markets.

10. **Policymakers should pay special attention to ensuring that necessary infrastructure will be available and implement reforms to permitting policies and processes to set a clear direction for industrial transitions and remove obstacles to investments.** Access to low-cost renewable electricity and faster and more predictable permitting processes were judged to be most important by our respondents. Public efforts to ensure that preconditions for successful investments in deep green industrial transitions are in place set out a clear direction for industrial transitions and decrease private actors' risk perceptions, clearing the way to mobilize more private capital.

11. **Policymakers should invest more in dialogue and coordination between private and public actors (including financial actors) to solidify long-term planning for deep green industrial transitions. Shared visions and strategies can play an important role in accelerating the willingness to invest.** Our respondents called for more state leadership in

terms of its long-term plans for supporting deep green industrial transitions. The clearer the political landscape is for industrial and financial actors, the more confidence they can have in developing their transition plans and in providing financing. To reach this there is a need for increased dialogue and coordination between private and public actors.

12. **As industrial transitions can evolve over decades, it is crucial that policymakers can deliver a stable and predictable framework that is credible over mandate periods.** A clear result is that significant swings in policy priorities can easily undermine the willingness to invest in risky deep green industrial transitions. Therefore, policymakers should, as far as possible, be sending coherent signals to industrial actors on what technologies, industrial inputs and products will fit into the evolving policy landscape for green industrial production.

1. Introduction

In its latest assessment reports, the Intergovernmental Panel on Climate Change stresses that there is a rapidly closing window of opportunity for global action to prevent and adapt to climate change and that mitigation and adaptation is needed now (Pörtner et al., in press). The need for action is urgent given that impacts are already worse and more widespread than previously expected and given the rate at which climate risks increase with temperature increases (Pörtner et al., in press). The Swedish Climate Policy Council has recently stated that a climate transition has been initiated in Sweden (national emissions are now about 35% lower than in 1990), but also finds that an acceleration of this transition is needed to reach the national target of net-zero emissions by 2045 (Klimatpolitiska rådet, 2022). Industry is responsible for about a third of Sweden's greenhouse gas emissions and investments in deep emissions cuts in this sector are key for reaching the national target. This involves investments in innovative technologies that enable increased efficiency in the use of materials and energy, increased circularity, and fuel and feedstock switches. For most industrial sectors several pathways are being implemented, although there remain large uncertainties and risks associated with the options they are pursuing.

Decarbonization of heavy industry is challenging from a technological perspective because vast amounts of energy are used to drive machinery and obtain process heat and because carbon dioxide emissions (CO_2) emerge from key chemical processes used to convert feedstock to product. This is the case for steel where CO_2 is a by-product from the reduction of iron ore and in cement where calcination of limestone entails the release of CO_2. Effectively implementing these technological and production changes can also require changes to infrastructure, for example strengthened power grids to supply electricity (Åhman et al., 2017; Nykvist et al., 2020).

As the technologies become more mature, the financial perspective is increasingly relevant because details are scarce on what the industrial transitions entail in terms of investments and prerequisites for investments to happen. A challenge from this perspective is that the use of new technologies will often increase both capital needs and operating costs, and there might also be periods when investments in new technologies have to overlap with old production processes while verifying new solutions (Material Economics, 2019; Swedish Energy Agency, 2019). Moreover, industrial sites have long lifetimes and long investment cycles. As a result, investments in technological and production changes that bring deep emissions cuts in heavy industry risk older assets having to be written off prematurely. At the same time, increased capital and operation costs make the business cases for investments in new production technologies more difficult. A better understanding is needed of how significant the challenges of capital investments and increased operating costs are and how to address financing and investment obstacles to industrial transitions.

1.1 Aim

The aim of this report is to better understand the key challenges for investments in technological and production changes that bring deep emissions cuts in heavy industry in Sweden. In this report we refer to this as investments in deep green industrial transitions. We investigate this matter from the perspective of both industry actors and actors from the financial sector. We investigate the following research questions:

- Is the size of the capital investments needed for green industrial production a significant challenge for bringing about these transitions in Sweden?
- What are the most important challenges for actors' willingness to invest in deep green industrial transitions and investors' willingness to provide financing for those investments?
- What policies do industrial and financial actors think can best support the willingness to invest in and provide financing for deep green industrial transitions in Sweden?

1.2 Delimitations

The report is focused on Sweden and the heavy industries that account for the largest share of greenhouse gas emissions in Sweden: iron and steel, cement, refining, and chemicals. In addition, the pulp and paper industry is included as it has large biogenic CO_2 emissions from the burning of biofuels (Garðarsdóttir et al., 2018) and thus has the potential to contribute to meeting the national net-zero target with so-called "negative emissions". The use of bioenergy carbon capture and storage (BECCS) can compensate for residual emissions that are very expensive to abate. The study also focuses on technological alternatives that can lead to radical reductions of process emissions. This means that incremental energy efficiency measures and reduced demand, although important, are not considered in this report.

1.3 Method

To answer our research questions, we applied a qualitative approach to data collection and analysis. First a literature study was conducted. Next, 15 semi-structured interviews were conducted with representatives from both industry and the financial sector; see Appendix 1 for an overview of interviewed firms. The industry representatives interviewed included roles such as head of treasury and head of research. Representatives from the financial sector were, for example, heads of asset management and head of sustainability. Interviews were conducted between October 2020 and June 2021 and lasted between 1 and 1½ hours. The interviews were all performed digitally (due to the restrictions during the COVID-19 pandemic). An interview protocol was used, which started with open questions on interviewees' engagements with investing in industrial transitions and the key challenges they face. The protocol then moved on to a set of questions based on predefined possible solutions that the interviewees were asked to rank and expand on; see Appendix 2 for the interview guide. The interviewees were given full anonymity in the report.

The material from the interviewees was analysed individually by each of the three members of the research team, coded thematically, and then the individual researchers' findings were compared and discussed among the research team. On 28 October 2021 all interviewees were invited to a workshop to verify preliminary results and to respond to additional questions and insights the research team had developed based on the interview data. The input from the workshop was used to update the interview results and draw final conclusions.

In addition to interviews and desk research, the project team also hired the student-run consultancy HandelsConsulting in Gothenburg to evaluate the financial strength of the largest companies in the industrial sectors in focus for this study: SSAB, LKAB, Cementa, Preem, Borealis and the new steel company H2 Green Steel. The consultants also interviewed this set of companies, which was selected by the research team, to get feedback on how they are financing their ongoing low-emission production initiatives and if they foresee any significant financing obstacles. No pulp and paper companies were selected for this part of the analysis given that at the time of this study there were no announced plans for implementing BECCS in this industry sector.

1.4 Structure of the report

Section 2 provides an overview of the technological pathways for decarbonization of the sectors assessed in this report. Section 3 provides estimates of the size of the capital investments needed to decarbonize production processes. The next three sections address obstacles to scaling up investments in industrial decarbonization. Section 4 examines how access to capital affects the ability to invest in deep green industrial transitions. Section 5 examines the challenge of weak or uncertain demand for green industrial products. Section 6 presents our respondents' perspectives on the direct support that public actors are already providing and what additional measures may be required. This section also addresses the state's role in ensuring that infrastructure and regulation create favourable conditions for investments in green industry. Section 7 summarizes our key findings and lays out recommendations to stimulate and facilitate investments in deep green industrial transformation.

2. Technological pathways and challenges in Swedish industry

This section provides an overview of different radical technological options for decarbonization of the steel, cement, refining, chemicals, and paper and pulp sectors in Sweden. For many industrial processes, multiple transition pathways are conceivable or are complementary parts of the same transition pathway. For example, industries that are considering carbon capture and storage (CCS) solutions as their main transition pathway may also be looking at carbon capture and usage (CCU) and BECCS as additional pathways for decarbonization. Industries that have hydrogen as the main transition pathway are also adopting an electrification strategy given the very large amounts of electricity needed to produce hydrogen through electrolysis. The technological alternatives outlined below are selected based on a literature study as well as feedback from key industry stakeholders from our interviews.

2.1 Iron and steel

The steel industry has several research and development projects under way aimed at deep green industrial transitions. Hydrogen reduction is the technological option that has the largest potential and is most prioritized by industry. The technological development is driven by the companies SSAB, LKAB and Vattenfall in a joint project, HYBRIT, which, if successful, will be the first hydrogen-based and very low-carbon steel plant. The HYBRIT project has built a pilot facility and will build a demonstration plant by 2025 (SSAB, 2021). SSAB recently announced that it plans to move forward the full decarbonization of its production by 15 years to 2030. SSAB notes that it plans to finance this with its own cash flow (SSAB, 2022). In February 2021, it was announced that H2 Green Steel AB intends to establish a steel plant in Boden with the aim to produce steel with a fossil fuel-free process using hydrogen (H2 Green Steel, 2021). Production is expected to start in 2024 with a capacity of 2.5 million tonnes per year. The planned investment in Boden is estimated at SEK 25 billion (EUR 2.4 billion). In addition to hydrogen reduction there is ongoing research and development on how electrification and biomass could be used in various ways to reduce emissions.

2.2 Cement

There are several different technological options available for the cement sector, of which CCS is perceived to have the greatest potential to reduce process-related emissions. In June 2021, Cementa, a subsidiary of HeidelbergCement, announced its intention to develop the world's first carbon-neutral cement plant in Slite in Gotland by 2030 (Cementa, 2021a). The installation at Slite will be scaled to capture up to 1.8 million tonnes of CO_2 annually, which essentially means the entirety of the emissions. Cementa has used fuel exchange to biomass and waste streams since the mid-1990s and it is considered an important technology option to achieve lower emissions; in combination with CCS it could even result in negative emissions (Cementa, 2021a).

2.3 Refining

The refining industry is facing a major transition as biofuel markets are growing rapidly and demand for fossil fuels is expected to become weaker in the future. One of the major actors in the refining industry in Sweden, St1, has identified biogas as its strategic focus to achieve its goal of net-zero emissions. In April 2021, St1 acquired E.ON Biofor, a leading actor in the Swedish biogas market (St1, 2021). In September it was announced that the Swedish timber, pulp and paper company SCA and St1 entered a joint venture to produce and sell liquid biofuels (SCA, 2021). Another large actor in the sector, Preem, joined forces with Setra in 2018 to produce bio-oil via pyrolysis of sawdust (Preem, 2021b). Production started in September 2021. In addition, within the Synsat project, Preem is rebuilding its Lysekil refinery to produce diesel from renewable raw materials, such as tall oil, rapeseed oil and recycled frying oil. The conversion is estimated to reduce emissions throughout the value chain by approximately 1.2–1.7 million tonnes of CO_2 each year.

The conversion to bio-based inputs has a domino effect for the refinery sector as it increases the need for hydrogen for hydrogenation. The industry is now exploring the possibility to switch to hydrogen production from electrolysis or biogas instead of natural gas, which would reduce emissions. A pre-study by Vattenfall and Preem that took place in the spring of 2021 has shown promising results and a plant of the order of 50 megawatts will now be investigated (Vattenfall, 2021). Fully developed refining based on hydrogen will require electricity corresponding to one-third of all electricity produced in Sweden today. Preem is also investigating CCS and BECCS implementation at its hydrogen production plant in Lysekil (Preem, 2021a). CCS or CCU are other options that are being explored as a possible solution for emissions from fossil fuel-based production.

2.4 Chemicals

The chemical industry has a complex composition of actors and business areas, of which the basic chemical industry generates the highest carbon emissions. The basic chemical industry is seen as particularly locked in because of its business model of delivering bulk industrial products where price largely determines sales in a highly competitive international market far from the end consumer. The industry identifies electrification, bio-based inputs, recycled inputs and CCU as key technological pathways.

In May 2021 the chemical company Perstorp presented its new research project, Project Air, in which biogas together with CO_2 and other residual streams will be used to produce methanol (Kihlberg, 2021). This process involves producing methanol from CO_2 captured from the company's production process and will allow the company to replace the fossil fuel-based methanol it purchases today. The company states that it is using a first-of-a-kind CCU process that combines gasification of biomethane and residue streams with the production of renewable hydrogen using electrolysis (Kihlberg, 2021). Thus, the electricity for the electrolysis plant will come from renewable sources. In September 2021 Borealis announced that it was going to test the use of renewable raw material in its cracker in Stenungsund (Borealis, 2021). The raw material for the cracker has traditionally originated from natural gas and petroleum but the company will now test the use of bio-based raw materials.

2.5 Paper and pulp

The Swedish pulp industry has undergone several transitions over the past 40 years and has managed to reduce its CO_2 emissions by 70% by replacing the most energy-intensive and fossil fuel-based processes with energy-efficient and renewable processes. As such the paper and pulp industry in Sweden is today almost fossil fuel free; however, there are still areas for development.

The paper and pulp industry is a large point source of biogenic CO_2 emissions, which means that BECCS is a conceivable opportunity for Sweden to achieve negative emissions. The emissions reduction could also be used to compensate for emissions in other sectors where it is difficult or very costly to reduce emissions (Ingenjörsvetenskapsakademien, 2019). There are currently no regulations or financial incentives and instruments for the pulp and paper companies to implement BECCS, but the Swedish government has recently announced that it will implement a system of reverse auctions for carbon capture and storage (Regeringskansliet, 2021c).

Table 1 provides a summary of the technological options, identified in the literature and our interviews, for deep decarbonization of heavy industry in Sweden.

Table 1. Summary of the deep green industrial transition options and initiatives for heavy industry in Sweden

Industry	Hydrogen	Electrific-ation	CCS, CCU, BECCS	Replacing fossil fuel with bio-based inputs	Thermo-chemically recycled inputs
Iron and steel	HYBRIT, H2 Green Steel	HYBRIT, H2 Green Steel		Höganäs Probiostål	
Cement		Cementa	Cementa – Slite 2030	Cementa	
Refining	Preem and Vattenfall	Preem and St1	Preem and St1	Preem and St1	
Chemical	Perstorp – Project Air	Borealis	Borealis	Borealis	Borealis
Paper and pulp		Stora Enso and Södra	Stora Enso and Södra		

3. The scale of investment needs

In previous research we found that with a total net increase in capital expenditure (CAPEX) investments of SEK 66 billion (EUR 6.5 billion) between 2020 and 2045 some 70% of domestic industrial emissions could be eliminated (Nykvist et al., 2020). By net CAPEX increases we mean investment levels above those that would be needed to maintain current production levels using existing technologies between 2020 and 2045. These net increases in investments in deep green industrial transitions would include:

- SEK 21 billion (EUR 2 billion) for the transition of primary steel production to a process based on hydrogen direct reduction
- SEK 2 billion (EUR 0.2 billion) for adding CCS to cement production
- SEK 16 billion (EUR 1.5 billion) for converting crackers in the petrochemicals sectors to use recycled plastics as feedstock
- SEK 12 billion (EUR 1.2 billion) for conversion to electrolysis production of hydrogen and adding CCS to oil refinery operations.

We also estimate that the remaining 30% of industrial emissions could be addressed by investing SEK 15 billion (EUR 1.4 billion) in CCS in the pulp and paper sector to achieve so-called negative emissions (Nykvist et al., 2020). It should also be noted that the technology pathways selected in the cost analysis from our previous work may not match exactly those that specific companies are considering today. Also, the figures above represent CAPEX costs once technologies are ready to scale commercially and there is good reason to expect them to be an underestimate of real-world costs, given the costs associated with research and development, piloting and demonstration that precede commercial-scale deployments. In our interviews respondents did tend to find that our estimates were low, but we were not able to get detailed feedback on how much higher real-world costs should be expected to be.

The most important result from the interviews with respect to capital requirements is that neither industrial actors nor financial actors find that the size of the capital investments is a fundamental barrier for transitioning to low-carbon industrial production. Rather, increased operating expenses and thus enduring increases in the costs of green industrial products are viewed as the most important obstacle to scaling investments, followed by issues related to supporting infrastructure and regulatory policies. We address these challenges in the following sections.

4. Access to capital and risk sharing

To understand what challenges financing could pose for deep green industrial transitions we did some preliminary assessments of the financial strength of a selection of heavy industry companies in Sweden: SSAB, LKAB, Cementa, Preem and Borealis. The assessment of financial positions was based on revenues in relation to earnings before interest, taxes, depreciation and amortization for the past five years, total fixed equity in relation to liabilities, and credit ratings. This analysis showed that leading industrial companies in Sweden have good financial positions and each of the established companies has a Creditsafe rating of 83% or higher, meaning that they have low or very low risks of defaulting on loans.[1] This assessment of the financial strength of those companies that are initiating or implementing decarbonization strategies helps to set the context for understanding our respondents' perspectives on the conditions for financing industrial transitions.

We also asked each of the selected companies and the new steel company H2 Green Steel how they are financing or plan to finance their low-emission production initiatives and if they foresee any significant financial obstacles for these initiatives. None of the companies surveyed indicated any meaningful financing obstacles at their current stages of development, nor have they indicated that they expect financing to be an important obstacle moving forward. Companies report that there is support and interest in financing deep green industrial transitions from public financing sources and support mechanisms, investment and commercial banks, investors and parent companies. However, several of these companies are at quite early stages of project development or at feasibility study stages. In these cases, larger financing decisions have yet to be made even though the companies interviewed report optimism that financing will be available.

The companies examined have different corporate structures and face different levels of expenditure for initiating deep green industrial transitions. As a result, they are financing their initiatives in different ways. This includes funding projects from their own cash flows, from parent company investments and from loans from commercial and investment banks. HYBRIT is a joint venture company that is piloting and demonstrating low-carbon steel production and is owned by SSAB, LKAB and Vattenfall. The HYBRIT consortium has received the largest amount of grant support that has been made available by the Swedish Energy Agency through its Industriklivet programme, but several of the companies surveyed have also received funding for pilot studies, research and development, and pilot projects from this programme (the details of this public support programme are described in Section 6). H2 Green Steel stands out as having raised a large amount of equity capital, as this is a completely new company.

In our broader set of 15 interviews that included both industry and financial actors we found similar results. All respondents indicated that there is good access to capital for heavy industry actors in Sweden and that financing as such does not represent a significant obstacle to decarbonization. Rather, it is the host of business case obstacles and transition risks noted above that are the central challenges that need to be overcome. However, as is shown below, our respondents did find that policies supporting financing and especially those that involve risk sharing are important for accelerating the pace of transitions.

[1] The credit ratings indicate risks of 0.2% or lower of bankruptcy within the next 12-month period for the assessed companies.

4.1 Policy alternatives

In our interviews we presented respondents with a set of policy options for improving access to and reducing the cost of capital. The policy options were:

- A green investment bank
  Bank capitalized with public funds that aims to leverage large amounts of private capital to green investments.
- Government credit guarantees
  Government provides credit risk mitigation to private lenders for a fee. This means that government will have to cover a portion of the lender's losses in case of default.
- Other concessional financing
  For example, blended finance where public funds take on first loss risks, or loans directly from public actors with below market rates.
- Green modifications of capital requirements
  The amount of capital banks are required to hold to issue loans is lower for "green" lending compared to other types of lending. This is meant to help decrease the cost of capital for green lending and incentivize banks to direct more capital towards green lending.
- Accelerated depreciation
  Depreciation of fixed assets at a faster-than-standard rate early in their economic life. This reduces the tax burden earlier in the economic life of an asset, shifting that tax burden to later periods. This can potentially help to incentivize investment in low-carbon production when these investments are capital intensive.
- Technical assistance office
  Activities could include supporting corporates in accessing both public and private financing, supporting investors in evaluating corporate transition plans, and supporting the structuring and due diligence of specific financing arrangements.

Respondents were asked to rank the usefulness of the proposed mechanisms for improving financing conditions or to identify other mechanisms not listed.

Many of our respondents found that government credit guarantees are an important way to reduce the costs of and improve access to finance and more importantly to share risk between private investors and the public. The Swedish government established a green credit guarantee programme for "green investments" in June 2021, in which the state can take part of the risk and give a guarantee for 80% of the loan. The guarantees are technology neutral and target large investments (i.e. more than SEK 500 million (EUR 48 million) for a maximum 15 years) in industry firms that contribute to the national objectives for environment and climate (Regeringskansliet, 2021b). For 2021 a maximum of SEK 10 billion (EUR 1 billion) in guarantees can be issued and for 2022 the limit is set to SEK 15 billion (EUR 1.4 billion). The guarantee is given to a bank that lends the money to the firm that makes the investment. This means that a bank must still be interested in issuing the loan, which in turn means that it must find a way to evaluate risks and handle uncertainties associated with the firm and the technological option it wants to invest in.

Industry interviewees agreed that green credit guarantees are an important mechanism to reduce risk and facilitate investment in technologies that can reduce emissions. However, our interviews were conducted prior to the government of Sweden's decision to initiate the loan guarantee programme and as a result none of our respondents had direct experience with this programme. We had some mixed responses on the role of a potential green investment bank. Some respondents, from both finance and industry, did not have a strong opinion and there was some uncertainty on what exactly the role of a green investment bank would be. One respondent indicated that having a green investment bank would be better than guarantees but felt that we already had such a bank in the European Investment Bank (EIB). In general, financial sector respondents emphasized that a new green investment bank would need to have a special mandate for its financing terms if it were to play a different role from that of existing investment banks such as the EIB and Nordic Investment Bank (NIB).

The EIB is committed to ensuring that 50% of its lending portfolio is supporting climate action and environmental sustainability by 2025 and that its entire lending portfolio is aligned with the goals of the Paris Agreement by the end of 2020. The EIB aims to support EUR 1 trillion in investments in climate action and environmental stability through to 2030 (European Investment Bank, 2020). In the area of green industry transitions, the EIB's InnovFin Energy Demonstration Projects programme provides loans, loan guarantees or equity-type financing to innovative demonstration projects that are at pre-commercial level or early commercialization stages of development. The EIB provides this funding for energy system transformation, including but not limited to renewable energy technologies, smart energy systems, energy storage, and carbon capture utilization and storage (European Investment Bank, 2019). Three Swedish companies have signed loan agreements with the EIB under this programme in recent years: Renewcell (circular clothing) EUR 31 million, Northvolt (batteries) EUR 52.5 million and Nilar (batteries) EUR 47 million (European Investment Bank, 2021). Northvolt, an example often mentioned by our respondents, has also received a USD 350 million loan from the EIB with financing support from the European Fund for Strategic Investments (EFSI). The EFSI is the main pillar of the Investment Plan for Europe and provides first loss guarantees that allow the EIB to invest in projects with higher levels of risk (European Commission, 2020d).

Few respondents were positive about green modifications of capital requirements, although one financial sector respondent did perceive such a policy as a powerful tool for mobilizing capital towards green investments generally (i.e. not specifically to heavy industry). Some respondents were more positive about a "brown" penalizing factor in capital requirements as opposed to a positive "green" factor. This, however, was thought to better reflect the actual financial risks associated with emissions-intensive investments given the need to decarbonize economies over the coming decades. The predominant perspective was that modification of capital requirements was a risky way of using policy to promote green investments and that capital requirements should be based on assessments of financial risks and not on other policy objectives. Respondents noted that it would also be difficult to develop definitions of what economic activities should benefit from green modifications of capital requirements.

Some but not all respondents were also positive about other forms of concessional finance or public de-risking in addition to government loan guarantees. However, our respondents did not have developed ideas or suggestions on what financial mechanisms or structures would be useful. A few of our industry respondents thought that accelerated depreciation could provide some benefit, but again views on this option were not developed among our respondents. With respect to a technical assistance office, the dominant view among our respondents was that these large, established companies and financial actors would not benefit significantly from this type of support. Some financial actors did, however, note challenges with respect to evaluating industrial transitions due to a lack of sector-specific expertise in-house.

4.2 Matching risk and sources of financing

Our financial actor respondents all indicated that they have strong incentives and mandates to invest sustainably and that they foresee increasing expectations from their customers and from policymakers to move capital into sustainable investments. Some respondents noted that the market pricing of stocks and bonds already reflects the premium that investors place on more sustainable companies and the risk aversion among investors with respect to exposure to high-emitting assets. Some of our bank respondents noted that they have added incentives to find sustainable assets to lend to because they can issue green bonds on those assets and benefit from lower capital costs (greenium). Our respondents all noted that they must limit their exposure to fossil fuels due to concerns about stranded assets and reputational risks. Several respondents noted that they have policies in place that limit the exposure to high-emitting companies and sectors. Examples include policies that limit exposure to fossil fuel extraction or that prohibit new funding of fossil fuel extraction. The EIB reported that it is aligning its financing to the sustainability performance standards of the European Union taxonomy or better.

Despite strong sustainability mandates, investors all indicated that they ultimately make investment decisions based on the risk reward profile of an investment and cannot deviate from that significantly for sustainability reasons. Not investing in certain high polluting sectors is the clearest way to combine sustainability mandates with return expectations and appropriate risk levels. Institutional capital (e.g. pension funds and insurance companies) tends to be focused on investment-grade low-risk investments. Regulations and their investing mandates mean that they cannot play a significant role in risky transitions. One respondent indicated that institutional investors may be better placed to invest in supporting infrastructure with secure cash flows. However, private investment in basic infrastructure is limited in Sweden.

If there are ways for institutional investors to invest in transitioning heavy industry companies on the credit side with lower-risk, then that is the most likely way that they would participate in financing these transitions. The main challenge is thus finding the right "owner" for the right level of risk. Several respondents indicated that there is a large role for public financing to play in taking on critical but higher-risk investments and for using risk sharing to increase the population of projects that the private sector can invest in.

Most of the companies in the industrial sectors studied in this report are well-established, large corporates that tend to finance themselves through their own balance sheet, parent companies, banks loans and debt markets (bonds). Investment and commercial bank respondents indicated that they are focused on the long-term viability of the companies in question and the viability of their decarbonization strategies in assessing the ability of companies to service their debts. Moreover, the implication is that the more certain the market demand the easier it is to secure financing.

An interesting point made by one respondent was that the lack of adequate data and communication on scope 3 emissions of companies higher up in value chains (e.g. emissions embedded in purchased industrial products or end-of-life treatment of sold products) was leaving too much focus on heavy emitting industrial sectors and too little focus on economic activities further down the value chain (e.g. manufacturers or the building sector). With a better understanding of scope 3 emissions, investors' true value chain exposure to emissions will be more transparent and there will be more incentives to engage on climate throughout value chains. Some financial actors noted that the EU taxonomy can help to make it easier to identify what is sustainable or "in transition" in these sectors and to communicate externally. Identifying where investors can get the biggest emissions reductions per dollar invested was also noted as an example of where financial actors could benefit from increased support or capacity. Box 1 presents a summary of policies for improving access to capital and for risk sharing.

Box 1. Summary of perspectives on policies for improving access to capital and for risk sharing

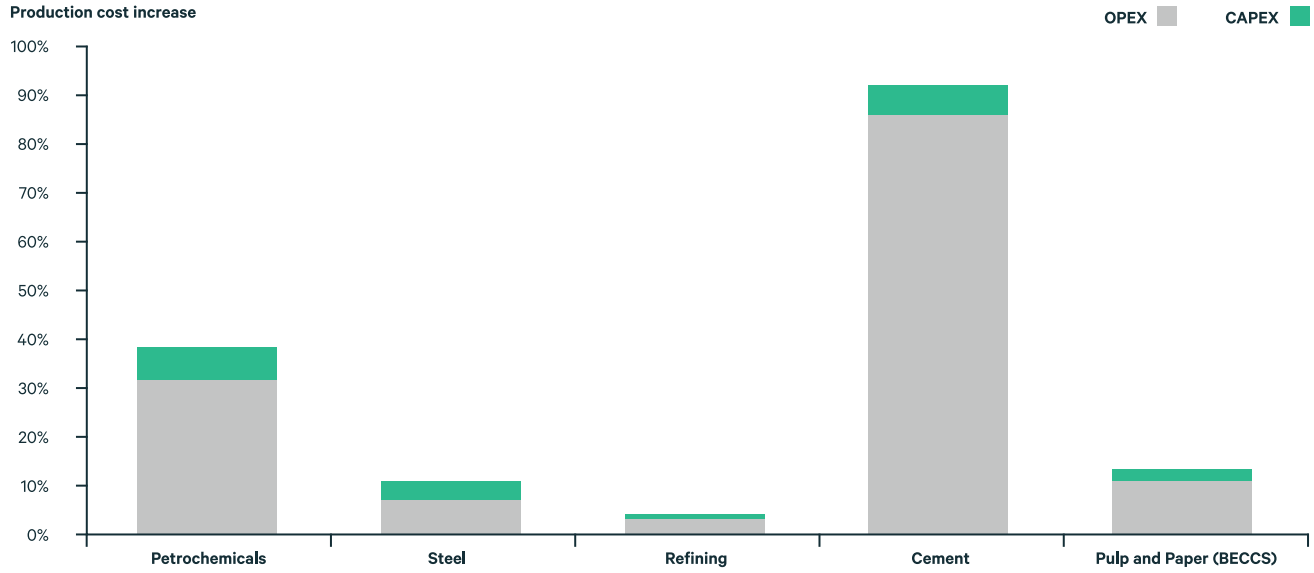
- Overall, industry reported good access to capital for transition investments.
- Respondents found governmental loan guarantees for larger investment in industrial decarbonization to be a good tool for risk mitigation and risk sharing.
- Modification of capital requirements was not perceived as an appropriate policy lever for stimulation of investment in green industry.
- There was little support for a new green investment bank given the roles already played by the EIB and NIB.
- We did not receive any detailed suggestions on additional financing mechanisms that would be important for access to capital.
- There was clear interest among financial actors in directing capital towards climate mitigation when the risks are in line with their investment and lending mandates. General recommendations that public actors can play a larger role in risk sharing.

5. Support for market formation and demand

The incentive to invest in new technologies and production processes is normally driven by efforts to increase efficiency and productivity, which lead to reductions in production costs. However, investments in deep green industrial transitions largely break with this logic, as these investments tend to increase production costs. As a result, the central obstacle to making investments in new low-carbon production has to do with the business case risks associated with increasing the costs of industrial products.

Figure 1 shows estimates for the production cost increases of moving to low-carbon technologies and separates out those increases associated with CAPEX and those associated with increased operating costs (OPEX). Note that these estimates are for the same technology pathways listed in Section 3.[2]

Figure 1. Production cost increase related to higher CAPEX and OPEX compared with typical cost in Europe



Source: Nykvist et al. (2020)

Because of the large share of OPEX in the cost estimates above, cost increases for green production are expected to be persistent even if companies can achieve further efficiency gains from technological development and learning and production optimization over time. The main business case risk highlighted by our industry respondents was the challenge of insufficient demand or at least uncertainty over the extent of future demand for green industrial products that are inherently more expensive than those produced using carbon-intensive technologies. The finance sector echoed closely the issue of demand-side risks and emphasized that if there are clear offtake agreements in place for green industrial products or otherwise strong evidence that there will be market demand, then the financing for these investments can be secured.

Those financial actors providing debt financing are more focused on the downside risks of companies not being able to service their debt and are concerned with the long-term viability of companies given that any specific lending decision often entails a longer-term relationship. This means that these financial actors are also highly aware of substitutability risks and technology risks that companies may face in the future. Thus, when future demand for an industrial product is expected to be maintained or increased over time and the technological pathway for

[2] Chemical recycling for petrochemicals, primary steel production based on hydrogen direct reduction, electrolysis production of hydrogen and adding CCS for oil refining, adding CCS to cement production, adding CCS to pulp and paper production (BECCS).

decarbonizing looks certain in the relevant market, then the case for providing financing is good. But if the broader societal transition to net zero looks like it will weaken demand for a specific industrial product or if the technological pathway appears uncertain and/or highly competitive, then the risk is higher and financing more difficult to secure.

One very positive piece of feedback from participants in the workshop we ran after the interviews were completed was a perception of increasing demand for green industrial products. One participant noted that increasing adoption of science-based targets in several sectors, such as transport and real estate, is spurring demand for industrial products with low embedded carbon. Orders from car manufactures like Volvo and BMW are, for example, helping to push Sweden forward as a leader in green steel production (BMW Group, 2021; Volvo Cars, 2021).

5.1 Policy alternatives

The policy options we presented to respondents for stimulating market demand for green industrial products were:

- Elevated carbon prices or taxes, for example EUR 45 per tonne, EUR 60 per tonne, EUR 90 per tonne of CO_2 *Carbon prices/taxes are charges per tonne of CO_2 emitted by a company in its operations (or other greenhouse gases converted to CO_2 equivalents). The EU Emissions Trading System (EU ETS) is the relevant pricing scheme for the sectors in this study and is described in detail below.*
- Carbon border adjustment measures
  These are trade measures that place tariffs on imports of carbon-intensive products which can also be complemented by rebates on the export of these same products. The tariffs are designed to increase the cost of foreign-produced products at the same rate that domestic carbon prices raise the cost of products produced domestically (i.e. to the extent that foreign producers face no or lower carbon prices). Export credits reduce the cost of domestically produced products that are exported to reflect the carbon pricing producers face in other jurisdictions. Another way to achieve this effect could be CO_2 consumption charges or taxes on embedded carbon in products sold within the jurisdiction with carbon pricing. The aim is again to equalize imported products' exposure to carbon prices.
- Public procurement of green industrial products
  Public authorities make commitments to purchase green industrial products when they are building out, for example, infrastructure or real estate. Public offtake agreements can thus play a role in producing lead markets for green industrial products.
- Production subsidies
  Subsidies can take many forms, but the basic idea is that producers receive public funds to partly or fully cover the additional production costs associated with new low-carbon production methods. Mechanisms could include carbon contracts for difference (CCfDs), feed-in tariffs or tax credits.

  CCfDs have received particular attention in recent years. They are a subsidy system where the government pays low-carbon producers the difference between the carbon prices all actors in the sector are exposed to and some agreed carbon price that aims to cover the actual increase in production costs associated with the use of low-carbon production technologies and processes. When the market carbon prices for the sector in question are below the carbon price agreed to in the CCfD, the producer receives a payment from the government for the difference on each tonne of low-carbon production. If the market carbon price becomes higher than the contracted carbon price in the CCfD the producer would pay in the difference between the market price and the contracted price to the extent that the producer is still emitting some CO_2 (although some proposals do not include this feature; see Bataille, 2020).[3]

[3] For an evaluation of how CCfDs could be used to help decarbonize the EU steel sector see Vogl et al. (2021).

- Carbon content standards and prohibitions
  Using regulations rather than prices to generate demand for green industrial products and/or increased requirements for circularity in production processes. This could entail requirements for reduced carbon content in materials or products, banning certain types of products (e.g. a ban on petrol and diesel cars or on fossil fuel-based plastics in certain applications), regulation of material flows and recycling.
- Concessions/private public partnerships (PPPs)
  These can take many forms, but the basic idea is that private actors make investments in the development of infrastructure or other public services that government would typically finance. This can be desirable, for example, when governments face budgetary constraints for large capital investments. In return, the private investors receive some form of concession over a specified period that allows them to recoup their investment and make a return (e.g. road tolls on a highway project). An example in Sweden is the Arlandabanan railway line.

Respondents were asked to rank the usefulness of the proposed mechanisms for improving the willingness to invest and financing conditions or to identify other mechanisms not listed.

A price or tax on CO_2, preferably on the global level, was put forward by all interviewees (from both industry and the financial sector) as the most desirable option. Carbon prices internalize the external cost of emitting and help to create demand for industrial products with low or zero emissions. Carbon prices broadly applied are also technology neutral, giving different industry actors the same prerequisites to innovate and find solutions that meet the demand of customers. However, from a political perspective robust carbon pricing has proved to be very difficult to implement and we remain far from anything resembling a global pricing system. For this reason, interviewees from both industry and the financial sector underlined the importance of the EU ETS at the European level.

The EU ETS is the world's first and largest carbon market, which includes emissions from the power sector, industry and airlines within EU countries. The EU ETS has historically struggled with low prices on carbon, but prices have now increased significantly, especially over 2021. Our interviews took place largely in the last half of 2020 and the first half of 2021 and as such only captured part of this recent rise in carbon allowance prices. Several interviewees believe further increases can be expected as the system is currently under review with the introduction and negotiation of the European Commission's Fit for 55 package (European Commission, 2021b). The historical low prices along with free allowances provided to industrial producers have provided limited incentives to change and innovate, but with higher prices and declining free allowances to 2035, incentives to cut emissions in production increase. Still, several interviewees from the financial sector would like to see even higher prices for the EU ETS to have a larger impact on demand and more than a marginal effect on industry.

As part of Fit for 55 the European Commission proposes a carbon border adjustment mechanism (CBAM) to create fair competition between industry actors within the EU ETS and those producing the same products outside Europe. From the European Commission's perspective, it is important to ensure that the EU's ambition to combat climate change inspires other regions and also avoids carbon leakage and the flooding of the EU market with carbon-intensive goods produced abroad (European Commission, 2021a). Interviewees from both industry and the financial sector agreed that without a global price on carbon, CBAM or some other competitiveness measures will be needed to level the playing field between actors within and outside the EU.

In addition to policy measures at the EU level, there are also national policy measures to stimulate demand targeting specific industry sectors or the industrial sector more generally. For the refinery industry a national reduction obligation was introduced in 2018 (SFS 2017:1201) to create demand for renewable fuels and reduce emissions of carbon. The reduction obligation implies a gradual increase

of the share of biofuels that should be blended into fossil fuels. The refinery industry is positive about the reduction obligation as it creates a credible and predictable demand for biofuels.

For the chemical industry there is no national policy targeting the industry or its emissions specifically. Representatives from the industry discussed how EU Directives (e.g. the EU Waste Framework Directive and Packaging and Packaging Waste Directive) could be complemented by national policies that help to prioritize the recycling of plastics over incineration, increase demand for products with recycled material, or set quotas for recycled polyethene. Because the cement sector mainly has a national or regional market and because the public sector plays a large role in financing infrastructure, public procurement can play an important role in creating demand for cement produced with low emissions. Cementa, the Swedish cement producer, has publicly highlighted the importance of public procurement for implementing its decarbonization plans (Cementa, 2021b), and this was also reflected in our interviews. Steel produced in Sweden is sold on the international market and national procurement can only have a limited impact. To stimulate demand for green steel our sector respondents suggested that an international labelling or standard could contribute, but so far this is only under discussion.

The incentives for the pulp and paper industry to implement technological options that can radically reduce their non-fossil fuel based (green) carbon emissions are low. This is because the biogenic CO_2 emissions from pulp and paper mills are not considered as making a net contribution to national emissions and are not subject to carbon pricing in the EU ETS or otherwise. As these emissions are not treated as an externality, the business case for CCS on pulp and paper plants is dependent on there being actors willing to pay for the costs of achieving negative emissions. Covering these costs would thus need to be supported by public funds or by including these negative emissions in some form of carbon market mechanism. A recent Swedish inquiry recommended a reverse auction system for public subsidization of BECCS or other carbon removal technologies (Energimyndigheten, 2021), and late in 2021 the Swedish government decided that such a system would be implemented (Regeringskansliet, 2021c).

During the interviews we also discussed production subsidies and CCfDs specifically. Some industry actors viewed this option as potentially positive but, overall, our respondents did not have very developed perspectives on CCfDs. Support for CCfDs is increasing in the EU and their use has been proposed as part of the EU Hydrogen Strategy (European Commission, 2020c). CCfDs are also mentioned as a mechanism states can use in the European Commission's recently updated *Guidelines on State aid for climate, environmental protection and energy* (European Commission, 2022).

The interviewees stressed that although policy measures to stimulate demand are important, so is the long-term predictability of chosen mechanisms, as this is central to evaluating future increases in demand for green products. Large investments in new technologies and in refitting or building new production sites stretch over political mandate periods, and for this reason our respondents emphasized that changes in political priorities expose them to risks. In a similar fashion we also noted concerns from some sectors on whether different policy measures or targets are sending consistent signals to market actors on how the policy landscape will develop. For example, respondents in the refining sector indicated that the Swedish "reduction obligation" for fuel is a powerful market-generating tool but that the proposed EU Fit for 55 legislation requiring new cars to have zero tailpipe emissions by 2035 (European Commission, 2021b) points in the opposite direction with respect to the role of biofuels.

A summary of the different policy alternatives discussed and the interviewees' perspectives on them is provided in Box 2.

Box 2. Summary of respondent perspectives on market formation policies

- A global price or tax on carbon was the most preferred option, but this is not likely to be introduced over the short or medium term.
- EU ETS and its price on carbon is key, but the price and price exposure has historically been too low in industry to drive investment in low-carbon technologies. Higher prices and greater price exposure are anticipated in the future.
- Interviewees were supportive of a CBAM and other competitiveness measures but stressed the importance of continuing to work for a level playing field both within and outside the EU.
- Interviewees were also positive about national policy to support demand and form markets. Particularly, the reduction obligation for the refinery industry and public procurement for the cement industry.
- However, industrial actors do not yet appear to have sufficient confidence in the long-term credibility of market-generating policies.

6. Direct public funding, infrastructure and permitting

Based on previous analysis and the results from this study, the capital costs of investing in low-carbon solutions are not in theory a hurdle to green industrial production if we assume technological readiness and that market demand and supporting policy and infrastructure are in place. However, in practice the large risk involved in scaling new technologies and production processes is one of the reasons decarbonization has been slow in industrial sectors (Löfgren & Rootzen, 2021). Given the inherent risks of large technological shifts in capital-intensive industrial sectors and the added risks of adopting technologies and production methods that tend to increase production costs, public financing can be needed to help companies manage risks and to incentivize them to implement ambitious decarbonization pathways (Popp, 2019).

6.1 Policy alternatives

There are several public support mechanisms at national and EU level that aim to stimulate innovation and support research, development and demonstration of new technological options. In the interviews for this project, we discussed these possibilities and how well they meet the needs of industry and financial actors (with a particular focus on the perspective of industry). In our interviews we presented respondents with the following policy options:

- Government infrastructure investments
  This regards the need for indirect investment in infrastructure to enable commercialization of the options for green industrial transitions. Examples of this are investments in power generation and power grids, infrastructure for hydrogen production and CCS networks.
- Reliable and accelerated permit processes
  Permits are needed for new industrial sites as well as for larger changes to existing ones and construction of new power grids. We discussed with the interviewees to what extent handling this possible bottleneck would contribute to accelerating investments in green industrial transition.
- Direct state financial support for innovation
  This policy option involves direct investments from public funds to innovation for research, development and piloting. Since demonstration and commercialization implies other challenges and involves larger sums this was discussed separately.
- Direct state financial support for demonstration facilities
  This regards direct investments from public funds into demonstration and commercialization of options that can be part of a green industrial transition. To the extent that public funding is provided at this stage of development it is most likely in combination with private funds, which will tend to dominate financing the closer options are to commercialization.
- EU financing and exemptions from state aid rules
  We discussed EU financing that provides direct support for innovation or demonstration such as the EU Innovation Fund. We also discussed exemptions from the state aid rules, for example in terms of funding for Important Projects of Common European Interest (IPCEIs).

Of greatest concern to our industrial sector respondents were investments in infrastructure and other supporting systems as well as more predictable and quicker permitting processes. Both industry and the financial sector emphasized the need for access to very large amounts of electricity generated with renewables and investment in the electricity grid. This is of central importance given that electrification and the use of hydrogen produced through electrolysis is key for several industrial transformation processes. HYBRIT, the joint venture between SSAB, LKAB and Vattenfall, estimates that it will need 15 terawatt-hours (TWh) of electricity for the realization of the fossil fuel-free steel production process (Jernkontoret, 2018). This represents about 10% of Sweden's current electricity production. The low-emissions pathway planned by LKAB will require 55 TWh of electricity, which is nearly one-third of Sweden's current production (LKAB, 2020).

Lack of sufficient grid capacity is, for example, an obstacle to Preem's efforts to cut emissions at its refinery in Gothenburg. According to the interviewee, current limits on how much electricity can be transferred to the site hinder the firm from implementing options that require large amounts of electricity such as electrolysis for hydrogen production. The interviewees underlined the importance of sufficient investment in the infrastructure necessary to implement technologies that radically reduce emissions. As an interviewee from the financial sector argued, "there is a chicken and egg situation with investments in technology and infrastructure that needs to be broken, but it is not simple". Infrastructure is needed to enable the realization of the technologies and to reduce risk for investments. On the other hand, investments in infrastructure should not be made before it is clear what is needed and will be used. Our respondents emphasized that government has an important responsibility for ensuring that infrastructure is in place to meet the needs of the industries investing to radically reduce their emissions in line with the national net-zero target.

Besides infrastructure, several industry and financial sector representatives stressed the predictability and speed of the permitting process for new or redesigned production sites as the next most important issue impacting investment decisions. Permitting processes are perceived to be time-consuming and difficult to predict, which becomes an additional obstacle that affects both new construction and larger changes to existing sites. An example is the permits required for transmission grids, where the process for permits takes much longer than the construction itself. Several initiatives have been taken or are under way to address this challenge, such as the government-initiated inquiry on the process for permits (Regeringskansliet, 2020).

Direct public financial support can target one or several of the phases of development for new technological options, which can be summarized as research and development, pilot, demonstration and commercialization. For the phase of research and development most industry interviewees are satisfied with the current support. Particularly the national programme Industriklivet, which is open to all studied industries, has a yearly budget of SEK 909 million (EUR 87 million for 2022), and supports research, innovation, feasibility studies, pilot and demonstration projects until 2029 (Energimyndigheten, 2022).

In Box 3 we briefly present several of the available programmes providing public financial support for developing new, climate-smart industrial production methods:

Box 3. Swedish and EU public financial support for climate-smart industrial production

- **Industriklivet** is a Swedish national initiative started in 2017 to support measures to mitigate Swedish process-related greenhouse gas emissions from industry as a step towards reaching the national net-zero target. Industriklivet provides grants for research, development and demonstration. The total budget for 2021 was SEK 750 billion (EUR 72 billion) to fund projects lasting until 2028. The budget for 2022 is SEK 909 billion (EUR 87 billion) (Energimyndigheten, 2022).
- **The EU Just Transition Fund (JTF)** is one of the three pillars in the EU Just Transition Mechanism (European Commission, 2020b). Sweden has been allocated EUR 324 million from the fund (European Commission, 2020a). The JTF started in 2021 and will continue until 2030 (Tillväxtverket, 2022). Currently, the Swedish government and the European Commission are reviewing the Swedish Energy Agency's proposed Just Transition Plans. These plans propose that four industries in four regions receive funding: the steel industry in Norrbotten, the mineral industry on Gotland, refineries and the chemical industry in Västra Götaland and the metal industry in Västerbotten (Tillväxtverket, 2022).
- **The EU Innovation Fund** will fund the commercial demonstration of innovative low-carbon technologies with around EUR 20 billion (depending on carbon prices), over 2020–2030.

Box 3. Continued...

The funding comes from the EU Emissions Trading System and can support up to 60% of the additional CAPEX and OPEX of large-scale projects; for smaller projects only CAPEX is covered (European Commission, n.d.-d). In November 2021 it was announced that two Swedish projects, HYBRIT and Stockholm Exergi, were granted funding from the Innovation Fund out of a total of seven large-scale projects. In total EUR 1.1 billion was granted to the seven projects (European Commission, 2021c).

- **Important Projects of Common European Interest (IPCEI)** is a mechanism designed to overcome market failures caused by lack of private support for innovation due to the significant risk involved in such projects. IPCEIs allow member states to jointly sup port such innovation (European Commission, 2019). This means that the funding comes from the member states rather than from the EU. Sweden is part of two of the three IPCEIs so far: the IPCEI on batteries and the IPCEI on hydrogen. For the IPCEI on hydrogen, Sweden has proposed a budget of SEK 200 million (EUR 19 million) for 2021, SEK 200 million (EUR 19 million) for 2022 and for 2023–2027 SEK 70 million (EUR 7 million) annually (European Commission, 2019, 2020e). Through the second IPCEI on batteries, Northvolt AB received SEK 238 million (EUR 22 million) (Regeringskansliet, 2021a).
- **Horizon Europe** is Europe's main funding programme for research and innovation, with a total budget of EUR 95.5 billion through to 2027 (European Comission, n.d.-a). The programme is divided into three pillars: Excellent Science; Global Challenges and European Industrial Competitiveness; and Innovative Europe. Support is mainly given to research, development and innovation, and demonstration.
- **The European Regional Development Fund (ERDF)** is under the European Structural and Investment Funds and finances programmes (European Commission, n.d.-c). The Commission and national and regional authorities in member states share the responsibility for the ERDF. The member states' administrations select projects to finance and are responsible for the ongoing management (European Commission, n.d.-b). In Sweden the ERDF has led to eight regional funds and a national programme (Tillväxtverket, n.d.-a, n.d.-b).

At the demonstration and then commercialization stages securing financing can be increasingly challenging for plants or processes based on innovative technology. This is because the investment needs become progressively larger while uncertainty and risk can remain high for first-of-a-kind solutions. One industry interviewee estimated the success rate of going from demonstration to full scale at only 50%. Industry interviewees see opportunities to moderate these risks with existing support mechanisms at both the national level (e.g. Industriklivet) and the EU level (e.g. EU Innovation Fund and JTF). At the same time, several respondents indicated that to accelerate the pace of change in line with Sweden's 2045 targets, governments will have to be willing to take on more of the demonstration and commercialization risk than would be required in "regular" innovation politics. What form this risk taking should take was, however, less clear in our results. Direct public funding at commercialization stages was not suggested by our respondents, but risk sharing in the financing of deployment was, as discussed in Section 4.

As has been noted, one of the main challenges for green industrial production is the increase in operating costs these new technologies and processes entail. Typically, public funding for industrial innovation is not provided to cover increases in operating costs once production is established. However, the Norwegian government's decision to provide public funding for the first large-scale implementation of CCS at a cement plant (Norcem) includes funding for increased operating costs over a 10-year period (Nykvist et al., 2020). The EU Innovation Fund can also provide support for operational costs. Our respondents were generally sceptical about the political feasibility and desirability of direct public funding of operating costs. However, as noted

in the previous section, public procurement and CCfDs did receive support from some of our industry respondents and in practice these mechanisms use public funds to help cover increases in production costs.

EU state aid rules regulate how much and under what conditions a member state can provide funding to its firms. For example, these rules must be considered in the design and execution of the national Industriklivet programme. IPCEI is a mechanism used within the EU allowing for limits to state aid to be exceeded for the development of technological options and value chains that are important for mitigating climate change in the EU and where several EU countries are involved. There is support among our respondents for public funding to play a larger role in industrial innovation, including relaxations of state aid, but several representatives from both industry and the financial sector also suggested that larger EU members seem to be finding ways to provide support to their national industries at higher rates than Sweden. For example, France recently announced an investment of EUR 5.6 billion for the decarbonization of its industry (Moussu, 2022). Although positive for technological development, there is a risk that this will affect fair competition within the EU. Thus, some of our respondents expressed concerns that the Swedish government was not doing enough to promote the interests of Swedish industry in an EU context. The worry is that Swedish industry or specific Swedish companies could find themselves at a competitive disadvantage in relation to larger EU countries that are more assertive or effective in mobilizing EU funding and providing direct support to their own national industries. A representative from the financial sector stressed that the Swedish government should work at the EU level to ensure that state aid rules create a level playing field rather than taking actions to further stimulate innovation and industrialization at the national level. The concern is that if countries ramp up industrial support at the domestic level, smaller countries like Sweden will find themselves at a disadvantage and that healthy market competition will be undermined.

A summary of the interviewees' perspectives on the different policy alternatives for direct state actions is found in Box 4.

Box 4. Summary of respondent perspectives on direct support policies, infrastructure and permitting

- Infrastructure such as electricity grids and the predictability and speed of the permitting process are key for mobilizing investments and for risk reduction.
- For research and development, most industry interviewees are satisfied with the current support, particularly the national programme Industriklivet.
- For commercialization and first-of-a-kind full-scale facilities, industry interviewees underlined the need to continue direct support for demonstration and commercialization as well as the importance of risk sharing between public and private actors.
- However, our results do not provide detailed suggestions on how increased public support for industrial transitions should be structured.

7. Recommendations for increasing the pace of investment

The aim of this report is to better understand the key challenges for investments in technological and production changes that bring deep emissions cuts in heavy industry in Sweden. We investigate the following questions:

- Is the size of the capital investments needed for green industrial production a significant challenge for bringing about these transitions in Sweden?
- What are the most important challenges for actors' willingness to invest in deep green industrial transitions and investors' willingness to provide financing for those investments?
- What policies do industrial and financial actors think can best support the willingness to invest in and provide financing for deep green industrial transitions in Sweden?

7.1 The scale of the investment and financing deep green industrial transition

Our key finding in this study is that neither the scale of capital investments needed for implementing low-carbon industrial production in Sweden nor access to financing to make these investments is perceived to be a significant obstacle by industry or financial actors. The scale of investments is large and for many industrial actors there are needs for direct support for early-stage development of new technologies and production processes. There may also be needs for risk sharing between public and private actors at stages close to or at commercialization. However, given a viable business case for green industrial products, capital requirements and access to finance do not appear to be critical obstructions once companies are prepared for commercial-level deployments. Instead, our interviewees emphasized issues related to creating market demand, infrastructure (especially access to renewable electricity), and a more predictable and reliable permitting process as most important for enabling investments in deep green industrial transitions.

According to our interview results, industry and financial actors find that existing direct financial support mechanisms and government credit guarantees are appropriate support and risk sharing tools. Measures that can help to reduce investment risks along the transition pathway, like loan guarantees, are positive for increasing the willingness to invest and may need to be expanded. However, in this study we have not been able to assess the effectiveness and significance of credit guarantees, given that none of the actors interviewed had made use of this instrument at the time of our interviews. Our results do not point to any specific and new financing support mechanisms that industry and financial actors would like government to put in place. However, respondents did indicate, in a general way, that the scale of government support, both direct financial support and financial risk sharing, may need to be ramped up as industrial decarbonization pathways move from early stages to demonstration and commercial deployment.

Some of our financial sector interviewees did not view themselves as the right type of financier for industrial transitions because of mismatches in risk profiles. These interviewees observed that the relevant companies are large, well-established firms that can finance their transitions in the same ways that they currently finance their operations. Some of our financial sector respondents are providing financing to green industry in Sweden, for example to Northvolt (batteries) and SSAB (green steel). Notably, the EIB stands out in our interviews with respect to financing solutions directed towards accelerating industrial transitions.

Our results with respect to financing should be understood in the context of the early stage of development of green industrial production for some, but not all, of our industry respondents. Currently our respondents are not reporting financing challenges and they are optimistic about the availability of financing at later stages of development. There is a general sense among

both our industry and financial respondents that access to capital is very good for sustainable investments and good for green industrial production given the right policy and market conditions. However, as many of the major investment decisions have yet to be made, our results may not reflect challenges that could occur at the point of commercial deployment. Moreover, it is very difficult to predict how financial markets will develop over the long timeframes for which investments in deep green industrial transitions are needed. As such it is still too early to make a judgement on the extent to which policy efforts could be needed to mobilize financing towards these transitions.

Recommendations:

- Our results suggest that loan guarantees are an appropriate method of risk sharing for commercial-scale investments in deep green industrial transitions. Based on evaluations of the success of the existing programme, decision-makers should determine whether expanding the scope and size of the programme can accelerate the rate of green industrial transition in Sweden.
- If needs for new financing solutions become apparent over time, our results suggest that public authorities will likely need to take a leadership role and set in motion proposals and dialogue with relevant private actors. In our results, we did not find detailed new proposals for public/private financing solutions.
- The responses from our interviews suggest that policies for improving the terms of financing will not likely play a large role in mobilizing the willingness to invest in deep green industrial transitions. Policymakers should instead pay particular attention to other areas of support outlined in the following sections.

7.2 Market formation and demand

Our results show that the key policy space for mobilizing investments into green industry is to support market formation and demand for green industrial products. Market formation and technological feasibility are preconditions for companies to see a business case for investment in low-carbon production and for financiers to provide capital. As confidence in technological solutions advances, more attention is focused on how the increased costs of green production can be transferred to end consumers. The most desired market generation policies from both industry and finance are general policies like carbon taxes or prices combined with measures to protect the competitiveness of industries, for example a CBAM or other carbon leakage measures.

We did not receive detailed responses on how competitiveness measures should be structured, and our interviews were conducted prior to the European Commission's mid-2021 (Fit for 55) proposal on the establishment of a CBAM. The issue of how a CBAM is designed will potentially have large impacts on industrial actors in the EU. Although there was not an opportunity to get responses on different actors' positions with respect to the CBAM proposal, our industry respondents did note concerns regarding potential negative impacts of a CBAM if poorly designed.

More general policies are preferred because of the emphasis our respondents placed on creating a level playing field between high and low emissions production (i.e. so that low-emissions production is not disadvantaged); between different industrial products, technologies and business models; and between domestic, EU and international competitors. At the same time, demand generation policies directed at specific sectors were emphasized by some actors. Adopting public procurement policies for green industrial products is important for the cement sector especially, while policies requiring the blending of biofuels into petrol and diesel are important for the refining sector.

Working with value chains to create demand for green industrial products, both through policy and bottom-up efforts, can accelerate the pace of transitions as has been proven in the case of green steel production in Sweden. Demand for green steel from car and other manufacturers has accelerated the pace of transition that steel producers in Nordic countries are aiming for. Repeating this dynamic in other regions and for other climate-intensive industrial sectors is of crucial importance.

Recommendations:

- Policymakers should focus on market generation efforts. Particularly important are current efforts at the EU level to ensure that carbon price signals are high enough to create business cases for green industrial products and efforts to prevent carbon leakage maintain a fair competitive environment.
- Both investors and policymakers should also continue to push for companies to deliver transparency and target setting with respect to their scope 3 emissions.
- The methods for and extent of demand-generating policies should be considered sector by sector as there may be divergence on the degree to which general policies and bottom-up approaches achieve the desired pace of change in different sectors.
- It is important that policymakers provide credible long-term commitments to market/demand-generating policies given the timeframes over which investments in green industrial transitions play out. An unstable policy climate has a clear risk of undermining private sector confidence in these investments.

7.3 Direct public financing, infrastructure and permitting

Although our respondents indicated that access to financing for commercial deployment is good (assuming good market demand indication), public funding is needed to incentivize and accelerate the pace of investment in deep green industrial transitions. Our respondents are largely satisfied with the levels of national and EU direct support for research and development, particularly the national programme, Industriklivet. For commercialization and first-of-a-kind full-scale facilities, industry interviewees underlined the need to continue direct support at demonstration and commercialization stages and they also emphasized the importance of risk sharing between public and private actors. At the same time, several companies indicated that they are confident they can secure financing for deploying low-carbon solutions. As our interview results only provide very general indications on potential financing needs, more research and dialogue are required to better understand the specific policy support measures that could be required in future.

Another key action policymakers can take is to have clear and credible long-term plans to ensure that the infrastructure and policies needed to support sectoral transition pathways are in place. Access to low-cost renewable electricity and faster and more predictable permitting processes were judged to be most important by our respondents. In general, our respondents called for more state leadership in terms of its long-term plans for supporting industrial transitions. The clearer the political landscape is for industrial and financial actors, the more confidence they can have in developing their transition plans and in providing financing.

Recommendations:

- Government should continue with its existing financial support mechanism, reviewing financing needs periodically, and work to ensure that Swedish industry is able to access support measures at the EU level.
- The Swedish government should work to ensure that support measures for industrial transitions are not undermining fair competition.

- Policymakers should emphasize ensuring that necessary infrastructure will be available and implement reforms to permitting policies and processes. These are efforts public actors can take that credibly set out a clear direction for industrial transitions and decrease private actors' risk perceptions, clearing the way to mobilize more private capital.
- Given the rapidly rising levels of ambition among industrial actors in Sweden, there is now a need to invest more in dialogue and coordination between private and public actors (including financial actors) to solidify long-term planning for green industrial production in Sweden. This is particularly important on issues of predictable and stable regulations and policy, infrastructure needs, permitting processes, and demand for products/material produced with low emissions. Shared visions and strategies can play an important role in accelerating the willingness to invest.
- Stable and predictable frameworks that are credible over mandate periods are particularly important as significant swings in policy priorities can easily undermine the willingness to invest in risky deep green industrial transitions.
- As far as possible, policymakers should be sending coherent signals to industrial actors on what technologies, industrial inputs and products will fit into the evolving policy landscape for green industrial production.

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Appendix 1: Interviewees

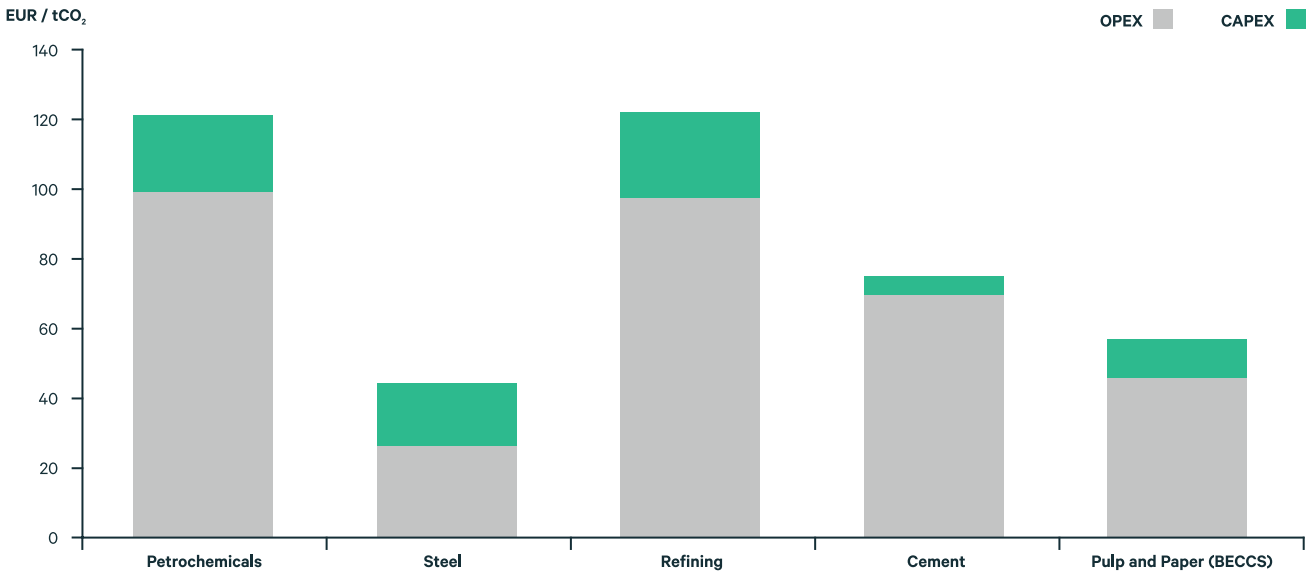
Organization	Interview date
Preem	2020-11-12
St1	2020-11-13
SSAB	2020-11-27
Södra	2020-11-27
Stora Enso	2021-01-29
Fossilfritt Sverige	2021-02-09
Nordic Investment Bank	2021-02-15
LKAB	2021-02-22
Skandia	2021-03-22
Hållbar Kemi	2021-03-30
European Investment Bank	2021-03-30
Folksam	2021-04-01
Nordea	2021-04-30
Danske Bank	2021-05-17
Cementa	2021-06-07

Appendix 2: Interview guide

- Introduction to the study, the researchers and the interviewee.
- From our understanding these are the main technological options for radical reduction of emissions in your industry. Do you share this view?

Industry	Hydrogen	CCS	CCU	Circular models	BECCS	Electrifi-cation	Bio-based fuel/ feedstock
Refining	●	●				●	●
Steel	●					●	●
Cement		●				●	●
Petrochemicals	●	●		●		●	●
Pulp and paper					●	●	

- Stockholm Environment Institute has estimated the size of the additional investment as the following … …. What do you think about this number?
  - SEK 21 billion – hydrogen-based production of steel
  - SEK 2 billion – carbon capture and storage (CCS) in cement production
  - SEK 16 billion – plastic production based on chemical recycling
  - SEK 12 billion – refineries with green hydrogen and CCS
  - SEK 15 billion – bioenergy carbon capture and storage (BECCS) in the pulp and paper sector
- What do you think of the following values for the contributions of capital expenditures (CAPEX) and operating expenses (OPEX) to total abatement cost?



- What challenges do you see for making this investment?
- In terms of direct support to RD&D, innovation and infrastructure, which of the following options do you see as most needed? Why?
  - Government infrastructure investments
  - Reliable and accelerated permit processes
  - Direct state financial support for innovation
  - Direct state financial support for demonstration facilities
  - EU financing and exemptions from state aid rules
  - Public support for early settlement of fossil-intensive assets
- In terms of market formation, which of the following options do you see as most needed? Why?
  - Elevated carbon prices or taxes (i.e. EU ETS)
  - A CO_2 consumption charge/tax
  - Carbon border adjustment measures
  - Public procurement of green industrial products
  - Production subsidies
  - Carbon content standards and prohibitions
  - Concessions (such as private public partnerships)
- How could your access to capital be improved?
- Which of the following actions do you see as most needed to increase access to capital? Why?
  - A green investment bank
  - Government credit guarantees
  - Other concessional financing
  - Green modifications of capital requirements
  - Accelerated depreciation
  - Technical assistance office

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