IMPLEMENTATION CONSULTING GROUP_

THE ECONOMIC IMPACT OF BECCS IN SWEDEN

January 2022

EXECUTIVE SUMMARY

In this report, we investigate the socioeconomic impacts for Sweden of investing public funds in maturing and scaling bio-energy carbon capture and storage (BECCS) technology. An effort which could form an integral part of reaching the country's net zero climate targets in 2045 with the right policy focus. By highlighting economic impacts, this report offers new perspectives on the funding of BECCS debate in Sweden.

Based on the IPCC's comprehensive work, we find that negative emissions are crucial for meeting Paris Agreement targets. In every single 1.5º pathway, negative emissions are relied upon, and in 95% of these pathways, BECCS are being used. In fact, the amount of BECCS assumed to be used in 2050 per year is roughly equivalent in magnitude to the current GHG emissions of the US, the worlds' second largest emitter.

Reaching global climate targets relies on negative emissions such as BECCS because it will be very costly or even impossible to remove every single GHG emission source, e.g. in industrial and agricultural applications. We have estimated that for a range of possible carbon mitigation costs, Sweden is likely to save between EUR 1-8 billion per year, if 10 million tons of BECCS are counted towards the net zero objective. The high range is based on a carbon cost of 900 EUR/ton. While being very difficult to estimate, this is likely to be significantly below the actual costs of mitigating the "last tons" since most modelling exercises show carbon costs of 2,000-3,000 EUR/ton.

In addition, if Sweden makes fuller use of its potential for BECCS and produces 30 million tons negative emissions per year, we estimate that this could result in revenue of around EUR 1.8 billion per year (conservative estimate), by exporting these emissions to other countries to help them meet their targets.

A mature and scaled BECCS industry will make investments, employ people, and demand goods and services from across the economy. If 10 million tons BECCS per year is realized through public investments, the industry will contribute SEK 6 billion to GDP and support 7,000 jobs throughout the Swedish economy. In a more scaled-up scenario, where public funding helps mature the technology and paves the way for marked-based funding of 30 million tons of negative emissions per year, the BECCS industry contributes SEK 24 billion to Swedish GDP and supports 28,000 jobs.

Based on economic literature, we find that public funding is prerequisite to ensuring that the BECCS industry is sufficiently mature to deliver the needed negative emissions to reach global climate targets. This is because of lacking private incentives for negative emissions, technological uncertainty and a minimum efficient scale for BECCS. Thus, public funding can help to reduce business case and technological uncertainty, bring down costs through learning and reach minimum cost-efficient scale.

Furthermore, learnings from maturing and scaling BECCS are to a large extent site-specific and will be more applicable to Swedish conditions. Early public investments will give Sweden the opportunity to leverage their current position and secure an advantage in the competition for market-based BECCS investments. This advantage comes on top of the fact that Swedish conditions for BECCS are among the best suited in Europe both in terms of costs and environmental impact.

INTRODUCTION

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SWEDISH CLIMATE AMBITIONS

Swedish politicians have committed Sweden to a target of achieving net zero green house gases (GHG) emissions before 2045. This is even more ambitious than the EU, which aims to achieve climate neutrality before 2050. It is ambitious, because the measures required to achieve the target are not fully known and rely on technologies that are still in the development phase. For some industries, it is even unclear if emissions can be reduced to zero without shutting down the industry.

To address this fundamental challenges, the Swedish Government has proposed so-called supplementary measures as a way of achieving net zero emissions. These supplementary measures constitute negative emission sources, which can compensate for emissions that prove too difficult and/or expensive to remove before 2045.

A key technology for negative emissions is bioenergy carbon capture and storage (BECCS). Carbon capture and storage (CCS) means capturing and permanently storing GHG instead of emitting them into the atmosphere thereby preventing them from contributing to climate change. When CCS is applied to emissions from fossil fuels (oil, coal etc.), it yields climate neutrality. With BECCS, CCS is applied to biogenic fuels (wood and other natural materials), which can yield negative emissions if the sources of natural fuels are sustainably managed. In this report, we apply the premise that BECCS in Sweden will only be counted as negative emissions when applied to biogenic fuels from sources which are credibly documented to be sustainably managed.

THE FUNDING OF BECCS

Given the importance of BECCS as a negative emissions technology and the urgency of having the technology in place at a sufficient scale before 2045, there is a need to ensure that sufficient investments are made to mature the technology. The Swedish Government has taken several steps to identify concrete political levers to support the development BECCS. This has been part of very extensive work on the general Swedish climate strategy by among others Statens Offentliga Utredningar and the Swedish Energy Authority.

At the time of writing (December 2021), the Swedish Parliament has decided to approve a joint budget reservation that includes a major investment in BECCS with the aim of achieving 2 million tons of negative emissions per year.

SOCIOECONOMIC IMPACTS OF BECCS

In the discussion on BECCS, the need for negative emissions has been thoroughly investigated and established as a prerequisite for meeting Swedish climate targets. In the discussion of the funding of BECCS, it becomes equally important to cast light on the socioeconomic impacts for Sweden of investing in maturing and scaling BECCS technology in Sweden.

This report investigates the economic benefits through three different lenses.

In Chapter 1, we investigate whether Sweden can deliver negative emissions from BECCS at costs below the cost of alternative Swedish abatement measures and below the willingness to pay for negative emissions credits from other countries. For the latter, this report works from the key premise that a legal framework will be established for trading credits for negative emissions internationally. This would allow other countries to buy credits for excess negative emissions from Sweden to offset these countries' very expensive/difficult to abate emissions.

In Chapter 2, we investigate three scenarios for a future BECCS industry in Sweden and estimate the contribution to Swedish GDP and the number of jobs supported by the industry.

In Chapter 3, we review the economic criteria for public funding to be an appropriate tool to accelerate the development of new technology, and we investigate whether BECCS in Sweden meets these criteria. Furthermore, we investigate the strongholds and challenges for BECCS in Sweden, which are important for attracting market-based funding in competition with other countries.

As mentioned above, the scope of this report is the economic perspective, and thus we do not go deeply into related issues such as the debate on sustainable management of natural resources, the future legal framework for trading negative emission credits, or the potential carbon capture and utilization (CCUS) as a substitute to storing carbon.

Our work has been funded by Stockholm Exergi and has been conducted in collaboration with their experts on the issue. However, Implement Consulting Group has had full editorial independence, and we are responsible for all content in the report.

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01.

THE ROLE AND BUSINESS CASE FOR BECCS

Negative emissions play a substantial role in pathways to net zero

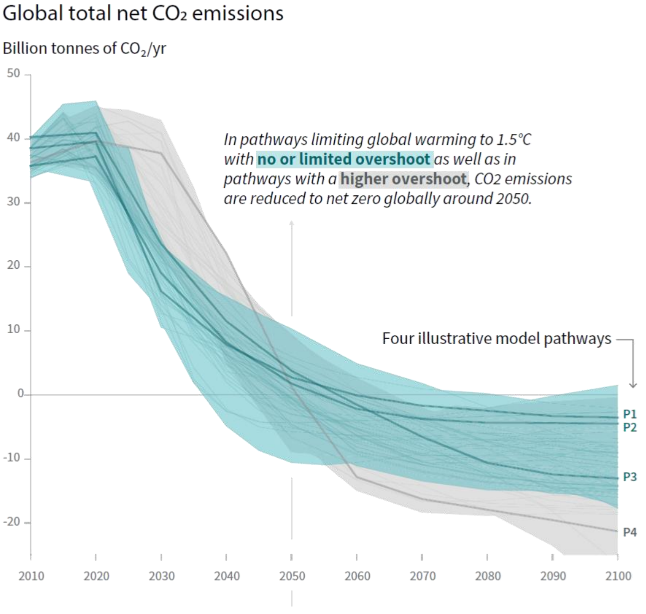
In 2050, 1.5º scenarios require as much BECCS per year as current GHG emissions in the US.

Leading up the Intergovernmental Panel on Climate Change (IPCC) special report on 1.5º in 2018, a comprehensive coordination and comparison of leading modelling exercises was done. More than 500 scenarios were submitted to the IPCC. 90 scenarios were deemed to be consistent with 1.5º and an additional 132 to be consistent with 2º.

Every single 1.5º scenario assessed by the IPCC made use of negative emissions before 2050,[1] highlighting how important negative emissions are to meet an ambitious climate target. 95% of the analyzed pathways made use of BECCS.

While the amount of BECCS varies significantly across scenarios, there is strong consensus that a substantial amount of BECCS is needed. Already in 2030, the scenarios suggest around 100-300 MT of BECCS per year, increasing to around 4-9,5 GT in 2050 (median around 5-7 GT). At the end of the century, the projections imply BECCS of around 8-16 GT per year (median 12-15 GT).[2] (see figure)

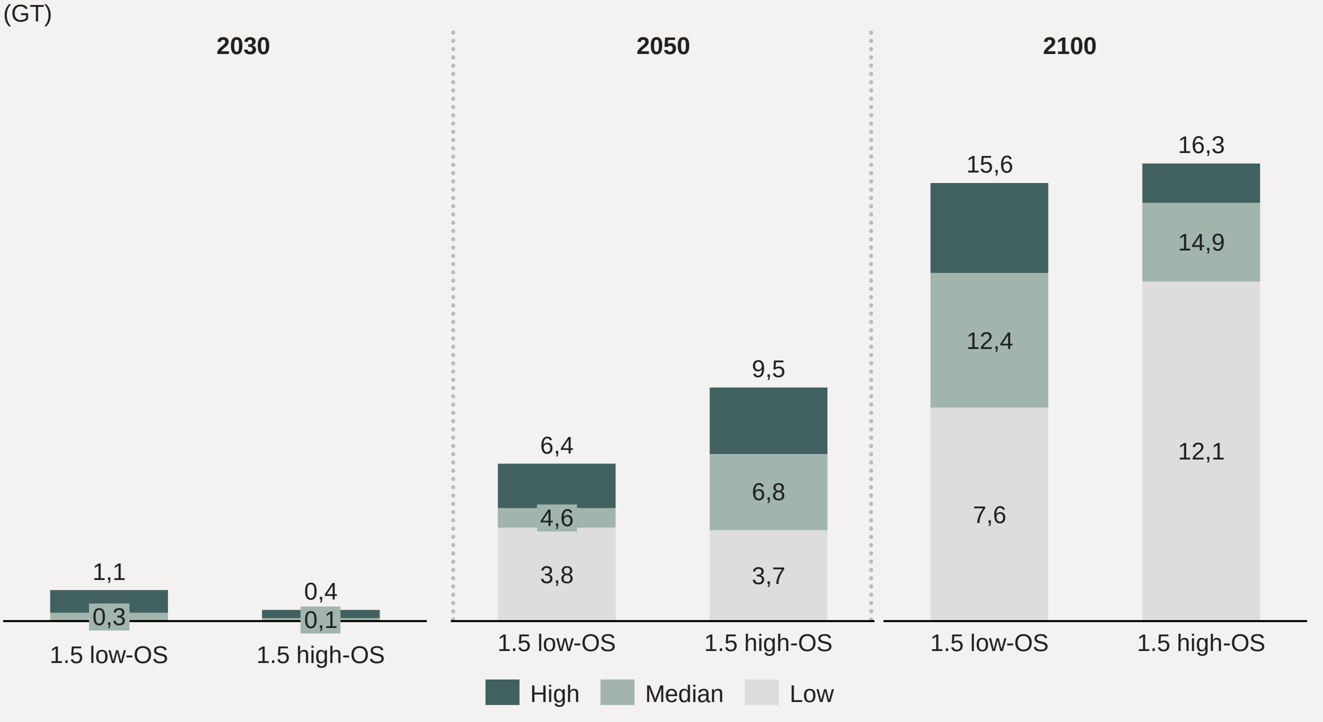
These amounts of BECCS are massive in scale. Global GHG emissions amounted to 52 GT in 2019,[3] so already in 2050, the scenarios require around 8-18% of total current emissions being offset through BECCS. This equals approximately current total GHG emissions of the US. This figure will increase to 15-30% in 2100.



Source: IPCC (2018), page 13

AMOUNT OF BECCS RELIED UPON IN IPCC 1.5º SCENARIOS

(GT)



Sources: [1] ÌPCC (2018), page 122 \\ [2] IPCC (2018), page 119 \\ [3] Rhodium Group (2021)

BECCS is one of the main negative emission technologies

With expected costs around 50-200 EUR/ton, BECCS currently seems to be the main negative emission technology. To truly scale, it needs to address biomass sustainability and availability issues.

The technologies available for delivering negative emissions are quite different in nature and costs. Currently, there are three main alternatives with different characteristics, namely BECCS, Direct Air Carbon Capture Storage (DACCS) and natural climate solutions such as forestation.

A main difference between BECCS and DACCS on the one hand, and natural climate solutions on the other, is the permanence of storage. If stored correctly, both BECCS and DACCS solutions are likely to keep the CO_2 effectively away from the atmosphere. In comparison, natural climate solutions are exposed to several risk factors such as extreme weather or just changes in forest management, which might return the CO_2 to the atmosphere.

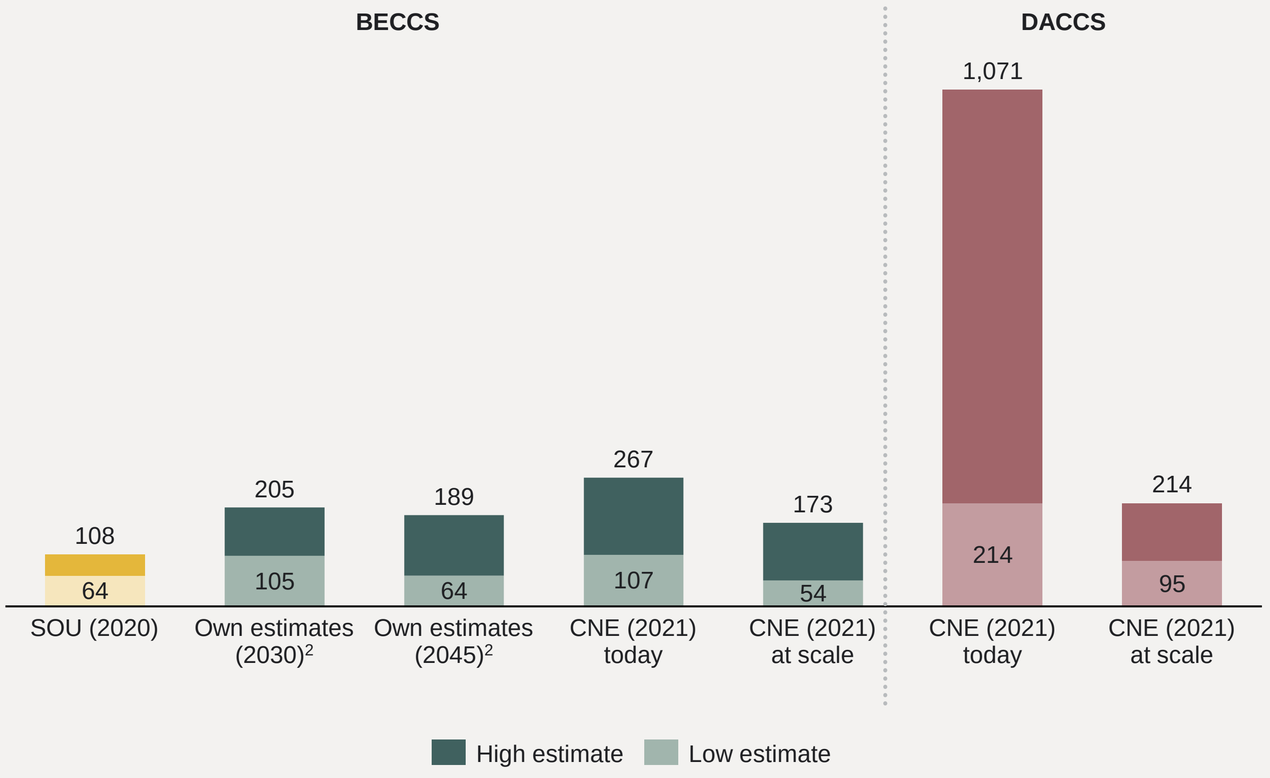
BECCS is currently a significantly more cost-efficient technology than DACCS and can deliver large quantities of negative emissions in long-term storage. There are, however, some environmental considerations, such as the use of likely scarce sustainable biomass, the use of water (scarce in some regions) and the impact on biodiversity (Chapter 3 of this report discusses these concerns in a Swedish context). A study suggests that there are at least 2-4 GT of sustainable BECCS production technically possible globally.[1]

DACCS is currently substantially more costly than BECCS but is expected to see large cost reductions from further technological improvements and scaling. DACCS is very flexible as it does not rely on specific point sources and the use of biomass like BECCS. A study suggests that at least 4 GT of sustainable DACCS production is technically possible today.[1]

Natural climate solutions are readily available to deliver negative emissions from biological storage at quite low costs. However, the realizable potential through changes in land-use and forestry is also limited mainly due to concerns on land availability. Furthermore, the risk of reversal is much higher than for BECCS and DACCS. For example, as forests are exposed to extreme weather, natural disasters, changing climate and future changes in forest management it cannot be guaranteed that the CO_2 will not return to the atmosphere.

Current estimates suggest a cost of BECCS of around 100-200 EUR/ton, possibly falling to around 50-150 at scale.

COST OF NEGATIVE EMISSION TECHNOLOGIES[2]
(EUR/ton CO_2 removed)



Notes: We have only considered BECCS projects relevant for scale production in Sweden.
Sources: [1] CNE (2021) \\ [2] Own estimates based on Johnsson et al. (2020) and Smith et al. (2021)

Negative emissions can yield substantial socioeconomic benefits

Main impact case of negative emissions is to avoid very costly abatement measures and as compensation for possibly overshooting targets.

GETTING TO NET ZERO REQUIRES REMOVING VERY HARD TO ABATE AND VERY EXPENSIVE EMISSIONS

Removing all GHG from Swedish territories is a massive task. However, it has become increasingly clear that we can come a very long way with available solutions and technologies, and that the transition does not have to be overly costly. A recent Swedish study concludes that the costs of achieving a net zero scenario for 2045 are manageable, and product price increases are likely to be below 1% even in difficult industrial sectors.[1]

While this is likely true, it is also true that removing <u>all</u> sources of GHG is going to be very difficult and very expensive. Some emissions, in particular in industry and agriculture, are associated with very large abatement costs or have no currently available technological solution.

The study mentioned above relies significantly on negative emissions (10-15% of total reductions) to avoid removing these very hard to abate sources.

The importance of negative emission technologies to avoid very hard-to-remove emissions is clearly illustrated in a new study from MIT.[2] Here, the authors find that with significant use of BECCS, the required carbon price in the EU can be kept around 210-220 EUR/ton to meet both 2º and 1.5º targets. However, without using negative emissions, the required carbon price would increase to a massive 2000-2850 EUR/ton by 2080-2100 due to the need for very expensive mitigation measures. This would, according to the study, translate into a reduction in consumption of 13-19%.

A similar finding was made by the IPCC where many of the 1.5º scenarios found carbon prices between 1,000 – 10,000 EUR/ton in 2070.[3] The exact size of the carbon price is not important for the purpose of this study, as modelling and technological uncertainty of this time scale is tremendous. It is, however, important that getting rid of that last remaining GHG without negative emissions will likely prove extremely costly.

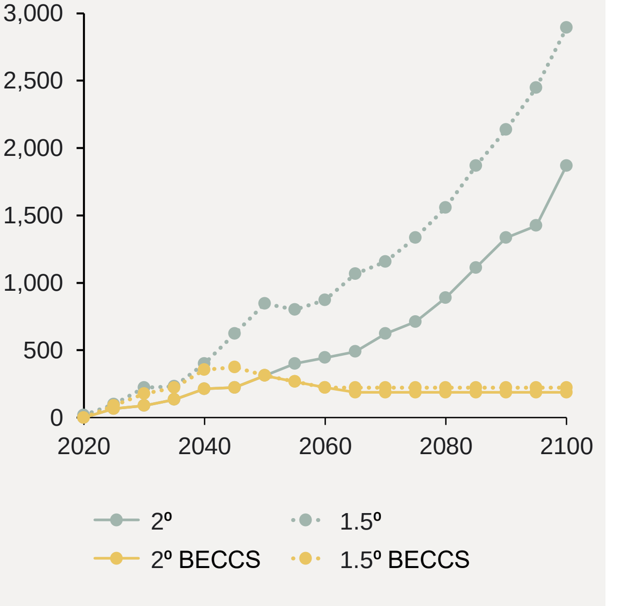
A recent report from Statens Offentliga Utredningar[4] also acknowledged this point and stated that even if we succeed in removing all fossil fuel use and emissions from industrial processes, we will continue to emit 15% of our current GHG emissions due to methane and nitrous oxide. Sources coming particularly from agriculture and wastewater treatment. The authors conclude that Sweden cannot reach its climate goals in 2045 through mitigation alone.

NEGATIVE EMISSIONS ARE ESSENTIAL IF POLICY MEASURES DO NOT DELIVER THE REQUIRED ABATEMENT

Substantial evidence suggest that the remaining carbon budget available for limiting global warming to 1.5º will probably be exhausted within this decade. The carbon debt generated thereafter will need to be compensated by negative emissions in order to prevent increased warming.[5]

In fact, while most pathways rely on about 70-90% of actual GHG reduction measures, the reality is that the longer these measures are delayed, the more need for negative emissions. For each year that we overshoot the reduction target, the carbon debt will increase, and the subsequent need for negative emissions grows.

REQUIRED CARBON PRICE TO MEET TARGET
(EUR/ton)



Source: MIT (2021)

Sources: [1] Material Economics (2021) \\ [2] MIT (2021) \\ [3] IPCC (2018), Figure 2.26 \\ [4] SOU2020:4 (2020) \\ [5] Bednar et al. (2021)

Applying negative emissions in Sweden can provide large savings

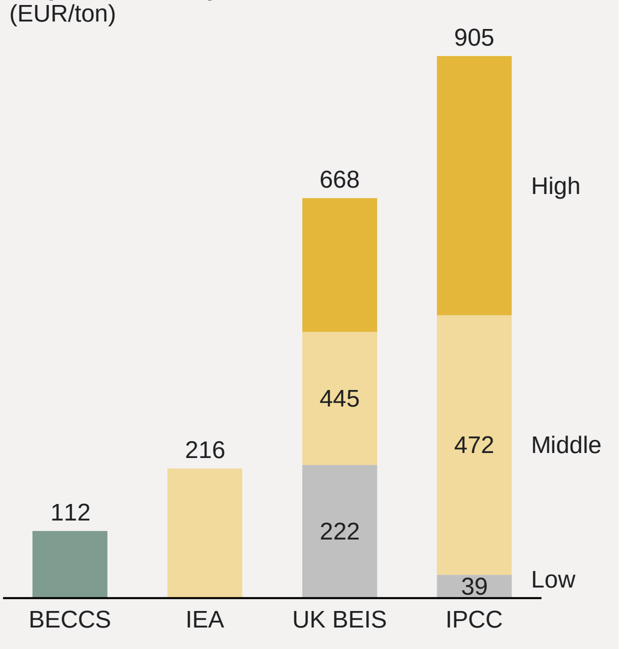
10 MT of BECCS can deliver savings in the billions.

We find that if Sweden succeeds in developing the approximately 10 MT of negative emissions per year stipulated in the national targets to become net zero, Sweden could potentially save around EUR 1-8 billion per year (see figure). Savings that would otherwise have to be spent on pursuing very expensive reduction measures.

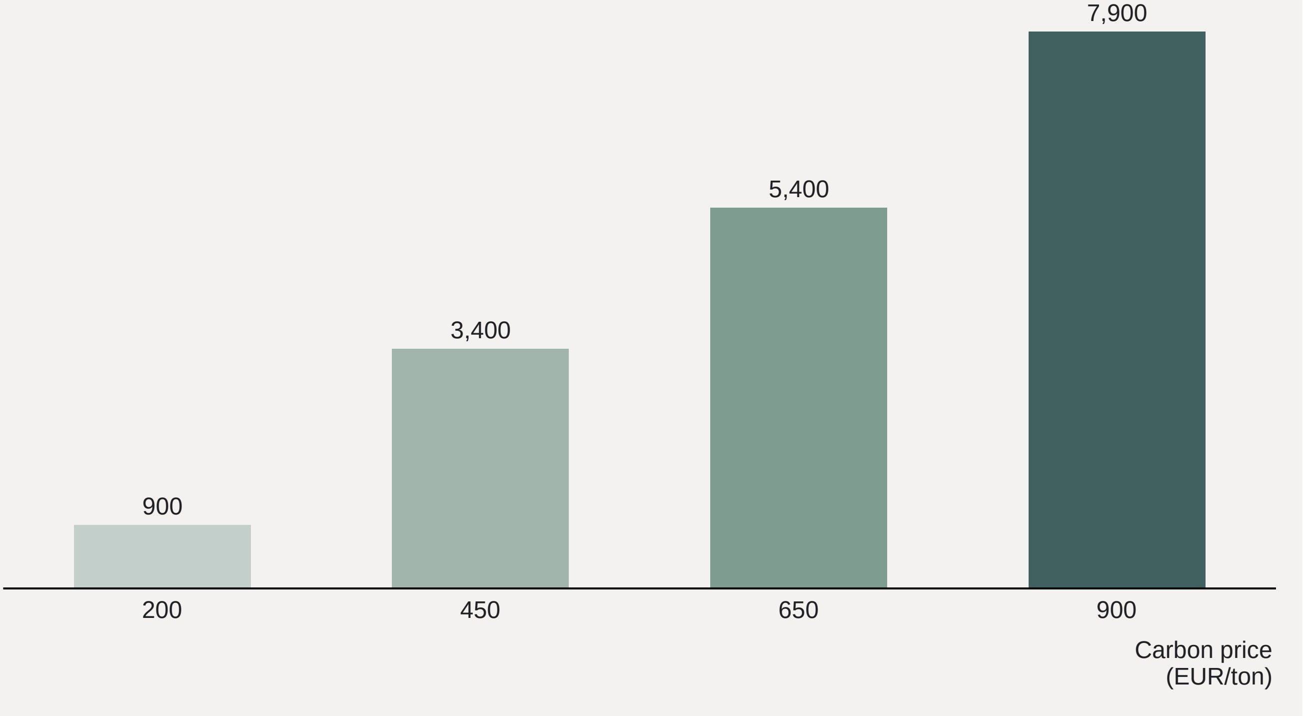
The calculation is based on international analyses of the required carbon price to realize pathways consistent with the Paris Agreement. These analyses suggest that required carbon prices to meet these targets in 2050 could range from around 200 EUR/ton to more than 900 EUR/ton in 2050. Naturally, such estimates are associated with significant uncertainty as both technological development, policy initiatives and market responses can differ substantially from the modelled pathway.

We note, however, that while 900 EUR/ton can seem high, the IPCC scenarios used to arrive at 900 EUR/ton rely substantially on negative emissions, thereby contributing to a much lower reduction cost on the margin. As noted previously, scenarios that do not rely on negative emissions easily find carbon prices of more than 2,000 EUR/ton. We also note that a carbon price of around 900 EUR/ton is relatively similar to what was found in Konjunkturinstitutet (2019) analyzing cost of meeting Swedish reduction targets within the transport sector.

Required carbon price, 2050
(EUR/ton)



Estimated savings by using 10 MT BECCS[1]
(EUR million)



Sources: [1] Own estimates based on IEA (2021), UK BEIS (2021), IPCC (2018), and Konjunkturinstitutet (2019)

Large potential gains from exporting negative emissions credits

By utilizing the full potential of Swedish point sources, Sweden could export negative emissions of around EUR 2 billion per year in the short term and possibly more in the long term with increasing carbon prices.

SWEDEN HAS A LARGE POTENTIAL FOR EXPORTING NEGATIVE EMISSIONS

Sweden has a large potential for BECCS compared to most other EU countries. Based on Rosa et al. (2021), we find that Sweden has the second highest potential in the EU, having large relevant point sources equalling 58% if its total emissions.

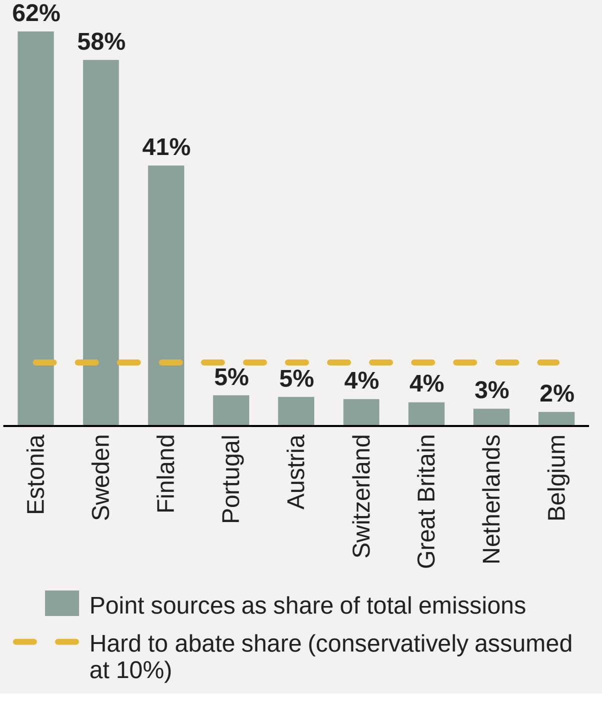
The study suggests that only Estonia, Sweden and Finland are likely to have sufficient potential of BECCS to be able to cover its own need and export remaining credits to other countries.[1] Consequently, if other countries in the EU (or abroad) going forward want or need to rely on negative emissions through BECCS to meet their own mitigation targets, Sweden has the potential to be a key supplier. Negative emission trading needs to be supported by a legal framework to become operational.

TRADING NEGATIVE EMISSIONS CAN FACILITATE A MORE COST-OPTIMAL PATHWAY TO NET ZERO

It is also likely that there will also be a substantial demand for negative emissions.

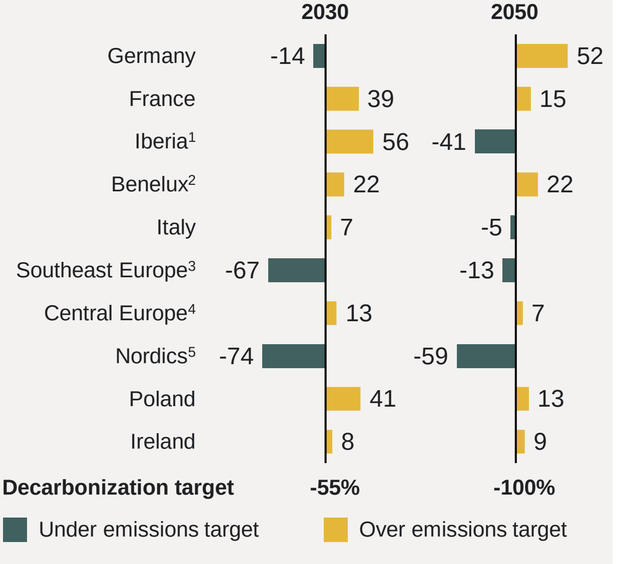
Because of differences in individual countries' starting points and possible decarbonisation options, it will likely be far more cost optimal to take a collective EU approach to decarbonisation than optimise individually. According to McKinsey (2021), since emissions in Iberia have increased substantially since 1990, Spain and Portugal will have to reduce emissions far more relatively than other countries that are currently closer to the EU reduction target. This could lead them to pursue overly expensive options as opposed to importing negative emission credits. According to this study, the Nordics is the region that could most cost-optimally supply the rest of the EU with negative emission credits both in 2030 and in 2050.

Biogenic emissions from point sources as share of total emissions, 2019



On the cost-optimal pathway, some countries' emissions reductions would compensate for others'.

(MT CO_2-e over/under EU decarbonization targets)



1. Spain & Portugal
2. Belgium, Luxemburg, Netherlands
3. Bulgaria, Greece, Romania
4. Austria, Croatia, Czech Republic, Hungary, Slovakia, Slovenia
5. Denmark, Estonia, Finland, Latvia, Lithuania, Sweden

Source: McKinsey (2021)

Adding to this, a potential substantial source of demand could come from large multinational corporations such as Microsoft who have made vocal and ambitious targets to acquire permanent negative emissions to offset the companies' emissions.

If Sweden is able to scale its BECCS industry to 30 MT (which is clearly within the range of its point sources – see Chapter 3), it will be able to sell 20 MT negative emissions credits at the prevailing carbon price. If the current ETS price of around 70-80 EUR/ton was to rise to say 200 EUR/ton in 2030, this would bring net profits to Swedish companies of around EUR 1.8 billion per year, which would increase their tax payments in Sweden. If willingness to pay for negative emissions was to rise beyond this, the export revenue would increase proportionally.[2]

Notes: [1] Data in the figure excludes wastewater point sources, which are very low in emission volume. Furthermore, data does not include distributed sources of biogenic emissions. Based on Rosa et al. (2021), we find that including these sources would not change the conclusion. [2] In the previous calculation we assumed that carbon prices could increase to 900 EUR/ton to be aligned with hard-to-abate costs. In this calculation, we take a more conservative approach to mimic a possible market price for negative emissions when negative emissions are already being used to meet climate targets.

02.

SOCIO ECONOMIC IMPACTS OF BECCS

The applied methodology

Relying on an input-output model, we assess the economic impacts of a mature BECCS industry in three scenarios.

Input-output analysis uses data on inter-industry transactions to estimate how increased demand in one sector impacts GDP and jobs in the entire economy.

We model three scenarios of a mature BECCS industry in Sweden. The size of the mature industry depends on investments into the BECCS industry in the coming years. In the three scenarios, the annual capture and storage vary from 2-30 MT CO_2 and an average expenditure of EUR 114-142 per ton CO_2 (see bottom figure for overview). When the amount of CO_2 captured increases from scenario I to II and III the price per ton decreases because of learnings, and the price increases because more difficult to exploit point sources must be used to reach larger scale.

The input-output model

The input-output model builds on the OECD's Structural Analysis Database (STAN). This database provides Swedish input-output tables for 36 industries[1] along with data on employment and labor compensation. The model provides industry specific multipliers for employment and GDP. An inherent feature of input-output models is that the structures of inter-industry flows are constant.[2]

The input-output model can be used to assess the economic impact of a BECCS industry in Sweden. The economic impact is measured in terms of jobs supported and the GDP contribution from the industry.

BECCS is a new technology, and the industry does not appear in current input-output tables. We therefore construct a BECCS industry based on the expected composition and level of activity at the BECCS facilities.

Investments in BECCS increase demand

We base the estimate of the size and composition of the increase in demand on expenditures from Stockholm Exergi's existing test facilities and the literature.[3] The main cost drivers in the BECCS industry are expected to be capital expenditures on construction, facility maintenance and equipment, and expenditures on transport and storage.

Construction, facility maintenance and equipment. Expenditures on construction, facility maintenance and equipment are capital costs that are expected to account for around 40% of total expenditures. The industries representing these activities in the input-output model are:

- Construction
- Computer, electronics and optical products
- Electrical equipment
- Machinery and equipment

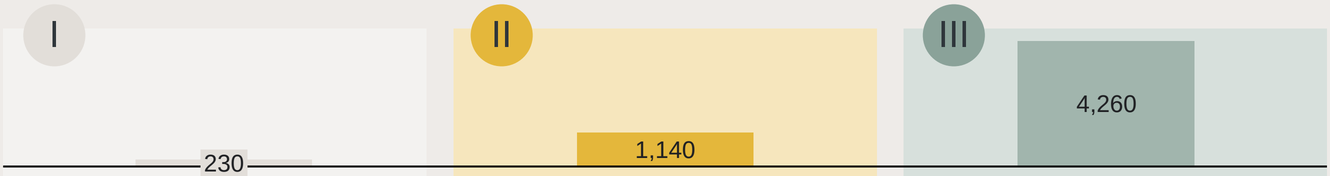
Operations. The operational expenditures are expected to account for 10-15% of total expenditures (when accounting for heat recovery). The operation of the BECCS facilities consists mainly of operating the control room, supervising capture on the ground and checking leaks. These activities resemble the activity at an average energy utility. The industry representing the operational expenditures is therefore:

- Electricity, gas, water supply, sewerage, waste and remediation services

Transport and storage. Transport and storage are expected to account for around 50% of total expenditures. In scenario I and II, the point sources will be located at the coast, and transport to the storage facilities (most likely oil fields) is expected to be mainly imported, since Sweden currently does not have domestic providers of transport and storage of CO_2. Expenditures on transport and storage are assumed to be 100% imports in scenarios I and II (no impact on the Swedish economy). In scenario III, we expect there to be multiple point sources in-land, and around 10% of the transport and storage expenditures are assumed to be used for domestic suppliers of transport. In the sensitivity analysis, we will relax the assumption of 100% imported transport and storage and model different scenarios of domestically supplied transport and storage. The industry representing transport and storage activities is:

- Transport and storage

Demand increase in different scenarios
(EUR million)



Scenario I

The Swedish Government is assumed to expand funding above the current level such that the industry can capture and store 2 MT CO_2 per year at EUR 115 per ton CO_2

The total increase in demand is EUR 230 million

Scenario II

Based on the public funding, the BECCS technology is assumed to mature, and the high abatement costs drive market-based investments in BECCS yielding 10 MT CO_2 per year at EUR 114 per ton CO_2

The total increase in demand is EUR 1,140 million

Scenario III

Sweden becomes a hub for BECCS, and the BECCS industry exports credits for negative emissions and attracts higher levels of private investments yielding a total BECCS of 30 MT CO_2 at EUR 142 per ton CO_2

The total increase in demand is EUR 4,260 million

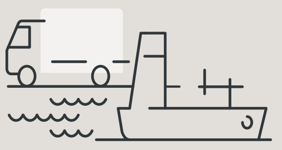
Notes: [1] The industry classification is based on ISIC Rev. 4 (see the UN classifications registry for more details) // [2] The constant structure of inter-industry flows is equivalent to constant returns to scale (Miller & Blair (2009)
Sources: [3] Smith et al. (2021) & Johnsson et al. (2020)

The activity in and around the BECCS industry spreads throughout the Swedish economy

The input-output model provides multipliers for direct, indirect and induced impacts on value added, wages and employment.

DIRECT

Direct impacts measure the activity at the BECCS facilities, which includes construction of the facilities, maintenances of the facility and purchase of equipment (e.g. management, mechanical and electronic maintenance and repairs, IT and system technicians). The direct impacts also include operations of the facility as well as transport and storage of CO_2.



INDIRECT

Indirect impacts arise when the BECCS industry purchases goods and services from local suppliers in Sweden. This includes purchases during the construction phase (e.g. construction and contracting) and in operations (e.g. services related to facility management).

INDUCED

Induced impacts arise when wages paid out to employees in the BECCS industry and its suppliers are spent in Sweden (e.g. shopping, restaurant visits and entertainment).

Indirect multiplier

Activities supported by purchases from suppliers

Induced multiplier

Activities supported by wage spending from own and suppliers' employees

Sources: Miller & Blair (2009)

Socio economic impacts

In the most conservative scenario, the BECCS industry will support 1,350 jobs. In the more ambitious scenario II, more than 6,700 Swedish jobs will be supported.

The impacts presented in this study are based on average annual expenditures over a 25-year period in the BECCS industry for a certain increase in demand. In reality, impacts will be characterized by periodic bursts driven especially by investments in construction and major renovations. The annual impacts will therefore be high during peaks in construction and renovation and low in periods with less investments. The impact measures the importance a future BECCS industry will have in the economy, in the form of GDP contribution and jobs supported. The investments and employees needed will come from other sectors in the economy and thus the impacts are not additional to todays GDP and employment.

I SCENARIO I

In scenario I, the BECCS industry will support 1,350 jobs annually and contribute with EUR 110 million to Swedish GDP.

Assumptions

The Swedish Government is assumed to expand funding above the current level such that the industry can capture and store 2 MT CO_2 per year at EUR 115 per ton CO_2. In total, this increases demand by EUR 230 million in the Swedish economy.

Impacts

The BECCS industry will directly employ 560 people, the majority of which will be within construction, facility maintenance and equipment. 80 people will be operating the facilities, including managing the control room and the ground floors. 480 people will be directly employed within construction, facility maintenance and equipment.

Through purchases from Swedish suppliers, the BECCS industry supports an additional 390 jobs (indirect impacts). The wage spending of own and suppliers' employees will support an additional 400 jobs throughout the Swedish economy (induced impacts). In total, the BECCS industry will support 1,350 jobs at annual demand of EUR 230 million for BECCS.

Annual employment (jobs)				
	Direct	**Indirect**	**Induced**	**Total**
Construction and facility maintenance	480	310	330	**1,120**
Operations	80	80	70	**230**
Total	**560**	**390**	**400**	**1,350**

The direct activity in the BECCS industry will contribute with EUR 50 million to Swedish GDP annually. Including the indirect and induced impacts, the industry will contribute with EUR 110 million to Swedish GDP.

Annual GDP contribution (EUR million)				
	Direct	**Indirect**	**Induced**	**Total**
Construction and facility maintenance	35	25	25	85
Operations	15	5	5	25
Total	50	30	30	110

II SCENARIO II

In scenario II the BECCS industry will support 6,700 jobs annually and contribute with EUR 565 million to Swedish GDP.

Assumptions

Based on the public funding, the BECCS technology is assumed to mature, and the high abatement costs drive market-based investments in BECCS yielding 10 MT CO_2 per year at EUR 114 per ton. In total, demand in the BECCS industry increases by EUR 1,140 million.

Impacts

The BECCS industry will directly employ 2,770 people, the majority of which are within construction and facility maintenance. 390 people will be operating the facilities and 2,380 will be directly employed within construction, facility maintenance and equipment.

Additionally, the BECCS industry will support 1,920 jobs through purchases from Swedish suppliers (indirect impacts) and 2,000 jobs through own and suppliers' employees' wage spending (induced impacts). In total, the BECCS industry will support 6,700 jobs if demand reach EUR 1,140 million per year.

Annual employment (jobs)				
	Direct	**Indirect**	**Induced**	**Total**
Construction and facility maintenance	2,380	1,530	1,650	**5,560**
Operations	390	390	350	**1,140**
Total	**2,770**	**1,920**	**2,000**	**6,700**

The direct activity in the BECCS industry will contribute with EUR 250 million to Swedish GDP annually. Including the indirect and induced impact, the industry will contribute with EUR 565 million to Swedish GDP.

Annual GDP contribution (EUR million)				
	Direct	**Indirect**	**Induced**	**Total**
Construction and facility maintenance	180	120	135	430
Operations	70	35	30	135
Total	250	155	165	565

Notes: Employment figures are rounded to nearest ten and GDP contribution figures are rounded to nearest five.
Sources: Implement Economics based the OECD STAN database for structural analysis and on client input

Socio economic impacts

In the most ambitious scenario III, Sweden will become a hub for BECCS, and the industry will support 28,190 jobs.

SCENARIO III

In scenario III, the BECCS industry will support 28,190 jobs annually and contribute with EUR 2,360 million to Swedish GDP.

Assumptions

Sweden becomes a hub for BECCS, and the BECCS industry exports credits for negative emissions and attracts higher levels of private investments yielding a total BECCS of 30 MT CO_2 at EUR 142 per ton CO_2. In total, demand in the Swedish BECCS industry is expected to increase by EUR 4,260 million.

In scenario III, 10% of the expenditures on transport and storage are assumed to be for domestic suppliers.

Impacts

The industry will directly employ 11,530 people, of which 8,880 will be within construction and facility maintenance. 1,470 people will be operating the facilities and 1,180 will work within transport and storage.

Purchases from Swedish suppliers will support an additional 8,240 jobs (indirect impacts). The wage spending of own and suppliers' employees will support an additional 8,410 jobs throughout the Swedish economy (induced impacts). In total, the industry will support 28,190 jobs.

Annual employment (jobs)

	Direct	Indirect	Induced	Total
Construction and facility maintenance	8,880	5,710	6,170	**20,770**
Operations	1,470	1,450	1,320	**4,240**
Transport and storage	1,180	1,080	920	**3,180**
Total	**11,530**	**8,240**	**8,410**	**28,190**

The direct activity in the BECCS industry will contribute with EUR 1,025 million to Swedish GDP annually. Including the indirect and induced impact, the industry will contribute with EUR 2,360 million to Swedish GDP.

Annual GDP contribution (EUR million)

	Direct	Indirect	Induced	Total
Construction and facility maintenance	665	440	500	**1,605**
Operations	265	125	105	**500**
Transport and storage	95	85	75	**255**
Total	**1,025**	**650**	**680**	**2,360**

SENSITIVITY ANALYSIS

In the sensitivity analysis, the BECCS industry will support 1,780 jobs in scenario I, 8,820 jobs in scenario II and 35,610 jobs in scenario III.

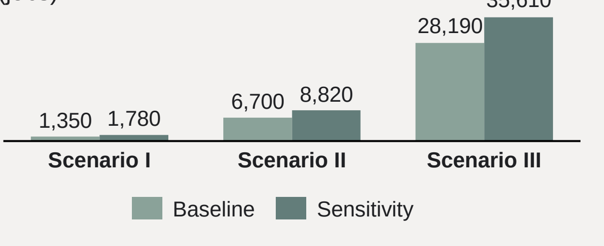
Assumptions

In the sensitivity analysis, we assume that increasing investments in BECCS make the business case for domestic transport and storage provision viable. In scenario I and II we assume that domestic suppliers account for 30% of the BECCS industry's total need for transport and storage yielding an import share of 70% (instead of 100% in the baseline). In scenario III we assume that domestic suppliers account for 40% of the industries need for transport and storage and the remaining 60% is imported (compared to 90% import in the base line). All other assumptions in the scenarios remain unchanged.

Impacts

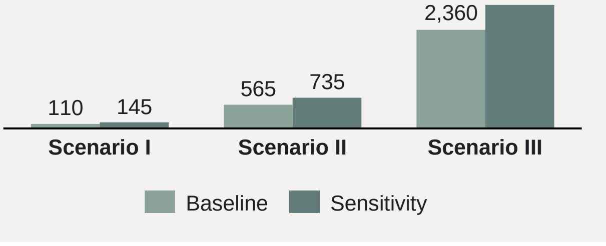
The impacts illustrated below include direct, indirect and induced impacts. The BECCS industry will support 1,780, 8,820 and 35,610 jobs in scenario I, II and III, respectively.

Annual employment incl. direct, indirect and induced impacts
(jobs)



The industry will contribute with EUR 145 million, EUR 735 million and EUR 2,955 million to Swedish GDP in scenario I, II and III, respectively.

Annual GDP contribution incl. direct, indirect and induced impacts
(EUR million)



Notes: Employment figures are rounded to nearest ten and GDP contribution figures are rounded to nearest five.
Sources: Implement Economics based the OECD STAN database for structural analysis and on client input

03.

THE CASE FOR SWEDEN TO SUPPORT DEVELOPMENT OF BECCS

WHY SHOULD SWEDEN CONSIDER SUPPORTING BECCS?

Policy measures are in some cases needed to influence market conditions in a way that serves specific common objectives and targets for society. The field of climate is an area that is already heavily affected by a range of policy measures, aimed at achieving different objectives. The economic literature on relevant public interventions and measures is well-established and offers several insights into how such policy could be designed to best deliver different types of objectives.

An important insight is that to stimulate the uptake of a new technology, policy instruments should consider the level of maturity of the technology. If the technology is very mature, market pull instruments such as a quota scheme or technology-neutral subsidies work well to ensure sufficient investments to scale the technology. If the technology is less mature, the relevant policy instruments should instead be aimed at facilitating scaling and commercialization of the technology through targeted public investments (see for example OECD (2011) and Zetterberg et al. (2021)).

The BECCS technology is still quite far from market maturity due to a combination of still being in a technological demonstration phase and the current absence of a market-driven business case. The EU ETS does not provide incentives to capture and store biogenic emissions, and there is not yet a private market for negative emissions. Consequently, the economic literature suggests that relevant policy measures should be targeted public investments and operation support.

In a globalized world, a relevant strategy would be to wait until other countries have funded the maturity journey of the specific technology and then deploy the mature technology at a lower cost. Indeed, smaller countries such as Sweden cannot aim to support the development of all technologies and can benefit by waiting until other countries have supported the maturity development (the initial maturity journey of solar PV was for example heavily supported by Germany).

Instead, a country like Sweden should focus on supporting technologies that have a larger chance of delivering high value to the Swedish society. For example, because the technology will bring higher value to Sweden than other countries or because support to the technology development will ensure that critical know-how and business strongholds are created in Sweden, with the possibility of establishing Swedish companies at the forefront of global technological roll-out.

In this chapter, we explore whether there are compelling reasons for Sweden to support the development of BECCS, and we focus specifically on comparative advantages, Sweden-specific factors, and possibilities for Swedish strongholds in a future demand for BECCS.

Learnings will be large but partially site-specific

Learning will yield significant cost-reductions in carbon capture, but they will be partially site-specific and thus not fully transferable.

THE TECHNICAL PERSPECTIVE IS IMPORTANT

As previously described, public funding for specific technologies, such as BECCS, can be optimal if it will result in comparative advantages for the funding country by benefitting the funding country more than other countries. In the following, we find evidence in the technical nature of BECCS suggesting that this will be the case for BECCS in Sweden.

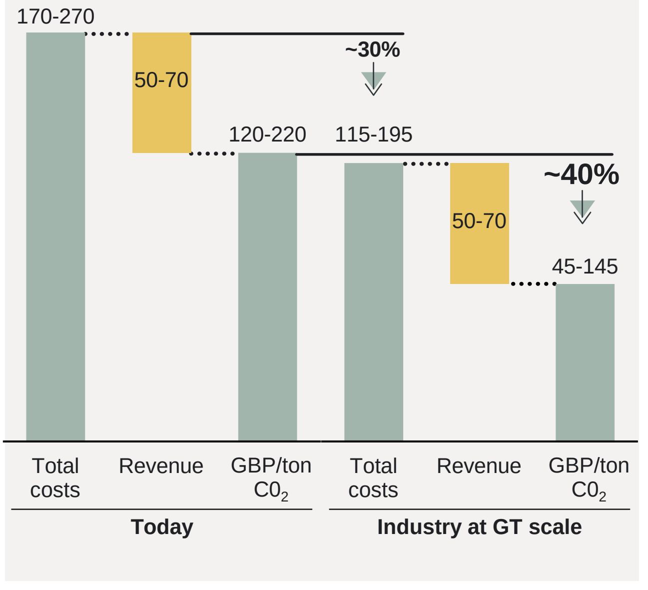
SIGNIFICANT COST-REDUCTIONS FOR CARBON-CAPTURE EXPECTED

Several carbon capture facilities are operated around the world providing proof of concept for the technology. However, few or none of them operate at full scale indicating that the technology is currently not fully mature. Studies find that significant cost-savings can be expected to arise from learning curves in capture technology when it is scaled sufficiently.

For example, McKinsey (2021) finds that potential cost reductions in carbon capture from flue gas stemming from power stations are between 30% and 65%. The study points out that the main cost reductions stem from improvements in the chemicals used in the capture process, gains from larger project scale and operational standardization.

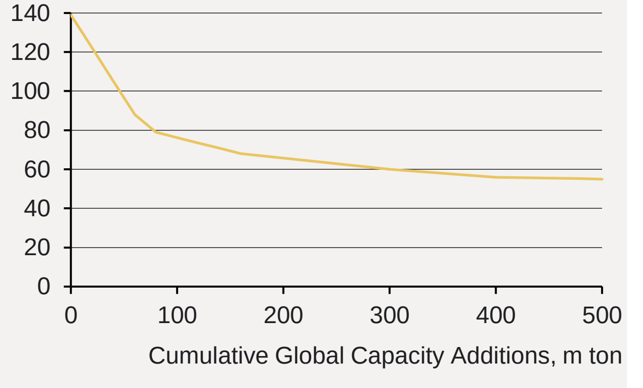
Furthermore, the study finds that the total cost of BECCS on power stations could drop by more than 40% when including reduced costs for transport, storage and financing.

Overall cost negative emissions today and at scale (GBP/ton CO_2)



DNV (2018) finds that that cost-decline for CCS will be very high for the first 50m ton of yearly capacity installed globally. They state that '*If we add 60 full-scale new plants to the world's capacity, we should be able to see cost reductions at around 30% of today's level'.*

Overall cost of negative emissions today and at scale ($/ton CO2)



The study further finds that the cost reductions are not happening because: *'…there are too few projects to trigger the real-world experience, expertise and industrial efficiencies that result in cost reductions.'*

TECHNOLOGICAL LEARNINGS AND COST-REDUCTIONS ARE PARTIALLY SITE-SPECIFIC

Having established that significant cost-reductions in capture technology can be expected when scaling BECCS, the interesting questions is to which extent the learnings will spill over from the sites and countries, which fund the first scale up of BECCS.

SOU2020:4 (2020) finds that the choice of separation technology will depend to a large extent on site-specific conditions. Examples of such more specific conditions are location availability for capture equipment, access to excess heat, the possibility to use waste heat through district heating, carbon dioxide concentration in the flue gases and whether the installation takes place at an existing plant.

Experts have pointed to the site-specific nature of the conditions causing learnings and cost-reductions to also be partially site-specific.[1] An example of site-specific conditions, which requires specialized learning/R&D, are sites where excess heat (used in the capture process) is available at lower than usual temperatures. These circumstances require development of new technical solutions (Johnson et al., 2020).

The evidence above suggests that BECCS is so far away from being a standard product, due to site-specific conditions, that learnings are not fully transferable.

Notes: [1] Based on input from expert interview with Professor Filip Johnsson at the Chalmers University of Technology

Learnings will yield a comparative advantage

As learnings are partially site- and point-source specific, publicly funded learnings in Sweden will benefit Sweden the most, but also other countries with similar site and point types.

LEARNING IS PARTIALLY POINT SOURCE-SPECIFIC

The previous section found evidence that learnings in capture technology can to some extent be expected to be site-specific. In addition, experts point out that learnings from a specific type of point source is more relevant to other sites with the same type of point source than to sites with other types of point sources.[1] This is likely to be caused by some of the site-specific conditions mentioned previously being more similar for sites with the same type of point source.

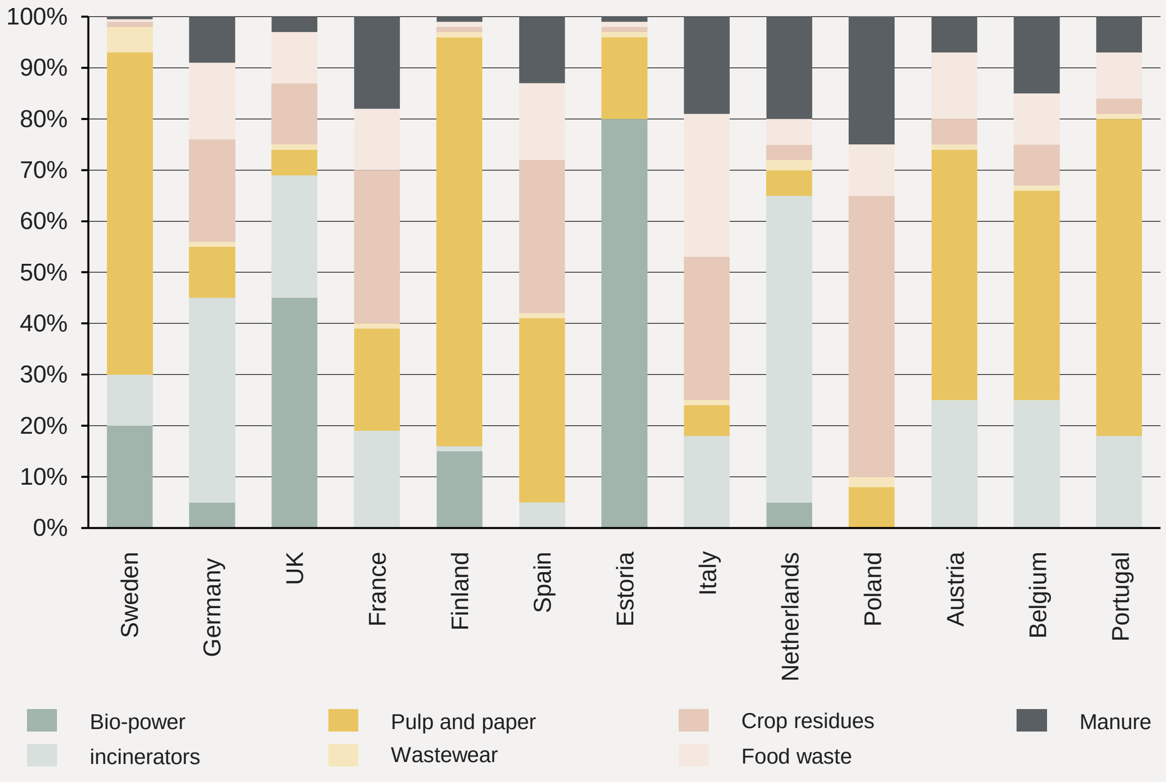
LEARNINGS IN SWEDEN WILL BENEFIT SWEDEN MOST

Rosa et al. (2021) find that Sweden is among the few European countries where the pulp and paper industry constitutes more than half of the biogenic point sources. This means that learnings from pulp and paper-based point sources will be most applicable in Sweden given the source-specific nature of learnings described above. However, Finland has a very similar composition of biogenic point sources and is thus expected to be able to benefit more than other countries from learnings made in Sweden based on public funding.

The conclusion above finds support in SOU2020:4 (2020), which finds that *'Swedish projects provide relevant experience for the underlying conditions that apply here; equivalent experience cannot usually be fully obtained by studying projects abroad' (translated from Swedish)'.*

It is also to be expected that there could be additional technological spillovers from fossil CCS, but this is outside the scope of this analysis

Share of total biogenic CO_2 (%)



Notes: [1] Based on input from expert interview with Professor Filip Johnsson at the Chalmers University of Technology

Regulatory uncertainty limits private incentives

Public funds can create certainty, which can pave the way for private investments.

LARGE CAPITAL INVESTMENTS AND LIMITED REGULATORY CERTAINTY MAKES PRIVATE FUNDING UNLIKELY WITHOUT SUBSTANTIAL PUBLIC SUPPORT

The BECCS technology is associated with three key factors that warrant public support: High up-front investment costs, technological immaturity and a business case that is determined by policy measures which are not in place yet.

The up-front capital costs of BECCS are expected to constitute around 40% of total costs (see Chapter 2), requiring investors to take a substantial risk by committing a large share of investments before any revenue streams are in place. Combined with the fact that the technology is still only being demonstrated in smaller scale and therefore adds technological risks to the investment, makes investors require a predictable revenue stream to provide a solid business case.

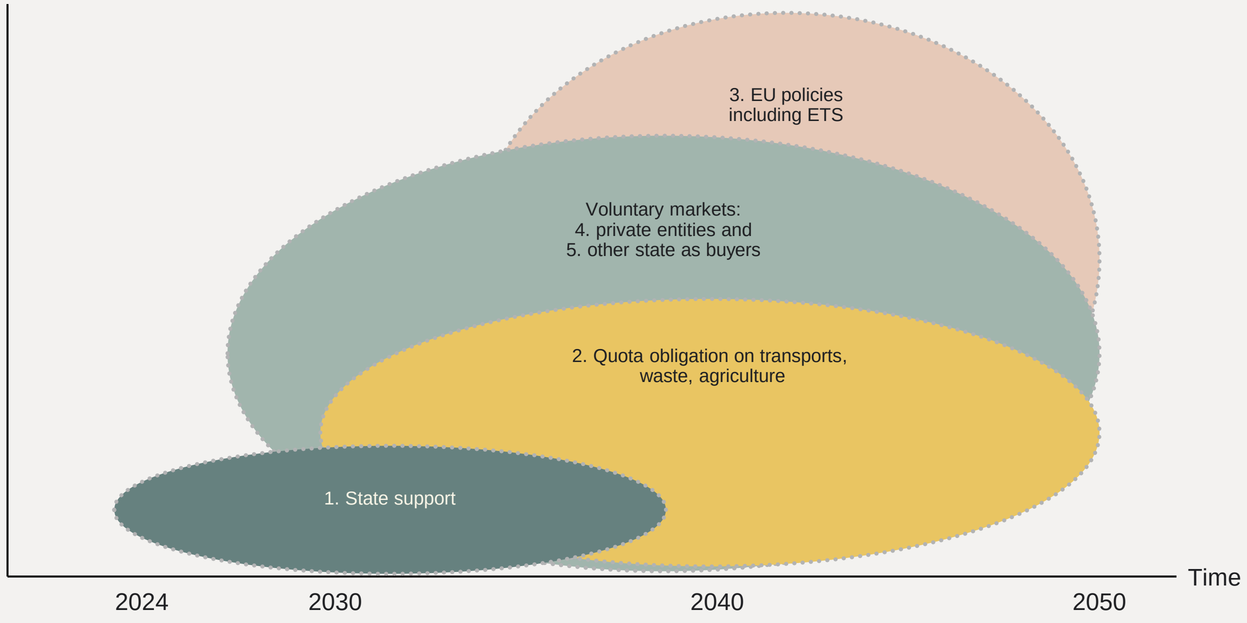
However, the main problem is that there is indeed no predictable revenue stream yet. Even though negative emissions are expected to play a major role in meeting the Swedish climate targets, there are currently no incentives to develop and commercialize the technology. The EU ETS price does not incentivize CCS on biogenic sources and there is not yet a private market for trading negative emissions. So, despite a strong ambition to become net zero in 2045, the policy measures to make this happen are not in place yet.

Consequently, without any public support, the entire business case for a private investor will be dependent on an expectation that policy makers will put in place the necessary measures in the future. An expectation that may become true but will mostly likely not lead to any private investments.

This is supported by Zetterberg et al. (2021) which find that incentives for BECCS should be focused on state support in the beginning and then gradually rely on a combination of direct control via quotas and indirect measures, such as voluntary markets, where companies and other governments can purchase negative emissions from BECCS, cf. figure below:

'…if the state would support the establishment of the first BECCS operators, this would facilitate for voluntary markets to procure credits and would help establishing a market price for BECCS.'

Potential size of funding (%)



Source: Zetterberg et al (2021), page 13

Effects of scaling BECCS

Public funds can help exploit economies of scale in supplying industries and distribution and storage, which can pave the way for private investments.

For new technologies, cost disadvantages from small scale (i.e. economies of scale) will be a barrier that has to be overcome. If the disadvantage from small scale and the investments needed to overcome cost disadvantages are large, it may deter private investments. Below, we discuss two sources of disadvantage of small scale in BECCS.

REACHING SCALE WILL REDUCE MARGINAL COST OF TRANSPORT AND STORAGE SIGNIFICANTLY

Based on Gardarsdottir et al. (2018), SOU2020:4 (2020) finds that a volume of at least 2 million tons of CO_2 per year is needed to exploit the economies of scale in distribution and storage:

'In an expanded CCS system where carbon capture takes place on several plants that can share certain transport infrastructure and storage location, the cost of carbon capture is the clearly dominant cost item. However, in a construction phase of CCS including bio-CCS, where the amount of secluded CO_2 is less than 2 to 3 million tons per year, investments in transport infrastructure may be in the same order of magnitude as investments in capture plants' (translated from Swedish).

This finding is supported by McKinsey (2021), where the authors point to cost-savings of around 50% by scaling from 1 to 10 million tons with the main part of the reduction realized already for 3 million tons, cf. the figure below.[1]

If the cost of BECCS is EUR 100 per ton CO_2, this means that the annualized investment to reach 3m ton per year is EUR 300 million per year. However, it is reasonable to assume that this is the annualized investment and operation cost over a 30-year period, and that as much as 30% of this is in fact up-front CAPEX investments. In this case, the amount needed for one investor to reach the cost-efficient scale alone is EUR 2.7 billion.

This amount is large enough to potentially deter private investments in BECCS.

LARGE SCALE BECCS COULD STIMULATE A COMPETITIVE LOCAL INDUSTRY

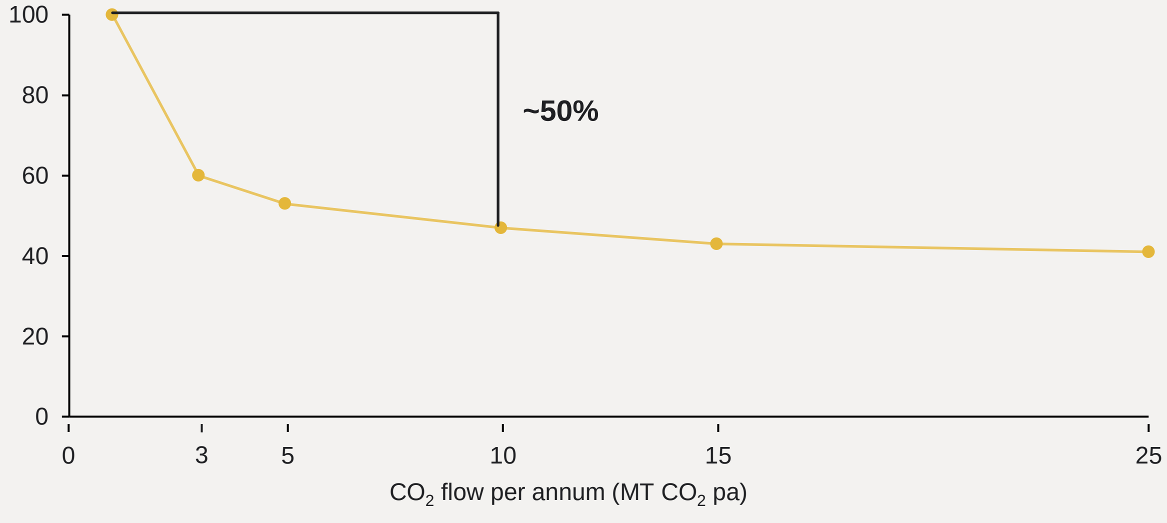
Our expert interviews point to a limited Swedish industry able to supply future BECCS construction and operation, which will yield high import shares and limited local competition. Without a well functioning and competitive supply chain, private investments will be more costly, more risky and thus less likely to happen.

If for example there is only one Swedish supplier who can install a particular piece of equipment, then this supplier can take a large mark-up over their costs. This increases the price for the total BECCS project and thus reduces the expected return for the investor. Furthermore, a single Swedish supplier may shut-down leaving the only option of bringing in a foreign supplier at a higher cost. In this example both the expected return and the risk is worse for the investor due to a limited number of suppliers.

PUBLIC FUNDING CAN HELP SWEDISH BECCS REACHING A CRITICAL MASS

Public funding can bring the market to a size where more suppliers can operate at an efficient scale, which will increase competition and lower prices of BECCS in Sweden, and which realizes the cost-reductions from scale in transport and storage. Beyond this point, it is more likely that private investors will be willing to fund new BECCS installations.

Cost of transport per ton (% indexed)



Notes: [1] McKinsey (2021) bases this on an average scenario, based on a pipe flowing over ~200km.

Swedish strongholds for BECCS

The Swedish bioenergy point sources are among the best suited for BECCS in Europe.

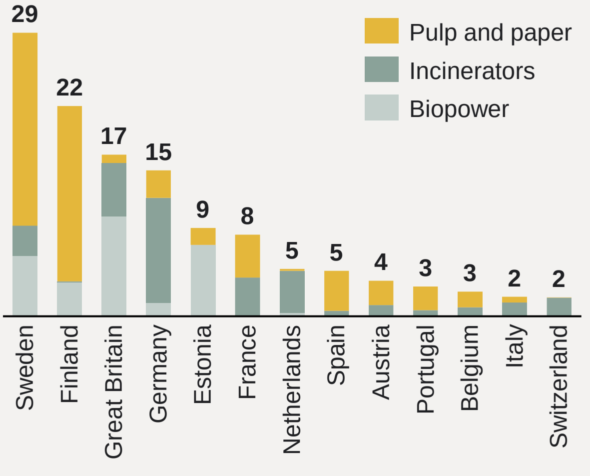
POTENTIAL FOR SCALE IN BECCS

The fundamental premise for scale in BECCS is that there are sources of biogenic emissions, which can be exploited at a reasonable cost compared to other sources of negative emissions or emissions abatement.

Sources of biogenic emissions can be either point sources, such as biomass-fueled power plants, or distributed sources such as crop residue, food waste and manure. Point sources are generally significantly cheaper to exploit, and this report thus focuses primarily on these.

Rosa et al. (2021) find that the combined amount of biogenic CO_2 emissions from point sources in Sweden is the highest in Europe, cf. the figure below (wastewater left out due to lack of data availability, however the volume is very low). Along with Finland, Sweden has a very large volume of point sources in the pulp and paper industry.

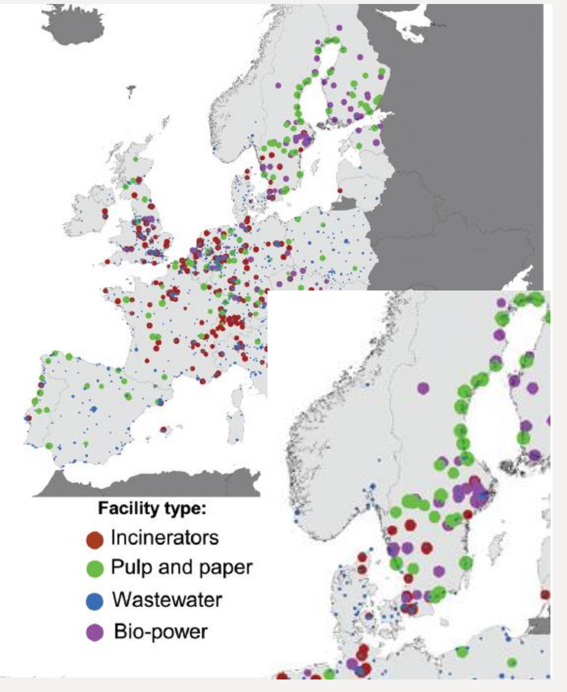
Emissions from biogenic point sources
(million tons per year)



SOU2020:4 (2020) finds that the abundant access to biomass as a raw material for the pulp and paper industry has resulted in Sweden having many significant point emission sources of biogenic CO_2. The authors further conclude that the potential for negative emissions through the application of BECCS at these sites is high. And finally, the authors argue that BECCS is well suited to be a cost-effective measure to attain the long-term climate goal of net zero emissions by 2045.

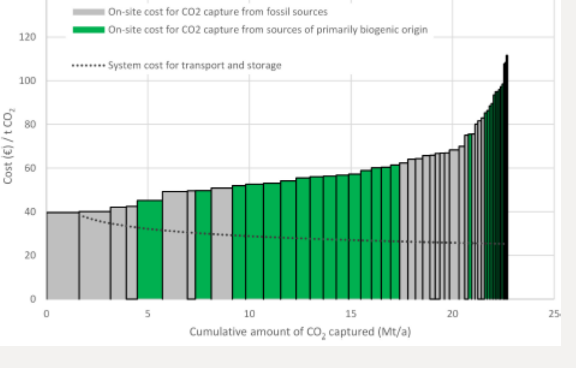
One of the drivers of cost-effectiveness is point source proximity to the coast, which is demonstrated in Rosa et al. (2021), where the authors find that many Swedish biogenic point sources are located near the coast, cf. top figure to the right. This drives lower costs for distribution because there is no need for on-land transport between the point source and a harbor from where the CO_2 can be shipped to a storage site.

Existing point sources in Europe



Johnson et al. (2020) find that the Swedish biogenic point sources are comparable to fossil point sources on expected costs of applying CCS/BECCS. Thus, the biogenic point sources are estimated to be in the middle of the marginal abatement curve of industrial CCS/BECCS in Sweden , cf. the figure below.

Costs for capture from Swedish point sources



Swedish challenges for BECCS

Sweden is well-positioned to handle the challenges related to storage, long investments cycles and environmental impact of BECCS.

SHORT-TERM STORAGE CHALLENGE IS LIKELY TO HAVE A SOLUTION

SOU2020:4 (2020) finds that there is likely to be a significant potential for CO_2 storage in Sweden, but knowledge of potential domestic storage sites is limited. Based on this, the authors conclude that currently Sweden should not prioritize establishing a storage site on Swedish territory.

This short-term lack of good storage in Sweden can likely be mitigated through international collaboration due to provisional allowance of cross-border transportation of CO_2 under the London Protocol. In such a setup, CO_2 would be transported by ship or pipeline across country borders to for example a Danish, Norwegian, UK or Icelandic storage site.

LONG LEAD TIMES AND INVESTMENT CYCLES CALL FOR IMMIDIATE ACTION

BECCS projects are associated with long lead times. Pilot studies, permit processes and setting up installations to capture, transport and store carbon dioxide will take several years in total for each individual project. If BECCS is to be able to play a significant role in climate policy in 2045, the first plants need to be operational in the 2020s, which demands immediate action on the part of the State (SOU2020:4, 2020).

Furthermore, experts point to long investment cycles and large re-investments coming up in the pulp and paper industry.[1] It is likely that the total cost of these re-investments and the investments needed to apply BECCS in the pulp and paper industry will be lower if they are coordinated. Thus, if funding is delayed there is a risk of large long-term investments being made without realizing synergies from coordinating with BECCS investments. This will make the costs of making BECCS operational higher.

As the Swedish Government is already in the process of setting up negative auctions to support BECCS, it should be possible to scale up the public funding to achieve cost-efficient scale in time.

LOW ENVIRONMENTAL IMPACT

Generally, BECCS has been criticized for risking to drive mono-cultural farming of crops with the purpose of delivering biomass for BECCS installations. If these crops are farmed on land, which was uncultivated before, it will harm bio-diversity. Furthermore, the farming of crops for BECCS will drive a large demand for water, which could create water scarcity. Rosa et al. (2021) find that most Swedish point sources are in the pulp and paper industry, which is associated with a low biodiversity and water scarcity impact in general. However, within the Swedish energy sector, BECCS is expected to primarily rely on slash (branches and tops and residues from the board, pulp and paper industries) and biogenic fractions of municipal solid waste.

Furthermore, it has been argued that large scale BECCS will compete with other uses of biomass. However, the IPCC (2021) notes with high confidence in their Special Report on 1.5º that '*The use of bioenergy can be as high or even higher when BECCS is excluded compared to when it is included due to its potential for replacing fossil fuels across sectors'*.

Notes: [1] Based on input from interview with senior advisor at the Swedish Energy Agency Svante Søderholm

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APPENDIX

Appendix

Mechanics of the input-output model to assess impacts of a mature and scaled BECCS industry.

The input-output model[1]

The input-output model is based on the Swedish national accounts.

Input-output analysis relies on inter-industry transactions data to estimate how an increase in demand affects the economy in terms of value-added and jobs.

The flows of goods and services between industries allow us to calculate industry-specific multipliers that map how the rest of the economy is affected when demand in one industry increases. In this case, the increase in demand is driven by accelerated investments in BECCS.

The intuition is that if demand for aero planes increases, for example, suppliers in the steal, textile and electronics industries also have to produce more. Similarly, if the steal, textile and electronics industries have to produce more, suppliers in the computer and wood industry have to produce more and so on. Below is an illustration of a basic input-output table.

The rows describe the distribution of a producer's output throughout the economy. The producers' output can go to other producers as input (e.g. the farmers produce to manufacturing) or to final demand (e.g. the farmers produce to private consumption or export).

The columns describe the composition of inputs required by a specific industry to produce its output. This includes input from other industries, as well as *value added* which includes labor, depreciation of capital, taxes and imports.

Assumptions about the demand increase

The modelling of the demand increase is conservatively based on costs rather than price.

We model the size of the demand increase based on the expenditures per CO_2 captured and stored. However, the estimated expenditures are unlikely to reflect the future auction price.

If the input-output table had included a BECCs industry, it would have been more appropriate to model the demand increase based on revenues rather than expenditures. We did not pursuit to use price projections in the input-output modelling as these are uncertain.

Basic input-output table[1]

		Producers as consumers									Final demand			
		Agri-culture	Mining	Con-struc-tion	Utilities	Trade	Trans-port and storage	Elec-trical equip-ment	Machi-nery and equip-ment	Human health	Personal consump-tion expendi-tures	Gross private domestic invest-ment	Govern-ment pur-chases	Net exports
Producers	Agriculture													
	Mining													
	Construction													
	Utilities													
	Trade													
	Transport and storage			Inter-industry flows										
	Electrical equipment													
	Machinery and equipment													
	Human health													
Value added	Employees	Employee compensation												
	Business owners and capital	Profit-type income ad capital consumption allowance									Gross Domestic Product			
	Government	Indirect business taxes												

Sources: [1] Miller and Blair (2009)

Export of credits

Currently, there is no operational legal framework for trading and exporting carbon removal credits.

NOT OPERATIONAL

Article 6 of Paris Agreement

- International cooperation towards achieving nationally determined contributions falls under Article 6 of the Paris Agreement, which enables cooperation through market and non-market approaches.
- Article 6 lays out the requirements for transfers between parties, including rules for their robust accounting, thereby enabling carbon markets to service the Paris Agreement.
- "Internationally transferred mitigation outcomes" (ITMOs) are defined, which can be produced through any mitigation approach provided that there is consistency with both the principles listed in Article 6.2 and the guidance provided by the parties.
- The detailed rules for Article 6 have not yet been agreed by the parties to the Paris Agreement. While the parties have made progress in the various negotiation rounds, several crucial issues remain to be resolved.[1]

NO LEGAL BASIS

EU ETS

- Installations, which provide for the capture and transport of CO_2 for subsequent storage, are presently included in the EU emissions trading scheme (ETS). This inclusion only applies, however, with regard to the obligation to hold allowances for CO_2 emissions and to surrender them accordingly. In other words, there is no obligation to surrender allowances for emissions that have been captured and transferred to an authorized installation for permanent storage.
- Strictly speaking, BECCS installations are not "not listed in Annex I" in terms of Article 24(1) of the ETS Directive, but rather expressly excluded from the scope of the Directive. Thus, if that provision was to be repealed, the installations concerned would in principle fall within the scope of the ETS Directive.
- So far, there is no clear timetable for any adaptation or modification of the existing EU ETS that would allow the integration of CO_2 removal. The first global stock take, to be carried out under the Paris Agreement in 2023, is expected to clarify the insufficiency of taken and proposed actions in meeting the Paris Agreement temperature targets so far, increasing the political momentum to rise ambition in terms of net emissions reductions.[2]

BECCS NOT INCLUDED

EU ESR

- Under the conditions specified in its Article 7(1), the effort sharing regulation (ESR) allows Member States to consider net withdrawals from land use, land use change and forestry (LULUCF) when accounting for the achievement of their individual emission targets, but only to a maximum EU-wide total of 280 million tons of CO_2 equivalents.
- Thus, a precedent exists in EU law for recognizing the need to offset hard-to-abate emissions through ecosystem-based CO_2 removals.
- However, BECCS is not included in the scope of Article 7 of the ESR.[3]

Additional considerations: A potential future framework for trading and exporting carbon removal credits must address several challenges beyond the legal issues mentioned above. As an example, the EU ETS may not be an appropriate framework as much of the hard to abate emissions are not included.

Notes: Parts of the text in this appendix are directly cited from the source, while other parts have been edited.
Sources: [1]https://www.frontiersin.org/articles/10.3389/fclim.2021.685227/full \\ [2]https://www.frontiersin.org/articles/10.3389/fclim.2021.690023/full \\ [3]https://www.ifw-kiel.de/fileadmin/Dateiverwaltung/IfW-Publications/Wilfried_Rickels/The_Future_of__Negative__Emissions_Trading_in_the_European_Union/KWP_2164.pdf

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