WHAT DO
THE FACTS
TELL US?

The climate impact by the Swedish forest-based sector

1990
2020

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In 2019, the Swedish Forest Industries presented a report that took a broad view on the climate impact of the Swedish forest-based sector (Swedish Forest Industries, 2019). Results showed that the sector made a very large positive contribution, reducing anthropogenic climate impacts at a level of -93 Mt CO_2e in the year 2017. By comparison, Sweden's reported territorial emissions were 53 Mt CO_2e in 2017. The positive contribution was achieved through a net carbon sink in forests and Harvested Wood Products, combined with wood-based products reducing demand for fossil-based material and energy. This report provides an update of the calculations, including a historical perspective of how the sector's contributions have developed since 1990.

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Summary

The overall impact on the global climate by the Swedish forest-based sector was estimated for each year in the period 1990-2020.

1

The climate effect of the sector has been consistently positive over the past 30 years.

2

The positive climate performance has improved by 1 million tons of CO_2e per year throughout the period 1990-2020.

3

In 2020 the overall positive effect was -93.5 Mt CO_2e, twice counteracting Sweden's reported territorial emissions at 46.3 Mt CO_2e.

4

Factors contributing to the positive performance are:
a) an increased carbon storage in Swedish forests and associated wood-based products
b) displacement of fossil/process emissions as society's demand for high-emission materials and energy is reduced.

Calculations have been based on official reports to the UNFCCC and on official national statistics. The main assumption affecting results is the level of displacement effects by different types of wood-based products. These displacement factors have been conservatively estimated and assumed constant throughout the period 1990–2020.

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Forests, Wood and Climate change

Origins of climate change mitigation policies

The United Nations Framework Convention on Climate Change (UNFCCC) defines two principal objectives for climate change mitigation (United Nations, 1992, Article 4.1):

These dual objectives – reducing emissions and enhancing sinks – have since 1992 formed a basic structure for climate negotiations, agreements and policy. At the global level, they feature in the Kyoto Protocol (UNFCCC, 1998, Article 3.3), and the Paris Agreement (United Nations, 2015, Articles 4.1 and 5). They provide a fundament for the European Green Deal through its Climate Law (European Union, 2021, Article 30) as well as for national climate law (e.g. Swedish Code of Statutes, 2017, Article 2.3). It is fair to say that this dichotomy shapes climate action on all levels.

Most policies take the dichotomy one step further by declaring that, in the future, emissions should be balanced by sinks, thereby achieving "net-zero" emissions. This appealing thought is formalized by the Paris Agreement, the EU Green Deal and national climate laws, such as in Sweden. As an example, the EU Green Deal includes a European Commission proposal that would by 2030 ”increase the EU net removal target to -310 Mt of CO_2 equivalent, which will put the Union on track towards climate neutrality in 2050”. (European Commission, 2022a). This means that emissions not eliminated under the first climate change mitigation objective are to be compensated by increased reservoirs, mostly in EU forests, under the second objective.

It is common that climate policies involving forests address only the second climate change mitigation objective – conserving and enhancing forest sinks and reservoirs of carbon. One example related to the EU Green Deal is the European Union regulation on Land Use, Land Use Change and Forestry (LULUCF) that aims at increasing the forest carbon stock in the European Union (European Commission, 2022b).

Contributions by the forest-based sector

The forest-based sector contributes to both principal climate change mitigation objectives:

1. **Wood-based products and bioenergy displace** (reduce the demand for) fossil-based alternatives, thereby reducing emissions (Swedish Forest Industries, 2019).

2. **Sustainable forest management with wood harvests** normally lead to higher sinks and reservoirs of carbon compared to unmanaged forests (Swedish Forest Agency, 2021).

Straddling the two principal objectives in climate mitigation policy requires that performance is measured against both, to assess the overall contribution by the forest-based sector towards climate goals.

One complication is that renewable wood-based products displace fossil emissions that are accounted for in other sectors, often in other countries. In other words, the contributions of wood-based products to reducing emissions are not attributed to the forest-based sector. The structure in regular climate reporting thereby hides the full contribution of forests, which may lead to suboptimal decisions and climate policies.

Given the ambiguous position within climate policy for the forest-based sector, initiatives seek to establish a more complete model for describing the sector's interfaces with the global climate, for example the Circular Bioeconomy Alliance (European Forest Institute, 2021). The Circular Forest Bioeconomy concept has been used by, e.g., JRC (2021) and Swedish Forest Industries (2021), and is also the basis for this report (Fig 1).

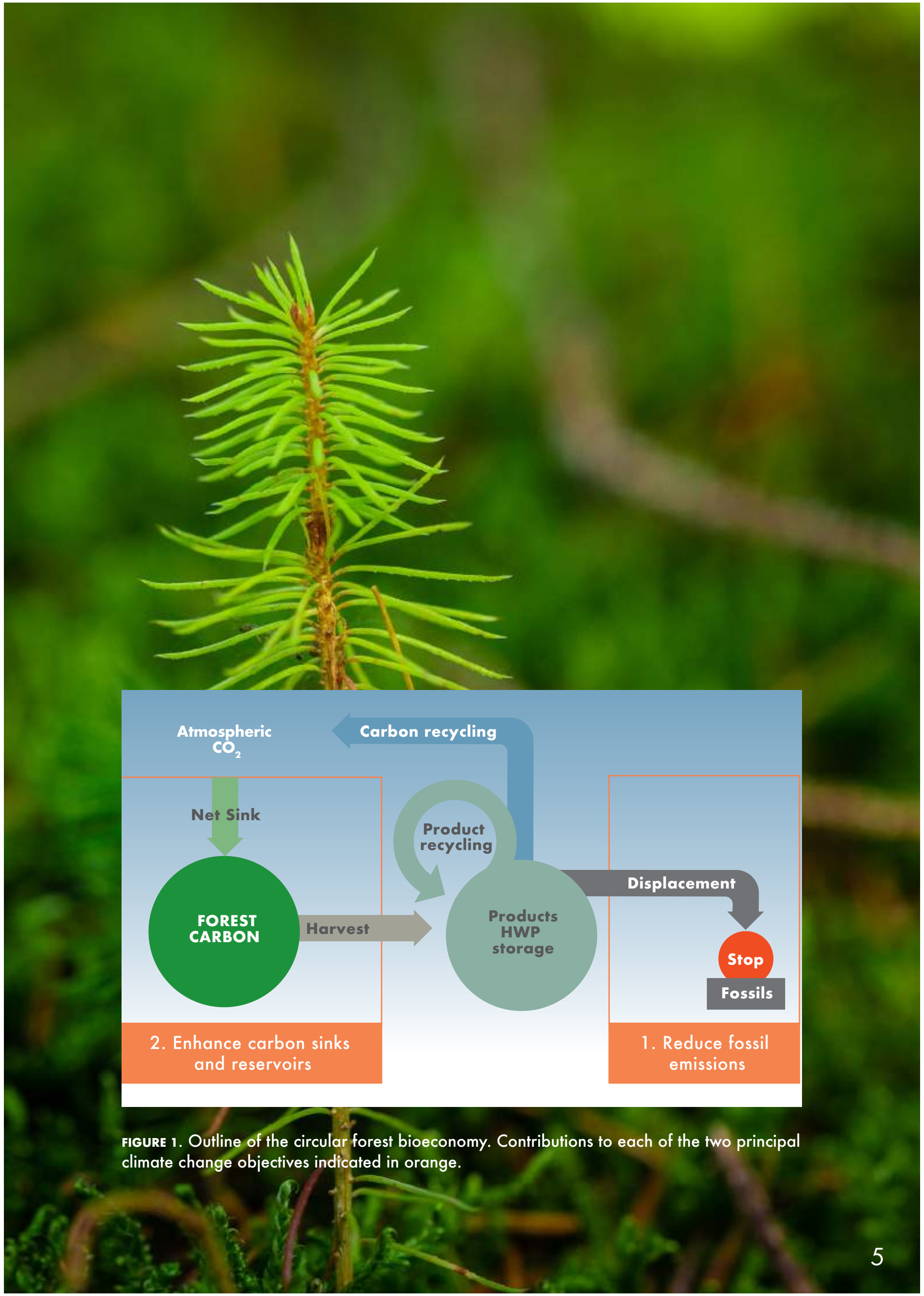

FIGURE 1. Outline of the circular forest bioeconomy. Contributions to each of the two principal climate change objectives indicated in orange.

Swedish forest-based sector developments 1990–2020

The Swedish forest-based sector has seen considerable structural changes and market developments over the past few decades. The focus of this report is on overall developments of the forest and wood-based product quantities, as these are the main determinants of the sector's impact on the global climate.

The boreal and temperate forests in Sweden grow relatively slowly and are typically harvested at stand ages of 70-120 years. Investments in improved forest growth therefore have a very long-term perspective and have been made since early 1900s, when forest legislation made regeneration mandatory after harvesting. Since then, forest management practices and seedling material have continuously improved. As a result, both forest growth, standing timber volume and harvest volume have all doubled in Sweden over the past 100 years. (SLU, 2021)

These investments in forest management have been motivated by a steady and increasing demand for wood-based products. To meet this increasing demand, Swedish forest industry has expanded over the past century. Through these investments, a highly integrated value chain has evolved, that makes use of all parts of harvested wood for solid wood products, fibre products and bioenergy. Driven mainly by the stable demand for wood, the price of forest land

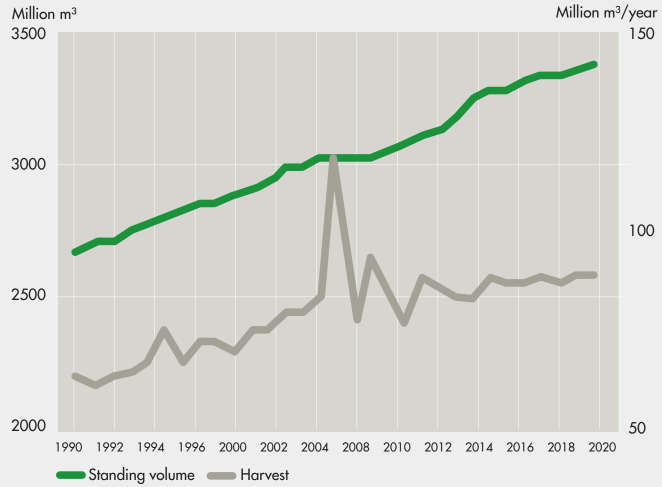

Figure 2
Development of standing timber volume on Sweden's 28 million ha of forest (left scale) and annual wood harvest (right scale) in Sweden 1990-2020. Higher harvests in 2005 were due to major storm fellings in that year.
Source: SLU (2021).

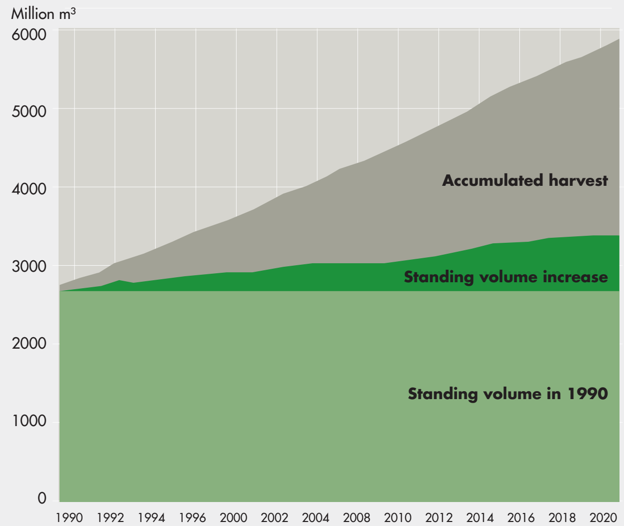

Figure 3
Swedish forests: Comparison of standing volume increase and accumulated harvests 1990-2020 with the standing volume in 1990.
Source: SLU (2021).

has concurrently increased, with annual return on investment at an average of 10 percent over the past 60 years (SCA, 2021, p29).

This report focuses on developments over the past 30 years. The period 1990-2020 was characterized by a continued increase of standing volume in the forest (+25 percent) and harvested wood volumes (+40 percent) (Figs 2,3). The area of wood harvest, however, did not change – instead the increase in wood removal reflects past long-term investments in forest management that have resulted in increasingly higher stocks in currently harvested forest stands (Swedish Forest Agency, 2022). The period also saw a corresponding continued increase of wood-based product delivery – in particular, quantities of sawnwood (+55 percent) and bioenergy (+130 percent). Total use of bioenergy in Sweden increased from 60 to 140 TWh/yr mostly based on domestic residues from forestry and forest industry, although imported transport biofuels contributed to the increase in the past ten years. Climate benefits from bioenergy are here only based on delivered electricity and district heating – not including bioenergy used internally in the forest-based dindustry. Delivered forest-based bioenergy increased from 7.5 TWh in 1990 to 50 TWh in 2020. (Fig 4).

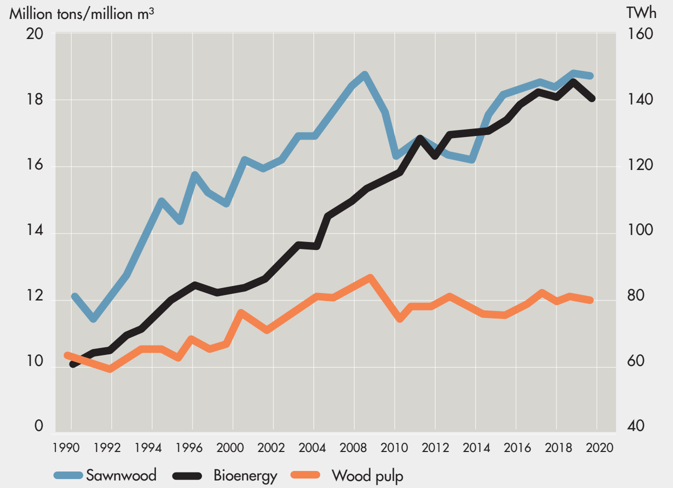

Figure 4
Delivery of woodbased products and bioenergy in Sweden 1990-2020. Sawnwood and Wood pulp - left scale with different units of measure (FAO, 2021) and total bioenergy – right scale. Bioenergy is predominantly produced from wood-based sources. In this report climate benefits are calculated based on delivery of electricity and district heating (ca 50 TWh in 2020) – excluding bioenergy used internally in the forest-based industry. (Swedish Energy Agency, 2022a).

Development of forest-based bioenergy in Sweden

Forest-based bioenergy has increased considerably in Sweden over the past 30 years – contributing strongly to the overall increased climate benefit of the forest-based sector. This is a result of conscious political action, leading to investments that have transformed a large part of the Swedish energy system. The developments have not led to the harvesting of more trees for bioenergy purposes – instead they can be attributed to:

1. A 40 percent overall increased wood harvest, without increasing the harvested area as earlier long-term investments in forest management has led to higher stocks in currently harvested stands. The increase in wood harvest has also led to a corresponding increase in bioenergy production from residue streams.

2. Enhanced utilization of harvested trees, including branches and tops (now contributing about 10 TWh/year), as well as residues from roundwood processing.

3. Efficiency gains in forest industry processes leading to larger residue streams for internal use, as well as increased production of marketed heat, liquid biofuels and electricity.

4. Investments in renewable energy infrastructure such as district heating.

The primary reason for the rapid growth of bioenergy sector in Sweden is broad political support and the use of strong general incentives such as the Swedish carbon dioxide tax (introduced in 1991), the green electricity certificates (introduced in 2003), and tax exemption for biofuels for transport, as well as direct investment supports, for example to Combined Heat and Power (CHP) plants. The transformation in district heating was profound. At the end of the 1970s heating oil accounted for 90 percent of the fuel in district heat plants. By 2014, the share of fossil oil was only two percent of the total fuel use in district heating. Biomass had taken oil's place, growing from a couple of percent at the end of the 1970s to more than 70 percent in 2014. (Andersson, 2015)

Today, bioenergy is the largest component in Sweden's energy supply, contributing more than 30 percent of all energy used, of which about 80 percent is sourced directly or indirectly from forest biomass. Annual bioenergy production increased by about 90 TWh from 1990 to 140 TWh in 2020, while annual fossil energy use decreased by about 70 TWh in the same period. Meanwhile the total energy use in Sweden was near-constant at about 360 TWh throughout the period (Swedish Energy Agency, 2022b). These developments explain to a large extent why overall territorial emissions by Sweden have declined by 35 percent since 1990 (see figure 5)

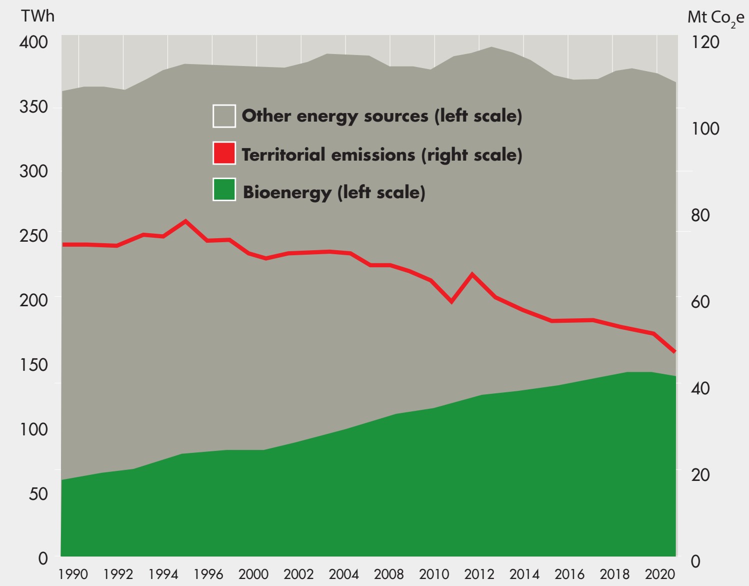

Figure 5
Share of bioenergy in the Swedish energy system (use of energy) 1990-2020 compared with Sweden's territorial greenhouse gas emissions.
Sources: Swedish Energy Agency, Swedish Environmental Protection Agency.

Sector impact on the global climate 1990–2020

Model and data for estimating climate impact

In 2019, the Swedish Forest Industries presented a report that took a broad view on the climate impact of the Swedish forest-based sector (Swedish Forest Industries, 2019). Results showed that the sector made a very large positive contribution, reducing anthropogenic climate impacts at a level of -93 Mt CO_2e in the year 2017.

This three-component model to present the overall climate effect was first applied by SCA, a Swedish forest industry corporation in its annual report for year 2018 (Holmgren and Kolar, 2019; SCA, 2019). Using a similar methodology, several listed forestry corporations have presented their positive climate effect in their annual and sustainability reports (BillerudKorsnäs, 2021; Holmen, 2021; SCA, 2021; StoraEnso, 2021). Positive climate impacts have also been calculated at the European level (CEPI, 2020).

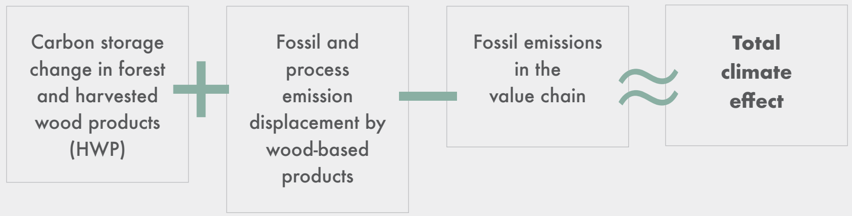

Figure 6. Three-component model for presenting the overall climate effect.

The model's three components are calculated as follows:

1. Carbon storage change in forest and harvested wood products (HWP)

This component follows the established IPCC methodology applied in official national inventory reports to the United Nations Framework Convention on Climate Change (UNFCCC, 2022). It uses the reporting for Land Use, Land Use Change and Forestry (LULUCF) as related to forest carbon pools and harvested wood products. Sweden and all EU countries submit national inventory reports on an annual basis (European Environment Agency, 2021). For Sweden, data are considered as official statistics and made publicly available (Statistics Sweden, 2022).

2. Fossil and process emission displacement by wood-based products

Displacement effects are not explicitly included in officially reported climate data, although the effect is implied by reduced emissions in a range of sectors where wood-based products and energy are used. For this reason, the avoided fossil/process emissions must be estimated based on available research data.

This report uses the findings in Holmgren and Kolar (2019) where conservative average displacement factors were established for broad product categories (1.5 tC/tC for solid wood products, 0.7 tC/tC for fibre products and 0.7 tC/tC for marketed bioenergy (excluding internal use of bioenergy). While these factors correspond well with published research (see e.g. JRC, 2021), they need further verification through research and life-cycle assessments. Currently they can be used to establish an approximate and conservative estimate of avoided fossil/process emissions that would be caused from the production of alternative materials and energy.

Input data for the production of wood-based products were obtained from official statistics (Statistics Sweden, 2022)

3. Fossil emissions in the value chain

Methods for calculating fossil emissions caused through the value chain are well established both through official climate reporting and from corporate reporting where emissions are detailed, usually applying the Greenhouse Gas Protocol (World Resources Institute, 2021).

Note that emissions from forest operations, through primary forest industry and transport to customers are included. However, emissions from chemical input goods and downstream emissions by customers and customers customers are not considered.

Data for industry emissions were obtained from the Swedish Environmental Protection Agency (Naturvårdsverket, 2022). Emissions from forest operations and transports were estimated based on emission factors in (Björheden, 2019; Trafikverket, 2022)

Results

Numerical results are provided in Annex 1.

Net sink in forest and harvested wood products

The Swedish net sink in forest and harvested wood products has been relatively stable throughout the past 30 years, with an average level at -45.5 Mt CO_2e/yr and a 2020 level at -45.7 Mt CO_2e of which -38.3 in the forest and -7.4 in harvested wood products. During the period 1990-2020, a total net -1.41 GtCO_2 was removed from the atmosphere as increased storage in Swedish forests and associated wood-based products. Of this storage increase, 84 percent was stored in Swedish forests and 16 percent in associated wood-based products.

This reflects:

- a build-up of carbon in living biomass as wood harvest has been lower than the forest growth (-1.03 Gt CO_2e in the period 1990-2020)
- a build-up of carbon in dead organic matter and forest soils (-0.16 GtCO_2e)
- an increasing volume of harvested wood products in use (-0.22 GtCO_2e)

Within the forest, 87 percent of the net storage increase was in living biomass, with the balance attributed to a net increase in dead organic matter and the soil, and net emissions from fertilizing, drainage and fire. About 60 percent of the current net forest carbon storage increase happens in production forests, with the remainder in low-productive forests and set-aside forests (Government Offices of Sweden, 2019).

Displacement

The displacement of fossil/process emissions by Swedish wood-based products increased by 87 percent during the period - from -27.8 Mt CO_2e in year 1990 to -52.1 Mt CO_2e in year 2020. For the entire period, the displacement was 1.3 GtCO_2e.

The increase in fossil/process emission displacement follows an increase of wood harvest throughout the period. Wood removals increased by about 40 percent from 1990-2020 – while maintaining the net sink in forests as per above. In 2020, net wood removals were 89 Mm3 stemwood, with a carbon content corresponding to c. 80 Mt CO_2e.

From the wood-based product perspective, the increased displacement effect is attributed to two factors. First, a 43 percent increase in production of solid wood products for a total of 19 Mm3 sawn wood in 2021. Second, a sharp increase in marketed bioenergy (electricity and heat) from the forest industry, as a result of efficiency gains in the value chain and society's investments in bioenergy infrastructure. By contrast, the quantity of fibre products has been stable throughout the period.

Emissions in the value chain

Emissions in the value chain in 2020 were 4.2 Mt CO_2e. This is about half the annual emissions in the 1990s, despite a considerable increase in wood harvest and product volumes, as per above.

Emissions within the forest industry in 2020 amounted to 1.4 Mt CO_2e, which is one third of the emissions in 1990, following investments in a transition from fossil to biobased energy in industry processes.

Transport emissions include wood supply to the industries and product delivery to customers. These are currently larger than emissions within the industry itself. However, thanks to efficiency gains in the transport sector, emissions have declined since 1990 – despite the increased industry production level. Emissions from transport, including forest operations, were 2.9 Mt CO_2e in 2020.

Overall climate effect

The overall climate effect is expressed as the sum of

- net increase in carbon storage
- displacement of fossil/process emissions
- fossil emissions caused in the value chain

In the 30-year period 1990-2020 the climate effect of the Swedish forest-based sector has increased from -64 to -93 Mt CO_2e/yr. That is, the annual improvement in climate performance has been about -1 Mt CO_2e.

The dominating factor of the improvement is increased displacement of fossil/process emissions. Emissions in the value chain have also declined, while the net sink in forest and harvested wood products has been relatively constant (Fig 7,8)

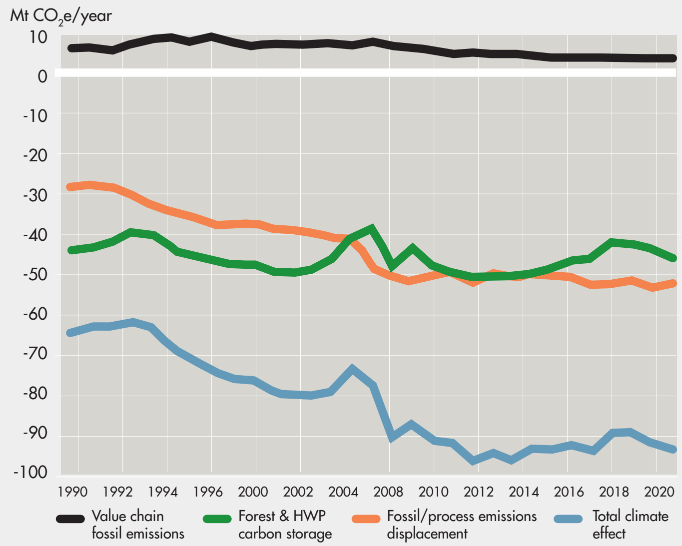

Figure 7
Climate effects of the Swedish forest-based sector 1990-2020.

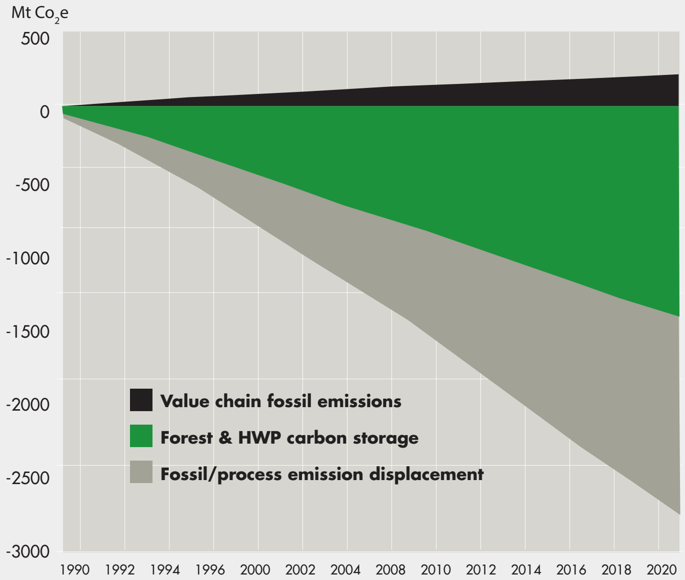

Figure 8
Accumulated climate effects of the Swedish forest-based sector 1990-2020.

Conclusions

- **The climate effect** of the Swedish forest-based sector has been consistently positive over the past 30 years;
- **The positive climate performance** of the sector has improved by 1 million tons of CO_2e per year throughout the period 1990-2020. In 2020 the overall positive effect was -93.5 Mt CO_2e;
- **During the same period,** Swedish territorial emissions decreased from 71 to 46 Mt CO_2e/yr, to a considerable extent due to increasing supply of renewable forest bioenergy and reduced emissions in the wood-based value chain (Figure 8);
- **Factors contributing** to the positive performance are (a) an increased carbon storage in Swedish forests and associated wood-based products, and (b) displacement of fossil/process emissions as the demand for high-emission materials and energy is reduced;
  - » The increase of carbon storage in forests and associated products was 1.4 GtCO_2e for the period 1990-2020;
  - » The accumulated displacement of fossil/process emissions was 1.3 GtCO_2e for the period 1990-2020;
- **Fossil emissions** in the wood-based value chain have been halved during the period 1990-2020. In 2020 they amounted to (and counteracted) about 4 percent of the positive climate effect;
- **Calculations have** been based on official reports to the UNFCCC and on official national statistics. The main assumption affecting results is the level of displacement effects by different types of wood-based products. These displacement factors have been conservatively estimated and assumed constant throughout the period 1990-2020.

»The climate effect of the Swedish forest-based sector has been consistently positive over the past 30 years«

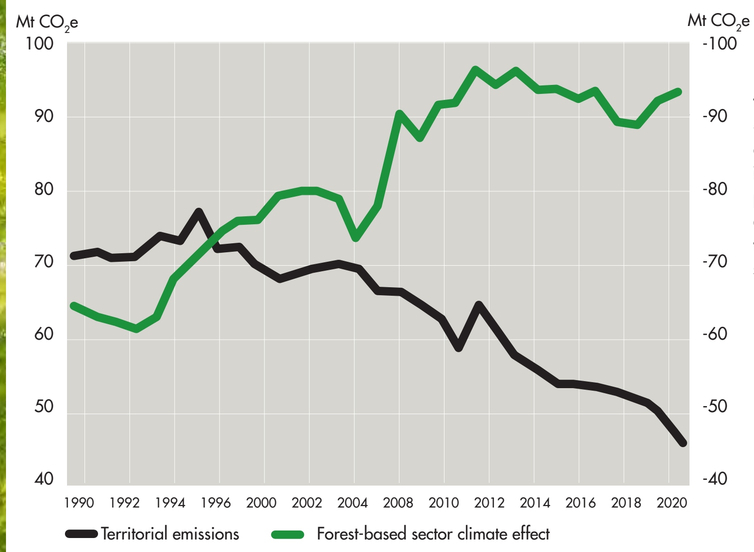

Figure 9
Declining territorial emissions in Sweden (left axis) compared with increasing positive climate effect of the forest-based sector.

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Annex 1. Tabular results

Results by the three components described in the main document. All estimates are million tons of carbon dioxide equivalents (Mt CO_2e). Displacement through bioenergy is based on delivered electricity and district heating – excluding bioenergy used internally in the forest-based industry.

	Net carbon sink			Displacement effect by product category				Value chain emis-sions	Total climate effect
Year	Forest	HWP	Total	Soild wood	Fibre	Bioenergy	Total		
1990	-39	-5	-43	-15	-10	-3	-28	7	-64
1991	-39	-4	-43	-14	-10	-3	-27	7	-63
1992	-38	-3	-41	-14	-10	-4	-28	7	-63
1993	-34	-5	-39	-15	-10	-4	-30	8	-62
1994	-34	-6	-40	-17	-10	-6	-33	9	-63
1995	-37	-6	-43	-18	-10	-7	-34	9	-68
1996	-39	-6	-45	-17	-10	-8	-35	9	-71
1997	-39	-7	-47	-19	-10	-8	-37	9	-74
1998	-41	-7	-48	-19	-10	-8	-37	9	-76
1999	-40	-7	-47	-18	-11	-8	-37	8	-76
2000	-41	-8	-49	-19	-11	-8	-38	8	-79
2001	-43	-7	-49	-18	-11	-9	-39	8	-80
2002	-41	-7	-49	-18	-11	-10	-39	8	-80
2003	-38	-8	-46	-19	-12	-10	-41	8	-79
2004	-31	-9	-40	-19	-12	-10	-41	8	-73
2005	-28	-10	-38	-21	-13	-14	-48	8	-78
2006	-36	-11	-48	-21	-14	-16	-51	8	-91
2007	-31	-12	-43	-22	-13	-16	-51	7	-87
2008	-38	-10	-48	-21	-13	-17	-50	6	-92
2009	-41	-7	-49	-19	-12	-18	-49	6	-92
2010	-43	-7	-51	-19	-12	-20	-52	6	-97
2011	-43	-7	-50	-19	-12	-18	-50	5	-94
2012	-44	-7	-51	-18	-12	-20	-50	5	-96
2013	-43	-6	-49	-18	-12	-20	-50	5	-94
2014	-41	-7	-48	-19	-12	-19	-50	5	-94
2015	-39	-7	-47	-20	-12	-19	-51	5	-93
2016	-38	-8	-46	-20	-12	-20	-52	5	-94
2017	-36	-6	-42	-20	-11	-20	-52	5	-90
2018	-36	-6	-42	-20	-11	-20	-51	5	-89
2019	-37	-6	-43	-21	-11	-21	-53	4	-92
2020	-38	-7	-46	-21	-12	-19	-52	4	-94

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