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CARBON ABATEMENT COST FOR TRANSPORT FUELS:

Electrofuels versus biofuels

Renewable fuels for transport are, in combination with direct electrification, needed to reach future climate targets. However, the potential future role of different biofuels, hydrogen, and electrofuels (produced by electricity, water, and carbon dioxide CO_2) in different transportation sectors remains uncertain. The introduction will strongly influence the possibility to reach targets for the transport sector [1] but will also influence the electricity demand for transport purposed in Sweden.

From January 2024, the Swedish government aim to reduce the ambition level of the Swedish reduction obligation system which require fuel distributors to reduce greenhouse gas (GHG) emissions from petrol, diesel, and fossil aviation fuels by gradually increasing the blending of biofuels, hydrogen or other electrofuels. That the GHG reduction mandate regulates climate performance rather than the proportion of renewable fuels means that fuels with low GHG gas emissions are favored, as these can be blended in lower volumes than fuels with poorer climate performance to achieve the same emissions reduction. Will this system and the proposed change influence the prerequisites for hydrogen and electrofuels in relation to biofuels?

1) https://www.energimyndigheten.se/nyhetsarkiv/2022/reduktionsplikten-ar-avgorande-for-att-na-sveriges-energi--och-klimatmal/

According to the reduction obligation system, for 2022 and 2023, the climate impact should be reduced by at least 7.8 percent from gasoline and 30.5 percent from diesel, compared to if the same product is produced only with fossil raw materials. A gradual increase until 2030 was previously proposed, but the current proposal from the government is that GHG reduction mandate will be reduced from January 1, 2024, until 2026 to a reduction of climate impact by 6% for gasoline and 6% for diesel.

The main findings from an updated analysis of the CO_2 abatement costs for various types of biofuels and electrofuels for road transport and aviation (Hansson et al., 2023), with a Swedish perspective is summarized.

Co_2 abatement cost for future transport fuels

The **CO_2 abatement cost**, i.e., the cost of reducing a certain amount of greenhouse gas (GHG) emissions with a certain fuel is central for the competitiveness of different renewable fuel pathways. This not the least in case of an emission reduction obligation system like Sweden (and Germany) and even more with reduced ambitions as this increases the competition between renewable fuels. The abatement cost of a specific fuel value chain depends on the fuel production cost and the GHG reduction provided by the fuel in comparison to fossil fuels. The CO_2 abatement cost (in SEK/kgCO_2) is calculated as:

$$CO_2 \text{ abatement cost} = \frac{\textit{(Fuel production cost – fuel production cost fossil reference)}}{\textit{(}CO_2\textit{ emissions fossil fuel reference – }CO_2\textit{ emissions fuel)}}$$

The renewable fuels are, depending on their type, assumed to replace fossil diesel, fossil gasoline, fossil aviation fuel (kerosene), or hydrogen produced from natural gas. The CO_2 abatement cost is presented as a span based on the upper and lower values for mapped production cost and GHG emission performance. This to illustrate the uncertainty in estimates. However, a reference value for each pathway was also chosen.

Comparison of almost 40 renewable fuel pathways

The fuels assessed include different production pathways for eight renewable fuel types produced from different feedstocks including **methanol, ethanol, methane**, renewable diesel including e.g. Fatty Acid Methyl Ester (**FAME**) and hydrotreated vegetable oil (**HVO**), **renewable gasoline**, **aviation fuel**, and **hydrogen**. The assessment covers biofuels based on crops and vegetable oil, derived from woody biomass or waste, hydrogen produced from woody biomass and water (electrolysis), several electrofuels but also so-called bio-electrofuels produced from biogenic excess CO_2 from biofuel production and electricity linked to the biofuel production (not requiring carbon capture technology). For a detailed description of the production pathways see Hansson et al (2023).

The mapping of fuel production costs and GHG emissions performance are based on recent literature but have to some extent been updated to consider the latest development in terms of increased prices etc. Som key assumptions include woody biomass cost 20 €/MWh, waste 0 €/MWh, electricity 50 €/MWh, oils and fats 90-130 €/MWh. The production costs used represent the production costs for a technically mature Nth of a kind plant (when the technology is deployed at a large scale) regardless of current technology maturity.

The GHG emissions include emissions from fuel use and production following the approach in the updated Renewable Energy Directive [2] from which also the fossil reference is used. The GHG performance of the electrofuels depend on the GHG performance of the electricity. For the electrofuels and bio-electrofuel pathways, a GHG emission factor for electricity production of 7 gCO_2eq./MJ is used for the reference and upper case, which represents the current Swedish electricity mix. For the lower level of the uncertainty interval electricity is assumed to have zero GHG emissions, which can be relevant for at least the northernmost Swedish region (where at least 90 percent of the electricity production is renewable) following the delegated acts on renewable fuels of non-biologic origin [3].

Carbon capture is not assumed for any of the biofuel pathways. Though, for hydrogen produced from biomass, three different ways of managing the CO_2-stream are included; (i) the CO_2 is vented, (ii) the generated CO_2 is sold (reducing the cost by the income of sold CO_2) referred to as CO_2 sold, (iii) the negative emission from direct in-situ CO_2 storage is credited (a cost for CO2 transport and storage is added) referred to as CCS.

2) Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the Promotion of the Use of Energy from Renewable Sources. https://eur-lex.europa.eu/TodayOJ/.

3) Commission delegated regulation (EU) of 10.2.2023 supplementing Directive (EU) 2018/2001 by establishing a minimum threshold for GHG emissions savings of recycled carbon fuels and by specifying a methodology for assessing GHG emissions savings from renewable liquid and gaseous transport fuels of non-biological origin and from recycled carbon fuels.

Main findings: electrofuels generally have relatively high CO_2 abatement costs

There is a considerable variation both in production cost and GHG emission performance for most pathways generating a large interval in the CO_2 abatement costs, see Figure 1.

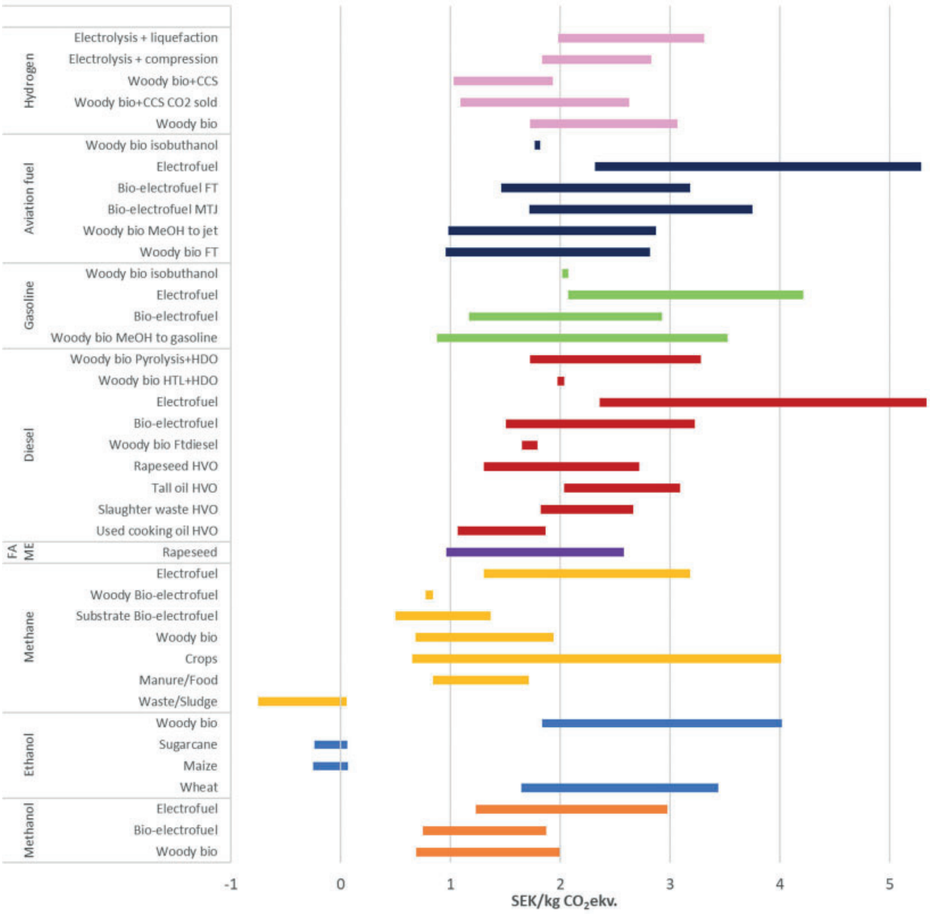


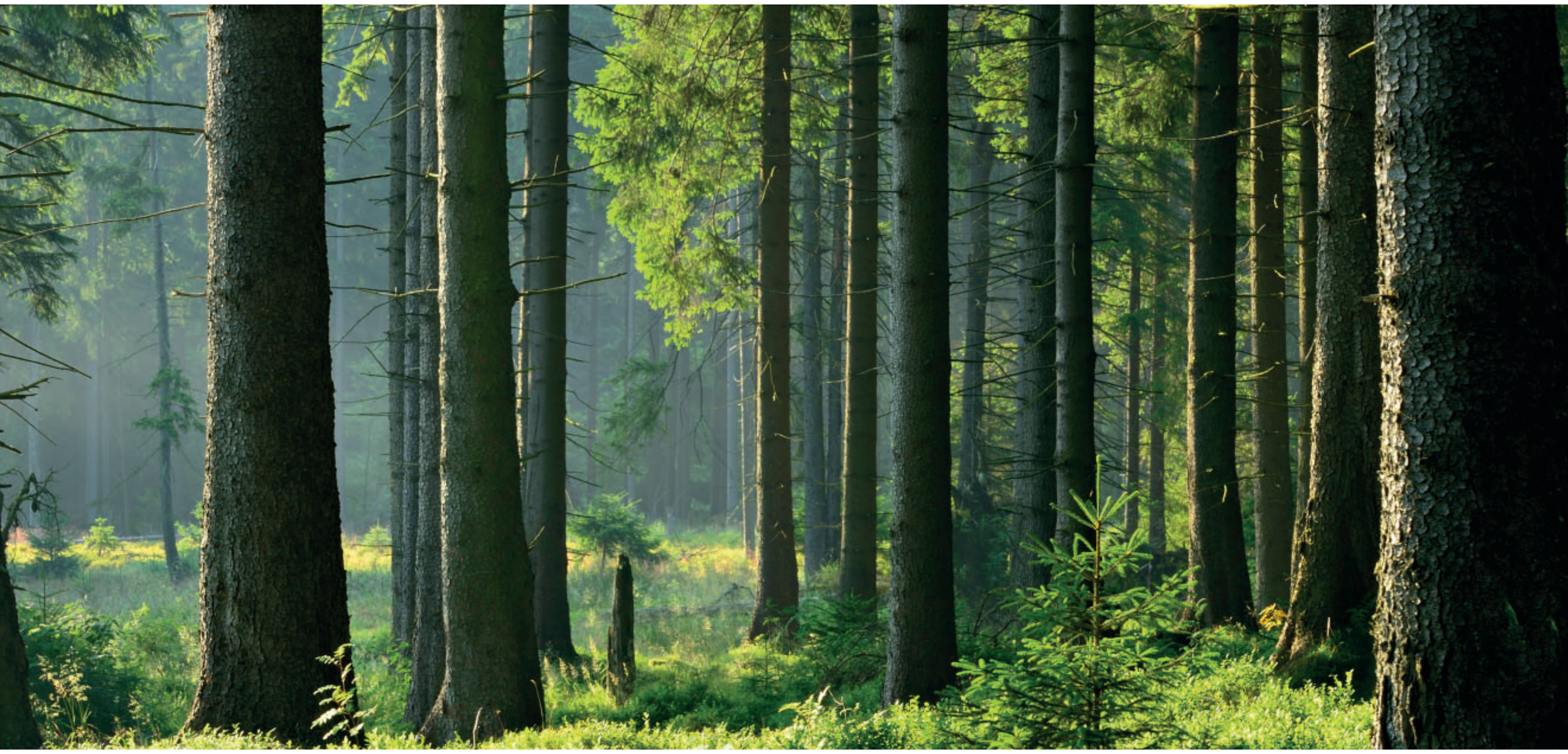
Figure 1. Estimated CO_2 abatement cost interval for all considered transport fuel pathways in SEK per kg of CO_2 equivalents. The pathways are described in more detail in Hansson et al (2023). CCS: carbon capture and storage, FT: Fischer Tropsch, MTJ: methanol to jet, HVO: hydrotreated vegetable oil, HTL: Hydrothermal liquefaction, HDO: Hydrodeoxygenation

Currently, commercial pathways have, in general, lower CO_2 abatement costs than pathways that are not yet deployed in large scale. Methane from anaerobic digestion of sewage sludge and ethanol from fermentation of sugarcane and maize end up with negative CO_2 abatement cost given the assumptions made. Electrofuels pathways have, on the other hand, relatively high CO_2 abatement costs. Also, bio-electrofuels generally have higher CO_2 abatement costs than the corresponding forest biomass-based biofuel pathway.

Two pathways stand out with high production and CO_2 abatement cost: production of diesel and aviation fuel from CO_2 and electricity (both electrofuels). Thus, the included biobased aviation fuels (and to some extent also bio-electrofuels for aviation) seem more promising in this perspective. In case of a GHG emission factor representing the Nordic electricity mix (of about 25 $gCO_2eq./MJ$) the upper level of the carbon abatement costs for all the assessed electrofuels increases by 50-100%. To conclude, electrofuels and hydrogen is found to be less competitive compared to biofuels for transport in the carbon abatement perspective and thus need additional support to be competitive.

Since most of the assessed renewable fuel pathways achieve substantial GHG emission reduction compared to fossil fuels, the fuel production cost is, in general, more important than the GHG performance to achieve a low CO_2 abatement cost. This can be exemplified by the hydrogen pathway produced from woody biomass through gasification combined with CCS, that have by far, the largest CO_2 reduction potential but end up with a CO_2 abatement cost that is in the same range as for the other pathways.

For forest biomass-based biofuels, bio-electrofuels and electrofuels, methanol and methane pathways in general have somewhat lower CO_2 abatement costs than renewable hydrocarbon-based fuels (renewable gasoline, diesel, and aviation fuel).



4) Beiron, J., et. al., 2022. A techno-economic assessment of CO_2 capture in biomass and waste-fired combined heat and power plants – A Swedish case study. International Journal of Greenhouse Gas Control Volume 118, July 2022, 103684 and Andersson, J., et. al., 2021. Bio-CCS från biogasanläggningar. (BECCS from biogas production). RISE Rapport 2021:92, ISBN: 978-91-89385-82-5.

Overall comparison with other measures

To promote other GHG reduction measures than renewable transport fuels, the Swedish government has launched support for large-scale investments in bio-energy applications with carbon capture and storage (BECCS). For comparison, several of the studied transport fuel pathways have a CO_2 abatement cost that is within the same range as the estimated cost of BECCS or lower (80-180 EUR/tonCO_2 but with the majority less than 155 EUR/tonCO_2 [4]). The CO_2 abatement cost presented in this work should, however, mainly be used to compare different renewable fuels for transport, with the same application. To reach the long-term climate goals the emissions in all sectors need to be substantially reduced.

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FURTHER READING:

This brief mainly summarizes the findings from the project ”Kostnader för att reducera utsläpp av växthusgaser från väg- och flygtransporter medbiodrivmedel och elektrobränslen” financed by the Swedish Energy Agency [Project no. P2021-00091 carried out within the Bio+ program (https://bioplusportalen.se/en/).

Hansson, J., et al., 2023. Costs for reducing GHG emissions from road and air transport with biofuels and electrofuels. Report C770, IVL Swedish Environmental Research Institute. ISBN 978-91-7883-511-9.
https://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1776832&dswid=8981

NORTH EUROPEAN ENERGY PERSPECTIVES, Nepp

North European Energy Perspectives, Nepp, is a multidisciplinary research programme. The purpose of Nepp is to show how the energy systems in Sweden, the Nordics, and Northern Europe, can achieve balanced and sustainable development paths and contribute to the green transition of society as a whole. The programme functions as a research cluster, where researchers from different organisations and universities conduct studies, that takes as starting point the challenges facing society in achieving the transition. Also, Nepp is an arena for dialogue, co-creation, and a holistic approach for the energy sector and energy research.

The research company Energiforsk is the host of Nepp and responsible for the programme's overall direction. Project leader is the consultancy and research company Profu.