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Working Paper

Accounting of negative and neutral emission technologies (NETs)

Finnish case studies on the coverage of BECCS, fossil CCS, enforced concrete carbonation, biochar and e-fuels in GHG inventories and EU targets: EU ETS, ESR, LULUCF and ECL / EU NDC 2030

Oeko-Institut Working Paper 4/2024

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Abstract

By means of case studies applied in the Finnish context we assess reporting and accounting rules applicable to negative and neutral emission technologies (NETs), including BECCS, fossil CCS, CCU / BECCU with long-term carbon storage involving enforced concrete carbonation, CCU / BECCU / DACCU with short-term carbon storage involving e-fuels and biochar. In terms of reporting and accounting frameworks, the paper analyses how NETs are covered in GHG inventories that are reported by Parties to the UNFCCC according to rules agreed under the Paris Agreement, in the EU emissions trading system (ETS), in the EU Effort Sharing Regulation (ESR), in the EU LULUCF Regulation, in the EU-wide targets under the European Climate Law (ECL) and the EU target for 2030 committed as a Nationally Determined Contribution (NDC) under the Paris Agreement, and in the EU Carbon Removal and Carbon Farming Certification Framework Regulation (CRCF). In the working paper we provide details on the covered reporting and accounting frameworks, explain the 'downstream' and 'upstream' reporting approaches for CCU emissions in GHG inventories, present the NET case studies and their detailed results and draw conclusions from the case study exercise and summarise key insights.

Zusammenfassung

Anhand von Fallstudien im finnischen Kontext untersucht das Arbeitspapier Berichterstattungs- und Bilanzierungsregeln für die negativen und neutralen Emissionstechnologien (NETs) BECCS, fossiles CCS, CCU / BECCU mit langfristiger Kohlenstoffspeicherung durch aktive Karbonisierung von Betonprodukten, CCU / BECCU / DACCU mit kurzfristiger Kohlenstoffspeicherung in synthetischen Kraftstoffen sowie Pflanzenkohle. Dabei analysiert es die Abbildung von NETs in verschiedenen Berichterstattungs- und Bilanzierungssystemen, nämlich in den Treibhausgas-Inventaren der UNFCCC-Vertragsparteien gemäß den Regeln des Pariser Übereinkommens, im EU-Emissionshandelssystem (ETS), unter der EU-Klimaschutzverordnung (ESR) und der EU-LULUCF-Verordnung, für die EU-weiten Ziele im Europäischen Klimagesetzes (ECL) und im nationalen Beitrag (NDC) der EU für 2030 unter dem Pariser Abkommen, sowie in der EU-Verordnung für die Zertifizierung von Kohlenstoffentnahme und Carbon Farming (CRCF). Das Arbeitspapier stellt Einzelheiten zu den erfassten Berichterstattungs- und Bilanzierungssystemen vor, erläutert die alternativen Ansätze, Emissionen im CCU-Kontext in THG-Inventaren „downstream" oder „upstream" zu berichten, stellt die NET-Fallstudien und ihre detaillierten Ergebnisse vor, zieht daraus Schlussfolgerungen und fasst die wichtigsten Erkenntnisse zusammen.

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1 Introduction

Achieving carbon neutrality and then carbon negativity will require the deployment of negative and neutral emission technologies (NETs). However, there are open questions and uncertainties related to how these technologies are and will be treated in greenhouse gas inventories and accounting frameworks for climate targets under EU law.

In the present paper, we assess reporting and accounting rules applicable to NETs by means of case studies for selected NET pathways. Case studies were selected with a view to be relevant and informative for the Finnish national context, and were partly inspired by R&D activities of Finnish enterprises (Kujanpää et al. 2023). Some case studies were carried out to illustrate differences between various value chains.

NET pathways analysed in this paper comprise the capture of fossil, biogenic or atmospheric CO_2 for storage in geological formations or in long-lived or short-lived products, and the production of biochar for long-term or short-term storage applications. The pathways involving CO_2 capture are commonly summarised as CCUS (carbon capture and use or storage). CCUS pathways involving biogenic CO_2 are usually referred to as BECCS, BECCU, BioCCS or BioCCU and CCUS pathways involving direct capture of CO_2 from the atmosphere are usually referred to as DACCS or DACCU. CCS involving capture of fossil CCS is referred to as FoCCS.

In terms of reporting and accounting frameworks, the paper analyses how NETs are covered in:

- greenhouse gas (GHG) inventories that are reported by Parties to the UNFCCC according to rules agreed under the Paris Agreement,
- in the EU emissions trading system (ETS),
- in the EU Effort Sharing Regulation (ESR),
- in the EU LULUCF Regulation,
- in the EU-wide targets under the European Climate Law (ECL) and the EU target for 2030 committed as a Nationally Determined Contribution (NDC) under the Paris Agreement, and
- in the EU Carbon Removal and Carbon Farming Certification Framework Regulation (CRCF)

In the working paper we

- provide more details on the covered reporting and accounting frameworks in section 2,
- explain the ‘downstream’ and ‘upstream’ reporting approaches for CCU emissions in GHG inventories in section 3,
- present the NET case studies and their detailed results in section 4 and
- draw conclusions from the case study exercise and summarise key insights in section 5, both by different NET pathways and by different reporting and accounting frameworks.

2 Covered reporting and accounting frameworks

In terms of reporting and accounting frameworks, the paper analyses how NETs are covered in **greenhouse gas** (GHG) **inventories** that are reported by Parties to the UNFCCC according to rules agreed under the Paris Agreement (UNFCCC 2018, 2021) using methodological guidance by the IPCC (IPCC 2006, 2014, 2019).

- The present analysis of GHG inventory coverage of NETs builds on the previous analysis detailed in Jörß et al. (2022) that highlighted elements in the available IPCC guidance allowing for diverging interpretation, in particular related to
  - the reporting on carbon temporarily stored in CCU products ('downstream approach' vs 'upstream approach' see section 3 of this working paper); and
  - a potential classification of CCU products as 'biomass' if the captured carbon stems from biomass (see also section 5.2.1).
- It is well noted that the IPPC decided at its 60th session in January 2024 that the IPCC Task Force on National Greenhouse Gas Inventories (TFI) will hold an Expert Meeting[1] on Carbon Dioxide Removal Technologies, Carbon Capture Utilization and Storage and provide a Methodology Report[2] on these by the end of 2027.
- After a potential adoption of the upcoming IPCC methodology report on CCUS and CDR by the Parties of the Paris Agreement, the updated guidance is likely not to take effect before 2033[3].

Furthermore, the paper analyses how NETs are reflected in the MRV system under **the EU emissions trading system (ETS)[4]** and how they affect accounting towards national targets for EU Member States under the **EU Effort Sharing Regulation (ESR)[5]** and under the **EU LULUCF Regulation[6]**

- For the **EU ETS**, detailed MRV arrangements are set out in Monitoring and Reporting Regulation (MRR)[7] and (for the monitoring of emissions from maritime vessels, covered in the EU ETS since 2024) in Regulation (EU) 2015/757[8]. A description of the approach taken in the MRR with respect to NETs is given in Jörß et al. (2022).

[1] This Expert Meeting took place 1-3 July 2024 in Vienna, Austria.

[2] A scoping meeting for this Methodology report took place 14-16 October 2024 in Copenhagen, Denmark. (IPCC TFI 2024)

[3] 2033 is the first year where GHG inventories covering 2031 will be due. Earlier GHG inventories covering 2030 as their latest year, and used to conclude on the achievement of 2030 NDCs, are not likely to be included in an adoption of updated IPCC guidance.

[4] Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC; https://eur-lex.europa.eu/eli/dir/2003/87/oj; consolidated text as of 1 March 2024: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02003L0087-20240301

[5] Regulation (EU) 2018/842 of the European Parliament and of the Council of 30 May 2018 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement and amending Regulation (EU) No 525/2013; https://eur-lex.europa.eu/eli/reg/2018/842/oj; consolidated text as of 16 May 2023: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02018R0842-20230516

[6] Regulation (EU) 2018/841 of the European Parliament and of the Council of 30 May 2018 on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework, and amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU; https://eur-lex.europa.eu/eli/reg/2018/841/oj, consolidated text as of 11 may 2023: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02018R0841-20230511 ;

[7] Commission Implementing Regulation (EU) 2018/2066 of 19 December 2018 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council and amending Commission Regulation (EU) No 601/2012, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018R2066; consolidated text as of 1 July 2024: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02018R2066-20240701

[8] Regulation (EU) 2015/757 of the European Parliament and of the Council of 29 April 2015 on the monitoring, reporting and verification of carbon dioxide emissions from maritime transport, and amending Directive 2009/16/EC; https://eur-lex.europa.eu/eli/reg/2015/757/oj; consolidated text as of 1 January 2024: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02015R0757-20240101

- The MRR has lately been amended in October 2023[9] to incorporate consequences of 2023 EU decisions on the 'Fit for 55'[10] package. A 2nd related amendment of the MRR was adopted by the European Commission on 25 September 2024[11]. For the MRV of emissions from maritime vessels, a Delegated Regulation to amend Regulation 2015/757 was adopted by the European Commission on 16 October 2024[12].
- For the purpose of the analysis of MRV rules in this paper, it was anticipated that the latest amendments (autumn 2024) of the MRR and of Regulation 2015/757 will codify the zero-rating of emissions from the combustion of CCU-based synthetic fuels where the energy content is based on renewable or on nuclear energy, i.e. RFNBOs[13] and 'synthetic low-carbon fuels'[14].
- Another recent amendment to the ETS MRV framework was enshrined Commission Delegated Regulation 2024/2620[15], adopted 30.7.2024, establishing conditions for GHGs to be considered permanently chemically bound in a product, and thus exempted from the surrender of ETS allowances.
- The MRV details related to the coverage of NETs in the **ESR** were lately changed in May 2024 by means of Commission Implementing Regulation (EU) 2024/1281[16] that amended Annex XV of Implementing Regulation (EU) 2020/1208[17], defining the calculation of ESR emissions to be reported annually by EU Member States under the EU Governance Regulation[18]: Negative emissions reported in the energy and industry categories of the inventory for the capture of

[9] Commission Implementing Regulation (EU) 2023/2122 of 17 October 2023 amending Implementing Regulation (EU) 2018/2066 as regards updating the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council; https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32023R2122

[10] See https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55/

[11] Commission Implementing Regulation (EU) 2024/2493 of 23.9.2024 amending Implementing Regulation (EU) 2018/2066 as regards updating the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council; https://eur-lex.europa.eu/eli/reg_impl/2024/2493/oj

[12] COMMISSION DELEGATED REGULATION (EU) …/... amending Regulation (EU) 2015/757 of the European Parliament and of the Council as regards the rules for the monitoring of greenhouse gas emissions from offshore ships and the zero-rating of sustainable fuels; C/2024/7210 final; https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=PI_COM:C(2024)7210

[13] Renewable transport fuels of non-biological origin, as defined in the Renewable Energies Directive

[14] Synthetic fuels defined in the September 2024 amendment of the MRR, acknowledging i.a. nuclear energy as the source of energy content under specific conditions.

[15] Commission Delegated Regulation (EU) 2024/2620 of 30 July 2024 supplementing Directive 2003/87/EC of the European Parliament and of the Council as regards the requirements for considering that greenhouse gases have become permanently chemically bound in a product, https://eur-lex.europa.eu/eli/reg_del/2024/2620/oj

[16] Commission Implementing Regulation (EU) 2024/1281 of 7 May 2024 amending Implementing Regulation (EU) 2020/1208 on structure, format, submission processes and review of information reported by Member States pursuant to Regulation (EU) 2018/1999 of the European Parliament and of the Council; https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32024R1281

[17] Commission Implementing Regulation (EU) 2020/1208 of 7 August 2020 on structure, format, submission processes and review of information reported by Member States pursuant to Regulation (EU) 2018/1999 of the European Parliament and of the Council and repealing Commission Implementing Regulation (EU) No 749/2014; https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32020R1208

[18] Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action, amending Regulations (EC) No 663/2009 and (EC) No 715/2009 of the European Parliament and of the Council, Directives 94/22/EC, 98/70/EC, 2009/31/EC, 2009/73/EC, 2010/31/EU, 2012/27/EU and 2013/30/EU of the European Parliament and of the Council, Council Directives 2009/119/EC and (EU) 2015/652 and repealing Regulation (EU) No 525/2013 of the European Parliament and of the Council; https://eur-lex.europa.eu/eli/reg/2018/1999/oj

biogenic carbon in the context of BECCS activities have been excluded from accounting towards ESR targets in the EU 2030 climate policy framework[19].

- With respect to the **LULUCF Regulation,** the analysis in the present paper focuses on the rules applicable for 2026-2030 emission, i.e. considering the revision of 2023[20] that abandoned complex accounting rules and led to a direct use of the LULUCF category of the GHG inventory for accounting towards Member States' LULUCF targets under that Regulation.

In addition, the paper analyses accounting towards the overarching EU-wide targets as set out in the **European Climate Law**[21] and in the **EU's NDC** (Nationally Determined Contribution) **for 2030**[22] under the Paris Agreement.

Finally, the paper analyses how NETs will be covered and quantified under the upcoming EU Carbon Removals and Carbon Farming Certification (**CRCF**) Regulation[23]. The CRCF Regulation aims at creating EU-wide voluntary framework for certifying carbon removals, carbon farming emission reductions and carbon storage in products across Europe.

3 The open question of reporting CCU in GHG inventories: downstream vs upstream approach

While the GHG inventory reporting approach for carbon capture dedicated to end up in geological storage (CCS, BECCS) is rather straightforward (Jörß et al. 2022), this is not the case for novel carbon flows in the context of CCU, involving short-term storage of carbon in products:

In a CCU pathway we observe (for FoCCU and BECCU) a generation of CO_2 where the CO_2 is not immediately released into the atmosphere but rather stored in a product for a short term (e.g. in the case of e-fuels probably week or months), for a medium term (e.g. in CCU-based chemicals / plastics probably for months, years or decades) or possibly for long term (e.g. CCU-fed carbonated concrete for centuries or longer). For short- and medium-term storage, the carbon stored in the product is bound to be released into the atmosphere at the end of the product lifetime, usually upon combustion as an energy carrier or in a waste incineration facility. Possibly, the combustion facilities might be equipped with carbon capture, as well, resulting in partially circular carbon flows in products. For DACCU pathways, no initial CO_2 generation is involved in the process chain.

[19] This exclusion was motivated by the claim that the ESR covers only emissions, not removals. In the view of the authors, however, the negative inventory emissions excluded from ESR reflect a CO_2 recovery rather than a CO_2 removal, and in GHG inventory logics represent a correction for an emission overestimation that occurs in the LULUCF category of the inventory in case of BECCS.

[20] Regulation (EU) 2023/839 of the European Parliament and of the Council of 19 April 2023 amending Regulation (EU) 2018/841 as regards the scope, simplifying the reporting and compliance rules, and setting out the targets of the Member States for 2030, and Regulation (EU) 2018/1999 as regards improvement in monitoring, reporting, tracking of progress and review; https://eur-lex.europa.eu/eli/reg/2023/839/oj

[21] Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law'); https://eur-lex.europa.eu/eli/reg/2021/1119/oj;

[22] https://unfccc.int/sites/default/files/NDC/2023-10/ES-2023-10-17%20EU%20submission%20NDC%20update.pdf

[23] On 10 April 2024, the European Parliament adopted the provisional agreement on the CRCF Regulation (https://www.europarl.europa.eu/meetdocs/2014_2019/plmrep/COMMITTEES/ENVI/DV/2024/03-11/Item9-Provisionalagreement-CFCR_2022-0394COD_EN.pdf). The agreement was adopted by the Council in November 2024 (https://data.consilium.europa.eu/doc/document/PE-92-2024-INIT/en/pdf). A publication in the Official Journal is not yet available by the time of drafting of this paper (November 2024).

According to the present IPCC guidance, when CO_2 capture technology is installed and used at a plant, it is good practice to deduct the CO_2 captured in a higher tier emissions calculation, but only CO_2 captured for long-term storage, also in products, can be reported as avoided or reduced emissions in the GHG inventory. The exception to this rule is that quantities of CO_2 captured for later use and short-term storage can be deducted as captured CO_2 emissions when subsequent emissions are accounted for elsewhere in the inventory.

The challenge for the GHG inventories is to avoid gaps or double counting in the reporting of emissions. It should be noted that final emissions into the atmosphere may occur in a different country than the carbon capture and in a different year, while both territory and year are key framework conditions for national GHG inventories.

Two fundamentally different CCU reporting approaches are available to address this issue which we call the 'downstream approach' and the 'upstream approach':

Under the **downstream approach**,

- CO_2 emissions would be reported 'downstream' for the year when and under the inventory category where the CO_2 is actually released into the atmosphere, e.g. domestic or international transport in the case of e-fuels. All CO_2 emissions from the combustion / end-of life of the CCU product (as well as fugitive emissions during transport and product manufacture) would be reported and included in the total national CO_2 emissions, ignoring the origin of the carbon in the CO_2 captured, which may be fossil, biogenic or atmospheric.
- The amount of captured CO_2 would be taken into account as reduced emissions (fossil CCU) or negative emissions (biomass CCU or DACCU) and would be considered in the inventory for the year and the inventory category where carbon capture takes place, e.g. power plants or industrial processes (for fossil or biogenic CO_2) or DAC for atmospheric CO_2.
  - In the case of fossil CCU the negative contribution assigned to captured CO_2 would balance the amount of fossil CO_2 that is calculated based on the carbon content of fuel or feedstock consumed in the combustion activity or industrial process where capture takes place. This would result in no CO_2 reported in the inventory category covering the activity equipped with carbon capture. Capture of fossil carbon for CCU would be treated just like carbon capture of fossil CO_2 for long term geological storage: The amount of captured CO_2 would not be visible as emission in capture activity.
  - For biomass combustion or biomass oxidation in industrial processes or the waste sector, respective CO_2 emissions are not included in total national CO_2 emissions in order to avoid double-counting with the LULUCF category reporting in the GHG inventory where losses in biogenic carbon are reported as CO_2 emissions and gains in biogenic carbon pools as CO_2 removals[24]. In the case of BECCU, a negative contribution would be assigned to captured CO_2 from biomass just like discussed above for fossil CCU. Given such treatment of CO_2 from biomass outside LULUCF, this negative contribution assigned to captured CO_2 mathematically results in a negative emission reported in the total national CO_2 for the non-LULUCF inventory category where capture takes place.
  - In the case of DACCU, a removal / negative emission would be reported for the process of direct air capture.

[24] The summarised logic of LULUCF reporting holds for primarily for woody biomass. The uptake of CO_2 into agricultural non-woody biomass subject to harvest, however, is not reported as a gain in carbon pool and therefore not reported as a removal. For consistency, the oxidation of such non-woody biomass as fuel, industrial feedstock or during waste treatment is not included in national totals, neither.

- The negative contributions assigned to carbon capture would in principle balance the emissions reported 'downstream' for CCU product use. However, the 'downstream' emissions may occur in different years than capture, and – considering international trade – in different national inventories.

Under the **upstream approach**, however

- CO_2 emissions would be reported 'upstream' for the year and under the inventory category where CO_2 was first generated (e.g. combustion of fossil fuels or biomass), and the impact of CO_2 capture for CCU would be ignored for the inventory category where the capture takes place. In the case of biomass combustion/oxidation, the exclusion of CO_2 from biomass from national totals as explained above would still apply; however, no negative emissions would be reported. Also for DACCU capture, no negative emissions would be recorded.
- The actual release of the previously captured CO_2 into the atmosphere from the combustion / end-of life of the CCU product would not be reported for the year and inventory category (and country) of actual release.

While both approaches do in principle result in sound balances, significant differences for national totals of GHG inventories would materialise in case of net imports or net exports of CCU products.

While the **downstream approach** for CCU appears more transparent, and closer to overarching inventory principle of reporting emissions when and where they occur[25], the **upstream approach** for CCU is closer to the present IPCC guidance on CCS[26] and more consistent with established EU climate policy instruments like the ETS and the RED[27] and the MRV systems established under both Directives.

As discussed in Jörß et al. (2022), international or at least EU-wide agreements on CCU reporting approaches to be used in GHG inventories should be helpful to avoid transnational gaps or double-counting. Further IPCC guidance on this issue may possibly be expected in the above-mentioned methodology report on CCUS and CDR that is scheduled for 2027.

4 Overview on NET case studies

Case studies for the visualisation of reporting and accounting rules were selected to cover a broad range of process chains / pathways that could possibly be relevant for the Finnish context[28]. Some case studies were carried out to illustrate differences between various value chains. The selection of case studies covers a range of settings with respect to

- carbon management classification (BECCS / BECCU; FoCCS / FoCCU; DACCU, Biochar),
- classification as 'neutral' or 'negative' emission pathways,

[25] The downstream approach would also be consistent with the IPCC guidance to the effect that CO_2 capture can reported/subtracted for short-term storage when the subsequent emissions are accounted for elsewhere in the GHG inventory.

[26] i.e. the impact of capture is reported only when the CO_2 is stored for long-term.

[27] 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/eli/dir/2018/2001/oj; consolidated text as of 16 July 2024: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02018L2001-20240716

[28] Note that case study #2 (featuring a new BECCS biomass district heating CHP plant using roundwood as feedstock) is not representative for the Finnish situation. It was rather chosen to exemplify the risk of a hypothetical setting where feedstock demand for BECCS processes would result in additional wood harvest.

- atmospheric, biogenic or fossil carbon feedstock types,
- relevance of product substitution effects[29] for the assessment of the process chain,
- relevance of biomass feedstock scarcity assumptions,
- assumed limitations to the availability of clean energy and
- the employed approach for the coverage of CCU pathways in GHG inventories (downstream approach vs upstream approach – see section 3 above).

An overview on the selected case studies is given in Table 1 below.

In Table 2 in the Annex (page 27) we explain how to read a case study results table. The detailed results of the case studies are subsequently presented in the Annex in Table 3 to Table 15 (pages (28 to 43).

[29] Note that substitution effects of CCU / BECCU / DACCU products were assessed in comparison to fossil alternatives.

Table 1 Overview on employed case studies

#	Title	Carbon management classification	NET / CDR classification	Carbon Feedstock type	Carbon storage duration	product substitution effects	Scarcity of biomass feedstock	Availability of clean energy	CCU inventory approach
1	**BECCS forest industry (black liquor)**	BECCS	negative	biogenic	Long-term	Not relevant	Not relevant	available	Not applicable
2	**new, additional BECCS biomass district heating CHP plant (roundwood)**	BECCS	negative ?[1]	biogenic	Long-term	Not relevant	relevant	limited	Not applicable
3	**CCS cement plant**	Fossil CCS	neutral	fossil	Long-term	Not relevant	Not relevant	available	Not applicable
4a, 4b	**Enforced concrete carbonation**	Fossil CCU & BECCU	2 options: neutral / or negative	2 options: Fossil / or biogenic	Long-term	Not relevant	Not relevant	available	Not applicable
5	**Biochar long-term**	Biochar	negative	biogenic	Long-term	2 options: not relevant / relevant	Not relevant	available	Not applicable
6	**Biochar short-term**	Biochar	neutral	biogenic	Short-term	relevant	Not relevant	available	Not applicable
7a, 7b	**MWI e-fuel production**	Fossil CCU & BECCU	Mixed: delayed emission / neutral	Mixed: fossil & biogenic	Short-term	relevant	Not relevant	available	2 options: downstream / vs. upstream
8a, 8b	**DAC e-fuel production**	DACCU	neutral	atmospheric	Short-term	relevant	Not relevant	available	2 options: downstream / vs. upstream
9a, 9b	**e-fuel import**	Fossil CCU, BECCU and/or DACCU	Possibly: delayed emission / neutral	Any: fossil, biogenic or atmospheric	Short-term	relevant	Not relevant	available	2 options: downstream / vs. upstream

[1] Under the assumed settings, case study #2 would not qualify for the environmental integrity of a net-negative removal measure.
CHP: Combined heat & Power; MWI: municipal waste incineration; CDR: carbon dioxide removal

5 Conclusions from the case study exercise

5.1 Learnings for specific NETs

5.1.1 NETs as process value chains

- NET-based removal or mitigation measures involve process value chains: A key 'negative' process step involves carbon capture (or storage), while other associated process steps usually involve emissions. The additional energy demand for capture and production of CCU products can be substantial, which can increase emissions depending on the source of energy.
- To ensure overall environmental integrity of NET-based removal or mitigation measures, gross negative emissions associated to the 'key negative' process step must exceed gross emissions of associated process steps. Where products are generated, avoided emissions due to substitution effects can be considered.
- Among the analysed reporting and accounting frameworks, an integrated assessment of the complete process value chain will take place only under the CRCF, as it attempts to safeguard the environmental integrity of certified activities. The CRCF covers some of the NETs (e.g. BECCS, DACCS, biochar). However, to date there is no integrated assessment framework available for the complete process value chains for fossil CCS or CCU. The GHG inventory and inventory-based targets build on separate reporting of process steps in different inventory categories and are thus not suited to assess environmental integrity of reported activities. LCA[30]-type assessments cannot be visualised in GHG inventories. However, the ETS applies some value-chain assessment as condition for zero-rating of CO_2 emitted from biomass or 'sustainable' fuels.

5.1.2 BECCS

- The assessment of BECCS process chains differs strongly between
  - BECCS processes based on biomass side and waste streams and
  - BECCS process chains where biomass demand would lead to additional wood harvest.

  In the Finnish context, such **biomass side and waste streams** include e.g. black liquor in forest industry and forest industry by-products in heating & power plants. Side streams and by-products of the forest industry account for approx. 75% of wood fuels used as an energy source in Finnish energy consumption (Vaahtera et al. 2023). Related BECCS projects based on the use of side and waste streams
  - would not induce additional LULUCF emissions for biomass feedstock,
  - could thus optimally be considered net negative and
  - can be upscaled with constant or declining logging levels.

  If BECCS biomass demand would lead to **additional wood harvest**, e.g. in the case of use of round wood or forest chips use in new and additional power or heating plants, BECCS gross negative emissions reported for carbon capture would be counterbalanced by additional emissions reported in LULUCF

[30] LCA: Life cycle analysis

- Negative emissions reported in the GHG inventory for carbon capture in BECCS process chains have been excluded[31] from ESR accounting by means of the 2024 amendment[32] of Annex XV of Implementing Regulation 2020/1208. This situation leads to an inconsistency between the EU net GHG target (ECL/NDC) on one hand and the sum of key target pillars ETS1, ESR & LULUCF-Regulation on the other hand: Negative inventory emissions reported for BECCS CO_2 capture will contribute to the EU NDC, while they would not be accounted as net GHG emission reductions under ETS1, ESR or LULUCF-Regulation.
  - Any sustainable BECCs (based on biomass side and waste streams) realised in the EU by 2030 – despite the lack of incentive under ETS, ESR or LULUCF – would thus function as a kind of 'BECCS safety margin' for achieving the EU NDC 2030 and the 2030 target under the ECL.
- 'Sustainable' BECCS (based on biomass side and waste streams) would contribute to net GHG reduction targets both for the EU (ECL & NDC) and for Finland under the Finnish National Climate Act[33]. However, such BECCS projects would not contribute towards Finnish Member State targets under the ESR or the LULUCF Regulation by 2030.
  - Under current EU law no incentive remains for FI to engage in BECCS. However, under the Finnish National Climate Act such an incentive remains.

5.1.3 Location of geological storage for CCS

On Finnish territory, geological formations suitable for CO_2 storage are not available. Finnish carbon capture projects would thus depend on storage sites abroad.

For fossil CCS,

- geological storage in countries that do not participate in the EU-ETS is not eligible for subtraction from ETS1 emissions; thus, storage in the UK (which is very active in developing CCS storage sites in the North Sea basin) is an unlikely option for Finnish ETS enterprises interested in CCS, unless ETS rules are adapted.
- Norway is eligible as an EU-ETS participant, as well as EU Member States like Denmark.
- Rules for fossil CCS in the EU ETS apply as well to BECCS in ETS installations where the biomass does not comply with ETS / RED sustainability and/or emissions savings rules and where the CO_2 from that biomass is consequently not zero-rated under ETS MRV rules set out in the MRR.

For BECCS,

- the location of carbon storage inside / outside EU-ETS (including Norway) does not affect the accounting, as BECCS is not acknowledged under ETS, anyway (Exception: BECCS from 'non-sustainable' / not zero-rated biomass). However, the coverage of BECCS under the ETS may possibly change in the review of the ETS Directive scheduled for 2026.
- For reporting the negative contribution of carbon capture for geological storage in GHG inventories (as recovery of CO_2 from exhaust gases), it does not matter whether the storage site is situated in the same country like the capture site. However, emissions occurring during injection and from

[31] See also footnote 19 on page 10 above.
[32] Commission Implementing Regulation (EU) 2024/1281 of 7 May 2024 amending Implementing Regulation (EU) 2020/1208 on structure, format, submission processes and review of information reported by Member States pursuant to Regulation (EU) 2018/1999 of the European Parliament and of the Council; https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32024R1281
[33] Finnish Climate Act 423/2022: https://www.finlex.fi/en/laki/kaannokset/2015/en20150609_20220423.pdf

storage sites would be reported by the country hosting the storage site. Furthermore, any fugitive emissions of CO_2 occurring during CO_2 transport outside national jurisdictions would not be included in the national GHG totals of any of the involved countries.

5.1.4 Enforced concrete carbonation (CCU)

Enforced concrete carbonation[34] based on recovered fossil or biogenic CO_2 represents a FoCCU or BECCU pathway involving long-term storage of CO_2.

- With Commission Delegated Regulation 2024/5294, adopted 30.7.2024, enforced concrete carbonation (using fossil CO_2) is admitted in the EU ETS as eligible for subtraction from generated fossil CO_2 as the carbon is considered 'permanently chemically bound'.
- However, IPCC methodological guidance on enforced concrete carbonation is not available for quantification in GHG inventories.
  - In the absence of IPCC guidance, countries may develop and use national estimation methodologies which would be subject to scrutiny by an UNFCCC technical inventory review.
  - Methodological challenge for a quantification: Enforced concrete carbonation of concrete products reduces the potential for later passive carbonation of concrete product under atmospheric conditions.
  - If EU Member States develop and apply such GHG inventory reporting, this would be the basis for accounting negative emission contributions of enforced concrete carbonation towards national and EU-wide net GHG targets.
  - We note that Japan reports on such carbonation in its 2024 National Inventory Document (NID) (Japan 2024, p.4-115) submitted under the Paris agreement to the UNFCCC. However, a technical review report is not yet available.
- CO_2 capture for enforced cement carbonation would be reported in inventory tables like CO_2 capture for geological storage:
  - as negative emission contributions assigned to the activity generating the CO_2.
  - In case of capture of biogenic CO_2 for enforced concrete carbonation, the same accounting rules for the ESR and for the ECL would apply in the 2030 climate legislation as discussed for BECCS: Exclusion from Member states' ESR targets, but consideration for overall EU wide ECL and NDC targets.

5.1.5 Direct air capture (DAC / DACCS)

- For DAC and DACCS, IPCC methodological guidance is not available for quantification in GHG inventories.
- In the absence of IPCC guidance, countries may develop and use national estimation methodologies which would be subject to scrutiny by an UNFCCC technical inventory review.

[34] ‚Enforced' concrete carbonation refers to the treatment of concrete with concentrated CO_2 under industrially contained conditions, as part of the production phase of pre-fabricated concrete structures. Such engineered processes should not be confused with the 'passive' carbonation of cement-based structures during their service life under atmospheric conditions.

- If EU Member States develop and apply such GHG inventory reporting, this would be the basis for accounting negative emission contributions of DAC / DACCS towards national and EU-wide net GHG targets.
  - Same situation like for enforced concrete carbonation
- The allocation of DAC/DACCS to an inventory category in the CRT (common reporting tables) systematics of the inventories strongly matters for accounting towards targets:
  - In the absence of IPCC guidance, the most likely candidates to be chosen by UNFCCC parties with their national methodologies would be:
    - CRT 6: 'other emissions and removals' or
    - CRT 2.H: 'other' subcategory of the industrial processes sector (CRT 2)
  - CRT 6 is clearly out of scope of the ***ESR*** and the ***EU NDC 2030*** as those are explicitly defined with reference to CRT categories 1-5 (for ESR: excluding CRT 4 (LULUCF) and ETS1 emissions)
  - CRT 2.H is included in the scope of the ESR and the EU NDC 2030
    - However, in case DACCS would be reported by Member States in CRT 2.H, the authors would expect another amendment of ESR accounting rules in Annex XV of Implementing Regulation 2020/1208 to exclude DACCS from the ESR, following the spirit of the BECCS exclusion from the ESR by means of Implementing Regulation 2024/1281
- Negative emissions reported for DACCS (or DACCU in the case of application of the CCU downstream approach (see section 3 above)) would be eligible for accounting towards ECL net GHG reduction targets
  - ECL scope is defined as 'emissions and removals regulated by Union law'
    - In the authors' view this would include DACCS removals, incentivised e.g. by the CRCF.

5.1.6 E-fuels

The additional energy used for CO_2 capture and subsequent e-fuel production will cause emissions, the amount depends on the energy source used. On the other hand, emissions may decrease when e-fuels substitute fossil fuels in transport. An overall assessment of e-fuels as a GHG mitigation measure and a 'neutral emission technology' depends on the overall balance of all these effects.

However, carbon capture for e-fuel production (and related energy use) and the combustion of e-fuels (and related substitution effects) may take place in different countries, thus differently affecting national reporting and accounting:

For consistent reporting across parties on e-fuels manufacture and use, IPCC guidance needed in relation to downstream vs upstream CCU inventory reporting options (see section 3). This may be expected in the announced 2027 IPCC methodology report on CCUS and CDR. Once that upcoming IPCC report is available, a decision related to the use of the latest IPCC methodologies would need to be taken under the UNFCCC / Paris Agreement for the post-2030 period. In the absence of such international agreement, however, an agreement on EU level should be sought beforehand.

Downstream vs. upstream CCU reporting options as explained in section 3 impact inventory net CO_2 totals both on national and EU levels with respect to CO_2 captured for e-fuel production and CO_2 released upon e-fuel combustion[35]

- for cases of e-fuel net imports or net exports and
- where e-fuels are supplied to international transport (aviation or maritime):
  - When domestic e-fuel production is consumed in domestic transport, related CO_2 capture and CO_2 release balance each other under both options (downstream / upstream) and are in total **neutral**[36] with respect to inventory national GHG totals.
  - When domestic e-fuel production is supplied to export or international transport (net export) the negative contribution assigned to CO_2 capture **reduces** inventory national GHG totals under the downstream option[37]; under the upstream option CO_2 capture would be **neutral** towards national GHG totals.[36]
  - Net e-fuel imports for domestic transport are treated like biomass fuels under the upstream option (**neutral** towards inventory national GHG totals). Under the downstream option, however, they would be treated like fossil fuels and CO_2 emissions from combustion are **reported**[38].
  - Net e-fuel imports for international transport are **neutral** towards inventory national GHG totals under both options (downstream / upstream) as emissions from international transport are not included in national GHG inventory totals, at all. However, reporting of CO_2 emissions for international navigation and aviation as a memo item will otherwise follow the same rules as reporting of CO_2 emissions from domestic transport.

MRV under the EU ETS is consistent to the upstream approach. However, the zero-rating of CO_2 released upon e-fuel combustion applies only if the e-fuels comply with RFNBO standards of the RED or nuclear low-carbon standards yet to be agreed in detail under EU legislation[39].

5.1.7 Biochar

For biochar, the type of (domestic) application / use of biochar is decisive for accounting of negative emission contributions, not the production of biochar:

- Biochar application in mineral soils
- Non-soil long-term biochar storage (e.g. in construction materials)
- Short-term storage applications of biochar (e.g. replacement of coal in industrial processes) would be reported and accounted like direct biomass use and do not entail negative emissions.

For **biochar application in soils,** IPCC guidance for quantification is available in the 2019 refinement of the 2006 IPPC guidelines (IPCC 2019); respective negative emission contributions

[35] Including fugitive CO_2 releases during e-fuel production processes.
[36] Additional energy demand for carbon capture and e-fuel production may result in additional emissions recoded in national totals, independently from the choice between downstream / upstream CCU reporting.
[37] In this case, an amendment of ESR accounting rules should be expected to prevent eligibility of such negative emissions for ESR compliance, as discussed in in section 5.1.5 for DACCS.
[38] This holds equally for the different potential origins of the carbon prior to capture (fossil, biomass or atmospheric).
[39] See delegated act (under preparation): https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/14303-Methodology-to-determine-the-greenhouse-gas-GHG-emission-savings-of-low-carbon-fuels_en

would be reported as removals in the LULUCF category of the GHG inventory, subject to availability of sufficiently granular data[40].

For non-soil long-term biochar storage (e.g. in construction materials), no IPCC guidance is available for quantification in GHG inventories.

- In the absence of IPCC guidance, countries may develop and use national estimation methodologies which would be subject to scrutiny by an UNFCCC technical inventory review.
- If EU Member States develop and apply such GHG inventory reporting, this would be the basis for accounting negative emission contributions of non-soil long-term storage towards national and EU-wide net GHG targets.
  - Same situation like for DAC / DACCS and enforced concrete carbonation.
  - We note that Japan reports on such non-soil long-term storage in construction materials in its 2024 NID (Japan 2024, p. 4-118) in category 4.H ('other' LULUCF). However, a technical review report is not yet available.

5.2 Summary by separate reporting / accounting frameworks

5.2.1 GHG inventories

As discussed in section 5.1.6 on e-fuels, IPCC guidance needed in relation to **downstream vs upstream CCU inventory reporting options** (see section 3).

- The choice of downstream vs. upstream options impact the net GHG balances for cases of e-fuel net imports or net exports and where e-fuels are supplied to international aviation or maritime transport.
- While the downstream approach appears more transparent, and closer to overarching inventory principle of reporting emissions when and where they occur, the upstream approach is more consistent to established EU climate policy instruments like the ETS and the RED[41] and the MRV systems established under both Directives.
- Updated IPCC guidance may be expected in the announced 2027 IPCC methodology report on CCUS and CDR. Once that upcoming IPCC report is available, a decision related to the use of the latest IPCC methodologies would need to be taken under the UNFCCC / Paris Agreement for the post-2030 period.
  - The 2027 IPCC methodology report might also be expected to provide guidance related to the question whether CCU products should be considered 'biomass' if the contained carbon stems from capture of biogenic CO_2: According to the present guidelines, CO_2 from 'biomass'

[40] Note that the 2019 refinement of the 2006 IPPC guidelines IPCC 2019 propose Tier 2 and 3 methods the estimation of soil carbon stock change from biochar amendments to mineral soils, requiring granular data. A draft for a simpler Tier 1 method, using default parameters, is not suggested for use but rather contained in an Annex as the basis for future methodological development. It may be expected that estimation methodologies for biochar will be revisited by the authors of the upcoming 2027 IPCC methodology report on CDR and CCUS IPCC TFI 2024.

[41] 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/eli/dir/2018/2001/oj; consolidated text as of 16 July 2024: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02018L2001-20240716

combustion or oxidation in industrial processes is not considered for national GHG totals (see section 3). In that context, the 2027 IPCC methodology might possibly also explain the difference between 'CO_2 from biomass' and 'biogenic CO_2'.

IPCC quantification methodology guidance is missing for inventory reporting of

- DAC/DACCS
- long-term storage of biochar (except application in soils): e.g. cement additive
- long-term storage of captured CO_2 by means of enforced carbonation of concrete or other construction materials

In addition to IPCC guidanc**e, data source time series need to be identified** or established by EU Member States' inventory agencies to support any future inventory reporting.

- Data collected in future under CRCF can possibly help (see section 5.2.6).

An **UNFCCC agreement (for post 2030**!) will be needed under the Enhanced Transparency Framework of the Paris Agreement (UNFCCC 2018, 2021) to

- approve updated IPCC guidance and
- specify appropriate CRT categories for
  - DAC/DACCS
  - long-term storage of biochar (except application in soils): e.g. cement additive
  - CO_2 captured from biogas, landfill gas, sewage gas in agriculture or waste sectors for CCS and CCU

5.2.2 EU ETS

Subordinate ETS legislation on MRV details has been adopted in autumn 2024 related to

- eligibility rules for carbon permanently stored in products and
- zero-rating rules for e-fuels based on renewable energies (RFNBOs) or on nuclear energy ('low-carbon' fuels).

For the definition of permanently stored carbon, the European Commission has adopted on 30 July 2024 the Delegated Regulation 2024/2620 establishing conditions for GHGs to be considered permanently chemically bound in a product, and thus exempted from the surrender of ETS certificates.

With respect to zero-rating rules for e-fuels based on renewable energies (RFNBOs) or on nuclear energy (as 'synthetic low-carbon' fuels), amendments have been adopted in autumn 2024 to the MRR[42] and, separately for e-fuel use in maritime transport under the ETS, to Regulation 2015/757[43]:

[42] Commission Implementing Regulation (EU) 2018/2066
[43] Regulation (EU) 2015/757 of the European Parliament and of the Council of 29 April 2015 on the monitoring, reporting and verification of carbon dioxide emissions from maritime transport

- A draft Implementing Regulation amending the MRR was adopted on 25 September 2024[44].
- A Delegated Regulation to amend Regulation 2015/757 was adopted on 16 October 2024[45].

The ETS Directive is scheduled for review with respect to the integration of negative emissions / removals, a respective report by the Commission is due by 31 July 2026[46]. Relevant discussion items in the context of NET accounting could possibly include:

- coverage of capture of biogenic CO_2 for BECCS or permanent BECCU in ETS installations
- admission of certain types of CRCF removal certificates
- eligibility of UK geological carbon storage

5.2.3 Effort Sharing Regulation (ESR)

Negative emissions reported in GHG inventories for BECCS CO_2 capture have been excluded from ESR scope by means of the 2024 amendment[47] of Annex XV of Implementing Regulation 2020/1208. That exclusion applies also to enforced concrete carbonation based on biogenic CO_2, as this would be reported in the inventory tables in the same way as BECCS.

Following the 2024 amendment of Annex XV of Implementing Regulation 2020/1208, the ESR appears to be politically fixed to exclude removals and negative biomass emissions until 2030. As the ESR is presently defined until 2030, coverage of removals / negative emission in a 'post-2030 ESR' is open for debate.

In the 'spirit' of the 2024 Annex XV amendment to exclude 'removals' from ESR, an ESR exclusion should thus also be expected for in the case inventory reporting (until 2030) of negative emissions for other novel NET pathways und certain specific inventory settings:

- Capture of biogenic CO_2 for e-fuel production, in case the CCU downstream approach (see section 3) is agreed in the EU
- Direct air capture, if reported as an industrial process in the inventory category CRT 2
- Non-soil biochar product use resulting in long-term storage, if reported as an industrial process in inventory category CRT 2

[44] Commission Implementing Regulation (EU) 2024/2493 of 23.9.2024 amending Implementing Regulation (EU) 2018/2066 as regards updating the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council; https://eur-lex.europa.eu/eli/reg_impl/2024/2493/oj

[45] COMMISSION DELEGATED REGULATION (EU) …/... amending Regulation (EU) 2015/757 of the European Parliament and of the Council as regards the rules for the monitoring of greenhouse gas emissions from offshore ships and the zero-rating of sustainable fuels; C/2024/7210 final; https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=PI_COM:C(2024)7210

[46] See Article 30(5) of the ETS Directive 2003/87/EC as amended by Directive (EU) 2023/959 of the European Parliament and of the Council of 10 May 2023.

[47] Commission Implementing Regulation (EU) 2024/1281

5.2.4 LULUCF Regulation

It should be noted that removals reported in the inventory LULUCF category may include removals by means of industrially engineered processes. Thus, they are not equivalent to 'nature-based solutions' or 'natural sinks':

- According to IPCC guidance (IPCC 2019) negative emissions for biochar application in mineral soils should reported in the LULUCF inventory category,
  - subject to availability of data supporting IPCC Tier 2 or Tier 3 methodologies.
  - Biochar production is clear a 'technical' or 'engineered' process.
- Such biochar use would contribute to meeting MS targets under the LULUCF Regulation.
- The same would apply for biochar long-term storage in concrete, if reported in CRT 4.H ('other LULUCF') like proposed by Japan in its 2024 GHG inventory (Japan 2024).

To safeguard the environmental integrity of BECCS projects it is crucial to **avoid 'additional' sourcing of woody biomass** feedstock. Such additional harvest of wood would imply (for the year of harvest and carbon capture) an increase of gross LULUCF emissions and a reduction of net LULUCF removals. When accounting for overall net GHG targets, the worse net LULUCF balance would offset BECCS negative emissions reported outside the LULUCF category.

5.2.5 European Climate Law & EU NDC 2030

Removals will not be included in scope of the EU NDC[48] for 2030 if they will be reported in inventory category CRT 6 'other', as the 2030 NDC scope is explicitly limited to CRT categories 1-5.

- This would affect a likely reporting option for DACCS (see section 5.1.5).
- However, in the author's opinion such removals / negative emissions reported in CRT 6 would nevertheless be included in the scope of the European Climate Law (ECL)
  - The ECL scope is defined as 'emissions and removals regulated by Union law' which (in the authors' opinion) includes all NETs that have been incentivised as mitigation measures under e.g. the CRCF or the RED.

The scope of both the ECL and the 2030 NDC include BECCS negative emissions, recently excluded from ESR scope (see section 5.2.3).

- Up to 2030 this 'inconsistency' is likely to remain of minor quantitative relevance at EU level.
- However, it can be important at Member State level for some Member States.

The architectural pillars for the EU 2030 target, i.e. ETS1, ESR and LULUCF-Regulation, ignore 'technical' removals and biomass negative emissions reported for capture of biogenic CO_2 for geological storage or enforced carbonation.

[48] Nationally Determined Contribution under the Paris Agreement

- An appropriate inclusion of the full range of removals remains a challenge for post-2030 EU target architecture, that should also clarify whether / how certificates generated under the CRCF Regulation should be considered.

The European Union's 1st Biennial Transparency Report (European Union 2024) under the Paris Agreement clarified reporting and accounting details with respect to emissions from international transport covered under the EU NDC. According to that report, those emissions are quantified by means of calculating an 'NDC share' of emission from international transport reported as memo items in the GHG inventory[49]. The approach taken for the NDC is consistent with the approach taken for the target of the ECL[50], as clarified in European Commission (2024). Thus, a potential application of the CCU downstream approach in GHG inventories (see section 5.2.1) would imply ECL and NDC coverage not only of CO_2 from e-fuel combustion imported for domestic transport but also of CO_2 from e-fuel combustion imported for international transport (see section 5.1.6) covered by the ECL and NDC, respectively.

5.2.6 CRCF-Regulation

- CRCF 'Permanent net removal benefit' units are not comparable to gross emissions / removals data in single GHG inventory categories which consist of
  - gross emissions,
  - gross CO2 recovery/capture (negative emissions) or
  - gross removals.
- CRCF removal units have no relevance at all for accounting towards present GHG targets at national and EU levels, only GHG Inventory data is decisive.
  - A reflection of 'exported' CRCF units in corresponding adjustments to NDC accounting under Paris Agreement is explicitly prohibited in the CRCF Regulation.
- For post 2030 EU targets, any interactions between inventory and CRCF is to be carefully designed to avoid gaps or double-counting.
- CRCF data might possibly support GHG inventory development for novel NETs,
  - if data requirements in upcoming specific CRCF quantification methodologies are carefully defined
  - To that end, GHG inventory experts should get involved in respective CRCF processes.

[49] As an alternative approach, the EU might have attempted to derive a share of ‚international' emissions from EU ETS monitoring data.
[50] Here, an 'ECL target' share of international emissions recorded in the inventory is calculated.

6 Publication bibliography

European Commission (2024): EU Climate Action Progress Report 2024. Report from the Commission to the European Parliament and the Council. COM(2024) 498 final, Brussels, 31.10.2024 (SWD(2024), 249 final). Available online at https://climate.ec.europa.eu/document/download/d0671350-37f2-4bc4-88e8-088d0508fb03_en, checked on 11/25/2025.

European Union (2024): The First Biennial Report from the European Commission to the United Nations Framework Convention on Climate Change under the Enhanced Transparency Framework. European Union. Biennial Transparency Report (BTR). BTR1. Publication date: 22 Nov 2024. Available online at https://unfccc.int/documents/644477, checked on 11/25/2024.

IPCC (2006): 2006 IPCC Guidelines for National Greenhouse Gas Inventories. With assistance of Simon Eggleston, Leandro Buendia, Kyoko Miwa, Todd Ngara, Kiyoto Tanabe. Japan. Available online at https://www.ipcc-nggip.iges.or.jp/public/2006gl/, checked on 10/29/2023.

IPCC (2014): 2013 Supplement to the 2006 IPCC Guidelines for national greenhouse gas inventories: wetlands. Methodological Guidance on Lands with Wet and Drained Soils, and Constructed Wetlands for Wastewater Treatment. Available online at http://www.ipcc-nggip.iges.or.jp/public/wetlands/.

IPCC (2019): 2019 Refinement to the 2006 Guidelines for National Greenhouse Gas Inventories. Available online at https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/, checked on 3/9/2022.

IPCC TFI (2024): Draft Terms of Reference - 2027 Methodology Report on Carbon Dioxide Removal Technologies, Carbon Capture, Utilization and Storage (Supplement to the 2006 IPCC Guidelines). Report of the IPCC Scoping Meeting 14-16 October 2024, Copenhagen, Denmark. IPCC Task Force on National Greenhouse Gas Inventories.

Japan (2024): National Greenhouse Gas Inventory Document of Japan 2024. Greenhouse Gas Inventory Office of Japan (GIO); Center for Global Environmental Research (CGER); Earth System Division (ESD); National Institute for Environmental Studies (NIES). Available online at https://unfccc.int/documents/637879, checked on 9/18/2024.

Jörß, W.; Emele, L.; Moosmann, L.; Graichen, J. (2022): Challenges for the accounting of emerging negative and zero/low emission technologies. Öko-Institut (Working Paper, 3/2022). Available online at https://www.oeko.de/fileadmin/oekodoc/WP-NET-accounting.pdf, checked on 6/22/2023.

Kujanpää, Lauri; Reznichenko, Alexander; Saastamoinen, Heidi; Mäkikouri, Sampo; Soimakallio, Sampo; Tynkkynen, Oras et al. (2023): Carbon dioxide use and removal : Prospects and policies. Edited by VTT Technical Research Centre of Finland Ltd, Finnish Environment Institute, Tyrsky Consulting. Available online at https://julkaisut.valtioneuvosto.fi/handle/10024/164795, checked on 6/5/2024.

UNFCCC (2018): Decision 18/CMA.1 - Modalities, procedures and guidelines for the transparency framework for action and support referred to in Article 13 of the Paris Agreement. Available online at https://unfccc.int/documents/193408, checked on 9/30/2024.

UNFCCC (2021): Decision 5/CMA.3 - Guidance for operationalizing the modalities, procedures and guidelines for the enhanced transparency framework referred to in Article 13 of the Paris Agreement. FCCC/PA/CMA/2021/10/Add.2. Available online at https://unfccc.int/documents/460951, checked on 4/1/2022.

Vaahtera, E.; Niinistö, T.; Peltola, A.; Räty, M.; Sauvula-Seppälä, T.; Torvelainen, J.; Uotila, E. (2023): Metsätilastollinen vuosikirja 2022. Finnish Statistical Yearbook of Forestry 2022. Luonnonvarakeskus (Luke). Helsinki. Available online at https://jukuri.luke.fi/handle/10024/553167, checked on 9/17/2024.

Annex: NET case study overview tables

Table 2 How to read a case study

NET case study #XX (negative/ neutral): NET title		**National GHG Inventory** 🇫🇮 ***CCU downstream/ upstream approach***		**ETS Directive** 🇪🇺 🇳🇴 🇮🇸 🇱🇮	**ESR**	**LULUCF Regulation**	**ECL / NDC** 🇪🇺	**CRCF units** 🇪🇺
Process steps	settings & high / low GHG options	Net GHG emissions	CRT	ETS 1 verified emissions	ESR target 🇫🇮	LULUCF target 🇫🇮	EU net GHG target	
Process steps 1…X key 'negative' process step identified	Explanation of relevant options	Separately for each process step: • Qualitative indication of whether/how negative (⇩), zero (⌀) or positive (⇧) emission contributions are reported / accounted under respective target. • Possibly ranges (⇧ ↔ ⌀) depending on high / low GHG options of process step or alternatives (e.g. ⌀ / ⇩ ?[1]) as explained in footnote. • Indication where process steps are out of scope of the respective target • Indication where emissions may take place in other year than the year of the key 'negative' process step						Jointly for full process chain full process chain under CRCF: • Indication of coverage in CRCF scope • Explanation of CRCF integrated quantification approach
Total mitigation / removal measure *(without substitution effects in case of product use)*	Assuming options to result in overall environmental integrity	Aggregation of direct effects process steps eligible to the target scope						
Where applicable (in case of product use): **Total substitution effects** (to be assessed jointly with direct effects of removal/mitigation measure)		Aggregation of substitution effects relevant for an integrated assessment of the removal / mitigation measure						Out of CRCF scope
(in case of product use:) Avoided emissions for relevant process steps **1…Y**	Explanation of relevant options	Separately for each relevant process step: • Qualitative indication of whether/how avoided emissions (⇩) from substitution effects are to be considered for an overall assessment of the mitigation measures or not (⌀). • Ranges (⌀ ↔ ⇩) depending on high / low GHG options for assumed baseline.						Out of CRCF scope

[1] Footnotes….

Table 3 Case study #1: BECCS in forest industry, CO_2 ship transport to Norway (or UK, DK)

NET case study #1 (negative): BECCS in forest industry, CO_2 ship transport to Norway (or UK, DK)		Negative (⇩), zero (⌀) or positive (⇧) emissions accounted for the mitigation measure for the year of carbon capture (where not indicated otherwise):						
		National GHG Inventory (CCU downstream approach[2])		ETS Directive	ESR	LULUCF Regulation	ECL / NDC	CRCF units
Process steps	settings & high / low GHG options	Net GHG emissions	CRT	ETS 1 verified emissions	ESR target	LULUCF target	EU net GHG target	
CO_2 capture at point source	from black liquor [1] combustion in pulp industry, covered by EU ETS	⇩	1.A.2	⌀	⌀ (2024 Update of IR 2020/1208, Annex XV)	⌀	⇩	Integrated assessment: **'permanent net carbon removal benefit'** n comparison to counterfactual baseline. Definition of scope boundaries, quantification methodologies and treatment of uncertainties to be agreed in subordinate CRCF legislation. CRCF quantification may integrate emissions occurring in several years.
Energy supply for CO_2 capture	Additional wood harvest vs efficiency gains	⇧ ↔ ⌀	4.A	⌀	⌀	⇧ ↔ ⌀	⇧ ↔ ⌀	
Electricity supply for CO_2 compression	Additional nuclear or non-biomass renewables	⌀	1.A	⌀	⌀	⌀	⌀	
CO_2 leakage (domestic handling & ship loading)	Occurring vs not occurring	⇧ ↔ ⌀	1.C.1	⇧ ↔ ⌀	⌀	⌀	⇧ ↔ ⌀	
Fuel GHG emissions from international CO_2 transport	Ship to NO/UK/DK fossil vs sustainable shipping fuel	⇧ ↔ ⌀	1.D.1.b (not included in national total)	⇧ ↔ ⌀	⌀	⌀	⇧ ↔ ⌀	
CO_2 leakage (international transport)	Ship to NO/UK/DK Occurring vs not occurring	Out of inventory scope		to NO / DK: ⇧ ↔ ⌀ to UK: Out of ETS scope	⌀	⌀	⌀ (out of scope)	
CO_2 leakage (injection)	in NO / UK / DK Occurring vs not occurring	NO / UK / DK: ⇧ ↔ ⌀	1.C.2.a	NO/DK: ⇧ ↔ ⌀ UK: Outside EU ETS	DK/NO: ESR / LULUCF targets: ⌀ UK: Outside EU & ESR / LULUCF Reg.		DK: ⇧ ↔ ⌀ NO / UK: Outside EU	
CO_2 leakage (from underground storage)	in NO / UK / DK possibly in future years Occurring vs not occurring	NO / UK / DK: future years ⇧ ↔ ⌀	1.C.2.b	NO/DK: ⇧ ↔ ⌀ (future years) UK: Outside EU ETS			DK: ⇧ ↔ ⌀ (future years) NO / UK: Outside EU	
Other associated GHG emissions, incl. energy and CO_2 infrastructure	Possibly abroad, possibly in past year of infrastructure generation	Possibly abroad and past years ⇧ ↔ ⌀	possibly all	Possibly in ETS 1 scope and in past years ⇧ ↔ ⌀	Possibly in FI ESR scope and in past years ⇧ ↔ ⌀	Possibly in FI LULUCF scope and in past years ⇧ ↔ ⌀	Possibly in EU scope and in past years ⇧ ↔ ⌀	
Total removal measure [1]	**Assuming options to result in overall environmental integrity**	⇩ ↔ ⇩		⇧ ↔ ⌀	⇧ ↔ ⌀	⇧ ↔ ⌀	⇩ ↔ ⇩	⇩ ↔ ⇩

[1] Roundwood harvest for pulp production, feeding into black liquor generation, is not considered in this overview as constant pulp output is assumed for an add-on BECCS GHG mitigation measure.
[6] The inventory treatment resembles the CCU downstream approach as any CO_2 leakage after capture would need to be reported as a (fossil) emission.

Table 4 Case study #2: BECCS in new biomass district heating CHP plant, CO_2 ship transport to Norway (or UK, DK)

NET case study #2 (negative?[1]): BECCS in new, additional biomass district heating CHP plant meeting RED sustainability criteria (domestic roundwood[2]), CO_2 ship transport to Norway (or UK, DK)		Negative (⇩), zero (⌀) or positive (⇧) emissions accounted for the mitigation measure for the year of carbon capture (where not indicated otherwise):						
		National GHG Inventory (CCU downstream approach[6])		ETS Directive	ESR	LULUCF Regulation	ECL / NDC	CRCF units
Process steps	settings & high / low GHG options	Net GHG emissions	CRT	ETS 1 verified emissions	ESR target	LULUCF target	EU net GHG target	
Roundwood harvest for CHP plant [3]	New, additional biomass district heating CHP plant [4] meeting RED sustainability criteria; exceeding EU ETS size threshold but excluded from EU ETS coverage as >95% biomass	⇧	4.A	⌀	⌀	⇧	⇧	Integrated assessment: **'permanent net carbon removal benefit'** in comparison to counterfactual baseline. Definition of scope boundaries, quantification methodologies and treatment of uncertainties to be agreed in subordinate CRCF legislation. CRCF quantification may integrate emissions occurring in several years.
CO_2 capture at point source		⇩	1.A.1	⌀	⌀ (2024 Update of IR 2020/1208, Annex XV)	⌀	⇩	
Energy supply for CO_2 capture	Covered by biomass harvest assumed for operation of CHP plant	⌀	4.A	⌀	⌀	⌀	⌀	
Electricity supply for CO_2 compression	Additional nuclear or non-biomass renewables	⌀	1.A	⌀	⌀	⌀	⌀	
CO_2 leakage (domestic handling & ship loading)	Occurring vs not occurring	⇧ ↔ ⌀	1.C.1	⇧ ↔ ⌀	⌀	⌀	⇧ ↔ ⌀	
Fuel GHG emissions from international CO_2 transport	Ship to NO/UK/DK fossil vs sustainable shipping fuel	⇧ ↔ ⌀	1.D.1.b (not included in national total)	⇧ ↔ ⌀	⌀	⌀	⇧ ↔ ⌀	
CO_2 leakage (international transport)	Ship to NO/UK/DK Occurring vs not occurring	Out of inventory scope		to NO / DK: ⇧ ↔ ⌀ to UK: Out of ETS scope	⌀	⌀	⌀ (out of scope)	
CO_2 leakage (injection)	in NO / UK / DK Occurring vs not occurring	NO / UK / DK: ⇧ ↔ ⌀	1.C.2.a	NO/DK: ⇧ ↔ ⌀ UK: Outside EU ETS	DK/NO: ESR / LULUCF targets: ⌀ UK: Outside EU & ESR / LULUCF Reg.		DK: ⇧ ↔ ⌀ NO / UK: Outside EU	
CO_2 leakage (from underground storage)	in NO / UK / DK possibly in future years Occurring vs not occurring	NO / UK / DK: future years ⇧ ↔ ⌀	1.C.2.b	NO/DK: ⇧ ↔ ⌀ (future years) UK: Outside EU ETS			DK: ⇧ ↔ ⌀ (future years) NO / UK: Outside EU	
Other associated GHG emissions, incl. energy and CO_2 infrastructure	Possibly abroad, possibly in past year of infrastructure generation	Possibly abroad and past years ⇧ ↔ ⌀	possibly all	Possibly in ETS 1 scope and in past years ⇧ ↔ ⌀	Possibly in FI ESR scope and in past years ⇧ ↔ ⌀	Possibly in FI LULUCF scope and in past years ⇧ ↔ ⌀	Possibly in EU scope and in past years ⇧ ↔ ⌀	
Total removal [1] measure		⇧ ↔ ⌀		⇧ ↔ ⌀	⇧ ↔ ⌀	⇧	⇧ ↔ ⌀	⌀ ↔ ⇩ **5**

[1] Under assumed settings, case study would not qualify for environmental integrity of net-negative 'removal' measure.

[2] Note that roundwood / forest chip use for district heating is not representative for current Finnish biomass use.

[3] Losses or gains in carbon sequestration on harvested area, in comparison to the 'no roundwood harvest' base case, are site specific and vary over future post-harvest years. They are not displayed in this tabular accounting overview for national GHG inventory, LULUCF Regulation and the Finnish climate act net GHG target.

[4] Efficiency gains or additional nuclear energy or non-biomass renewables assumed as base case for the heat and power supplied by the CHP plant.

[5] Size and algebraic sign of calculated 'net removal benefits' sensitive on CRCF scope boundary definitions yet to be agreed.

[6] The inventory treatment resembles the CCU downstream approach as any CO_2 leakage after capture would need to be reported as a (fossil) emission.

Table 5 Case study #3: fossil CCS in cement industry, CO_2 ship transport to Norway (or UK, DK)

NET case study #3 (neutral): FoCCS in cement industry, CO_2 ship transport to Norway (or UK, DK)		Negative (⇩), zero (⌀) or positive (⇧) emissions accounted for the mitigation measure for the year of carbon capture (where not indicated otherwise):						
		National GHG Inventory (CCU downstream approach[4])		ETS Directive	ESR	LULUCF Regulation	ECL / NDC	CRCF units
Process steps	settings & high / low GHG options	Net GHG emissions	CRT	ETS 1 verified emissions	ESR target	LULUCF target	EU net GHG target	
CO_2 capture at point source	Cement industry [1], covered by EU ETS	⇩	2.A, 1.A.2	for NO/DK: ⇩ for UK: ⌀ [2]	for NO/DK: ⌀ for UK: ⌀ / ⇩ ? [3]	⌀	⇩	GHG emission mitigation by means of fossil CCS is excluded from the scope of the CRCF.
Energy supply for CO_2 capture	Additional fossil fuel vs. efficiency gains	⇧ ↔ ⌀	1.A.2	⇧ ↔ ⌀	⌀	⌀	⇧ ↔ ⌀	
Electricity supply for CO_2 compression	Additional nuclear or non-biomass renewables	⌀	1.A	⌀	⌀	⌀	⌀	
CO_2 leakage (domestic handling & ship loading)	Occurring vs not occurring	⇧ ↔ ⌀	1.C.1	⇧ ↔ ⌀	⌀	⌀	⇧ ↔ ⌀	
Fuel GHG emissions from international CO_2 transport	Ship to NO/UK/DK fossil vs sustainable shipping fuel	⇧ ↔ ⌀	1.D.1.b (not included in national total)	⇧ ↔ ⌀	⌀	⌀	⇧ ↔ ⌀	
CO_2 leakage (international transport)	Ship to NO/UK/DK Occurring vs not occurring	Out of scope		to NO / DK: ⇧ ↔ ⌀ to UK: Out of ETS scope	⌀	⌀	⌀ (out of scope)	
CO_2 leakage (injection)	in NO / UK / DK Occurring vs not occurring	NO / UK / DK: ⇧ ↔ ⌀	1.C.2.a	NO/DK: ⇧ ↔ ⌀ UK: Outside EU ETS	DK/NO: ESR / LULUCF targets: ⌀ UK: Outside EU & ESR / LULUCF Reg.		DK: ⇧ ↔ ⌀ NO / UK: Outside EU	
CO_2 leakage (from underground storage)	in NO / UK / DK possibly in future years Occurring vs not occurring	NO / UK / DK: future years ⇧ ↔ ⌀	1.C.2.b	NO/DK: ⇧ ↔ ⌀ (future years) UK: Outside EU ETS			DK: ⇧ ↔ ⌀ (future years) NO / UK: Outside EU	
Other associated GHG emissions, incl. energy and CO_2 infrastructure	Possibly abroad, possibly in past year of infrastructure generation	Possibly abroad and past years ⇧ ↔ ⌀	possibly all	Possibly in ETS 1 scope and in past years ⇧ ↔ ⌀	Possibly in FI ESR scope and in past years ⇧ ↔ ⌀	Possibly in FI LULUCF scope and in past years ⇧ ↔ ⌀	Possibly in EU scope and in past years ⇧ ↔ ⌀	
Total mitigation measure *	**Assuming options to result in overall environmental integrity**	⇩ ↔ ⇩		for NO/DK: ⇩ ↔ ⇩ for UK: ⇧ ↔ ⌀ [2]	for NO/DK: ⇧ ↔ ⌀ for UK: ⇧ ↔ ⌀ / ⇩ ↔ ⇩ ? [3]	⇧ ↔ ⌀	⇩ ↔ ⇩	Out of CRCF scope

[1] Fossil CO_2 generated during cement production from carbonate use or fossil fuels is not considered in this overview as constant clinker output is assumed for an add-on CCS GHG mitigation measure.

[2] Under present ETS rules CO_2 captured for geological storage in the UK would not be subtracted from the generating installation's emissions. Fossil CCS at EU ETS installations is thus unlikely to involve storage in the UK until those rules might possibly be changed.

[3] The present ESR rules can be interpreted to allow for accounting such negative emission contributions as ETS fossil emissions would be recorded while no emissions would be reported in the GHG inventory. As discussed in footnote 2, the option of shipping CO_2 to UK is not likely under present ETS rules. However, In case of such arrangements to ship ETS-based CO_2 to UK, it might be expected that the ESR rules would be amended in analogy to the 2024 amendment of IR 2020/1208 to exclude ESR accounting of such negative emission contributions.

[4] The inventory treatment resembles the CCU downstream approach as any CO_2 leakage after capture would need to be reported as a (fossil) emission.

Table 6 Case study #4a: BECCU enforced concrete carbonation, using biogenic CO_2 from forest industry

NET case study #4a (negative): BECCU enforced concrete carbonation, using biogenic CO_2 from forest industry		Negative (⇩), zero (⌀) or positive (⇧) emissions accounted for the mitigation measure for the year of carbon capture (where not indicated otherwise):						
		National GHG Inventory (CCU downstream approach[8])		ETS Directive	ESR	LULUCF Regulation	ECL / NDC	CRCF units
Process steps	settings & high / low GHG options	Net GHG emissions	CRT	ETS 1 verified emissions	ESR target	LULUCF target	EU net GHG target	
CO_2 capture at point source	from black liquor [1] combustion in pulp industry, covered by EU ETS	⌀ / ⇩? [2]	1.A.2	⌀	⌀ / ⇩? [3]	⌀	⌀ / ⇩? [4]	Integrated assessment: **'permanent net carbon removal benefit'** in comparison to counterfactual baseline. Definition of scope boundaries, quantification methodologies and treatment of uncertainties to be agreed in subordinate CRCF legislation. CRCF uncertainties re...
Energy supply for CO_2 capture	Additional wood harvest vs efficiency gains	⇧ ↔ ⌀	4.A	⌀	⌀	⇧ ↔ ⌀	⇧ ↔ ⌀	
Electricity supply for CO_2 compression	Additional nuclear or non-biomass renewables	⌀	1.A	⌀	⌀	⌀	⌀	
CO_2 leakage (domestic handling & distribution)	Occurring vs not occurring	⇧ ↔ ⌀	1.C.1	⌀	⇧ ↔ ⌀	⌀	⇧ ↔ ⌀	
Fuel GHG emissions from domestic CO_2 transport	fossil vs sustainable fuel, zero-emission vehicles	⇧ ↔ ⌀	1.A.3	⌀	⇧ ↔ ⌀	⌀	⇧ ↔ ⌀	
Carbonation of concrete (curing)		⌀	none [5]	⌀	⌀	⌀	⌀	
CO_2 emissions during curing process	Occurring vs not occurring	⇧ ↔ ⌀	2.H.3	⌀	⇧ ↔ ⌀		⇧ ↔ ⌀	
Other associated GHG emissions, incl. curing and CO_2 infrastructure	Possibly abroad, possibly in past year of infrastructure generation	Possibly abroad and past years ⇧ ↔ ⌀	possibly all	Possibly in ETS 1 scope and in past years ⇧ ↔ ⌀	Possibly in FI ESR scope and in past years ⇧ ↔ ⌀	Possibly in FI LULUCF scope and in past years ⇧ ↔ ⌀	Possibly in EU scope and in past years ⇧ ↔ ⌀	
Total removal measure	**Assuming options to result in overall environmental integrity**	⇧ ↔ ⌀ / ⇩ ↔ ⇩ ? [6]		⇧ ↔ ⌀	⇧ ↔ ⌀ / ⇩ ↔ ⇩ ? [7]	⇧ ↔ ⌀	⇧ ↔ ⌀ / ⇩ ↔ ⇩ ? [6]	⇩ ↔ ⇩

[1] Roundwood harvest for pulp production, feeding into black liquor generation, is not considered in this overview as constant pulp output is assumed for an add-on BECCS GHG mitigation measure.

[2] Reporting of negative emissions for recovery of biogenic CO_2 to be defended in inventory review as explicit IPCC guidance is missing. Approach could be challenged as industrial concrete carbonation reduces the potential for later carbonation of concrete product under atmospheric conditions. Note than Japan reports on such carbonation in its 2024 NID (https://unfccc.int/documents/637879) that has not yet been subject to UNFCCC technical review by June 2024.

[3] In case of inventory reporting of negative emissions (footnote 2), the present ESR rules can be interpreted to allow for accounting such negative emission contributions. In the case of an EU-wide acknowledgement of such an approach in inventories, however, it should be expected that the ESR rules would be amended in analogy to the 2024 amendment of IR 2020/1208 in order to exclude ESR accounting of such negative emission contributions.

[4] ⇩ in case of ⇩ reporting in inventory, ⌀ in case of ⌀ reporting in inventory (footnote 2)

[5] Negative emissions are reported for the capture of CO_2 rather than the enforced carbonation process.

[6] ⇧ ↔ ⌀ only in case inventory reporting of negative emission for CO_2 capture at point source would not pass inventory review (footnote 2).

[7] ⇩ ↔ ⇩ only in case inventory reporting of negative emission for CO_2 capture does pass inventory review (footnote 2) and ESR rules would not be amended to exclude such negative emissions (footnote 3).

[8] The inventory treatment resembles the CCU downstream approach as any future high-temperature combustion of carbonated concrete, leading to a release of CO_2, would need to be reported as a (fossil) emission.

Table 7 Case study #4b: Fossil CCU enforced concrete carbonation, using fossil CO_2 from cement industry

NET case study #4b (neutral): FoCCU enforced concrete carbonation, using fossil CO_2 from cement industry		Negative (⇩), zero (⌀) or positive (⇧) emissions accounted for the mitigation measure for the year of carbon capture (where not indicated otherwise):						
		National GHG Inventory (CCU downstream approach[8])		ETS Directive	ESR	LULUCF Regulation	ECL / NDC	CRCF units
Process steps	settings & high / low GHG options	Net GHG emissions	CRT	ETS 1 verified emissions	ESR target	LULUCF target	EU net GHG target	
CO_2 capture at point source	Cement industry [1], covered by EU ETS	⌀ / ⇩? [2]	1.A.2 / 2.A.1	⇩ [3]	⇧ / ⌀ ? [4]	⌀	⌀ / ⇩? [5]	GHG emission mitigation by means of fossil CCU is excluded from the scope of the CRCF.
Energy supply for CO_2 capture	Additional wood harvest vs efficiency gains	⇧ ↔ ⌀	4.A	⌀	⌀	⇧ ↔ ⌀	⇧ ↔ ⌀	
Electricity supply for CO_2 compression	Additional nuclear or non-biomass renewables	⌀	1.A	⌀	⌀	⌀	⌀	
CO_2 leakage (domestic handling & distribution)	Occurring vs not occurring	⇧ ↔ ⌀	1.C.1	⌀	⇧ ↔ ⌀	⌀	⇧ ↔ ⌀	
Fuel GHG emissions from domestic CO_2 transport	fossil vs sustainable fuel, zero-emission vehicles	⇧ ↔ ⌀	1.A.3	⌀	⇧ ↔ ⌀	⌀	⇧ ↔ ⌀	
Carbonation of concrete (curing)		⌀	none [6]	⌀	⌀	⌀	⌀	
CO_2 emissions during curing process	Occurring vs not occurring	⇧ ↔ ⌀	2.H.3	⌀	⇧ ↔ ⌀		⇧ ↔ ⌀	
Other associated GHG emissions, incl. curing and CO_2 infrastructure	Possibly abroad, possibly in past year of infrastructure generation	Possibly abroad and past years ⇧ ↔ ⌀	possibly all	Possibly in ETS 1 scope and in past years ⇧ ↔ ⌀	Possibly in FI ESR scope and in past years ⇧ ↔ ⌀	Possibly in FI LULUCF scope and in past years ⇧ ↔ ⌀	Possibly in EU scope and in past years ⇧ ↔ ⌀	
Total mitigation measure	**Assuming options to result in overall environmental integrity**	⇧ ↔ ⌀ / ⇩ ↔ ⇩ ? [7]		⇩ ↔ ⇩	⇧ / ⇧ ↔ ⌀ ? [8]	⇧ ↔ ⌀	⇧ ↔ ⌀ / ⇩ ↔ ⇩ ? [7]	Out of CRCF scope

[1] Fossil CO_2 generated during cement production from carbonate use or fossil fuels is not considered in this overview as constant clinker output is assumed for an add-on CCS GHG mitigation measure.[1] Roundwood harvest for pulp production, feeding into black liquor generation, is not considered in this overview as constant pulp output is assumed for an add-on BECCS GHG mitigation measure.

[2] Reporting of negative emissions for recovery of biogenic CO_2 to be defended in inventory review as explicit IPCC guidance is missing. Approach could be challenged as industrial concrete carbonation reduces the potential for later carbonation of concrete product under atmospheric conditions. Note than Japan reports on such carbonation in its 2024 NID (https://unfccc.int/documents/637879) that has not yet been subject to UNFCCC technical review by June 2024.

[3] ETS1 Subtraction of carbon stored in construction material expected under upcoming Implementing Regulation under Art 12(3b) of ETS Directive on carbon permanently stored in products, expected for summer 2024.

[4] In case of ⌀ reporting in inventory (footnote 2), the present ESR quantification rules would result in ⇧ ESR emissions accounted to balance ⇩ ETS 1 subtractions (footnote 3). In case of ⇩ reporting in inventory, ESR emissions would stay unaffected by the mitigation measure.

[5] ⇩ in case of ⇩ reporting in inventory, ⌀ in case of ⌀ reporting in inventory (footnote 2)

[6] Negative emissions are reported for the capture of CO_2 rather than the enforced carbonation process.

[7] ⇧ ↔ ⌀ only in case inventory reporting of negative emission for CO_2 capture at point source would not pass inventory review (footnote 2).

[8] The inventory treatment resembles the CCU downstream approach as any future high-temperature combustion of carbonated concrete, leading to a release of CO_2, would need to be reported as a (fossil) emission.

Table 8 Case study #5: Biochar production for long-term carbon storage (soil application, cement additive)

NET case study #5 (negative): Biochar production for long-term carbon storage (soil application, cement additive)		Negative (⇩ [1]), zero (⌀) or positive (⇧) emissions accounted for the mitigation measure for the year of biochar application (where not indicated otherwise):						
		National GHG Inventory		ETS Directive	ESR	LULUCF Regulation	ECL / NDC	CRCF units
Process steps	settings & high / low GHG options	Net GHG emissions	CRT	ETS 1 verified emissions	ESR target	LULUCF target	EU net GHG target	
Biomass production / harvest	Use of sustainable biomass waste feedstock assumed	⌀	4	⌀	⌀	⌀	⌀[3]	Integrated assessment: ‘ **temporary/permanent net carbon removal benefit’** in comparison to counterfactual baseline. Definition of scope boundaries, quantification methodologies and treatment of uncertainties to be agreed in subordinate CRCF legislation. CRCF quantification may integrate emissions occurring in several years.
Biochar production	GHGs released from biomass feedstock during the pyrolysis / torrefication process: Occurring vs not occurring	⇧ ↔ ⌀ [2]	1.B	⌀	⇧ ↔ ⌀ [2]	⌀	⇧ ↔ ⌀ [2]	
Energy supply for pyrolysis / torrefication	Fossil fuel vs from used biomass	⇧ ↔ ⌀	1.A / 1.B	⇧ ↔ ⌀	⇧ ↔ ⌀	⌀	⇧ ↔ ⌀	
Energy supply replacing 'lost' energy use of waste biomass feedstock	May be relevant for some waste streams, possibly additional biomass harvest	⇧ ↔ ⌀	1.A / 1.B / 4	⇧ ↔ ⌀	⇧ ↔ ⌀	⇧ ↔ ⌀	⇧ ↔ ⌀	
Fuel GHG emissions from biomass feedstock and biochar distribution	fossil vs sustainable fuel, zero-emission vehicles	⇧ ↔ ⌀	1.A.3	⌀	⌀⇧ ↔ ⌀	⌀	⇧ ↔ ⌀	
Biochar application in domestic mineral soils	Durable biochar and data availability according to IPCC methodology guidelines assumed	⇩	4	⌀	⌀	⇩	⇩	
Domestic biochar application as cement additive	Without substitution effects for avoided emissions due to substitution effects see lower part of table	⌀ / ⇩ **?** [3]	6 / 2.H.3 / 4.H [4]	⌀	⌀ / ⇩ **?** [5]	⌀ / ⇩ **?** [6]	⌀ / ⇩ **?** [7]	
Export of biochar (for durable applications) to EU		Out of FI scope [8]		⌀	EU outside FI: ⌀ / ⇩ **?** [9]	EU outside FI: ⇩ [10]	⌀ ↔ ⇩ [11]	
Export of biochar (for durable applications) to non-EU				Out of EU scope				
Other associated GHG emissions, incl. biochar infrastructure	Possibly abroad, possibly in past year of infrastructure generation	Possibly abroad and past years ⇧ ↔ ⌀	possibly all	Possibly in ETS1 scope and in past years ⇧ ↔ ⌀	Possibly in FI ESR scope and in past years ⇧ ↔ ⌀	Possibly in FI LULUCF scope and in past years ⇧ ↔ ⌀	Possibly in EU scope and in past years ⇧ ↔ ⌀	
Total removal measure without substitution effects [12]	**Assuming options to result in overall environmental integrity**	⇧ ↔ ⌀ ↔ ⇩ [13]		⇧ ↔ ⌀	⇧ ↔ ⌀ (↔⇩ ?[14])	⇩ ↔ ⇩	⇧ ↔ ⌀ ↔ ⇩ [15]	⇩ ↔ ⇩
Total substitution effects[12, 16] related to the use of biochar (avoided emissions)		⌀ ↔ ⇩		⌀ ↔ ⇩	⌀ ↔ ⇩	⌀ ↔ ⇩	⌀ ↔ ⇩	Out of scope
Avoided emissions[16] from domestic cement production	In case of biochar application as cement additive	⌀ ↔ ⇩	1.A.2 / 2.A.1	⌀ ↔ ⇩	⌀	⌀	⌀ ↔ ⇩	Out of CRCF scope
Avoided emissions[16] from cement production, biochar export to EU		Out of FI scope		EU outside FI: ⌀ ↔ ⇩	EU outside FI: ⌀	⌀	⌀ ↔ ⇩	
Avoided emissions[16], biochar export to non-EU				Out of EU scope				
Other associated avoided emissions[16], incl. infrastructure	Possibly abroad, possibly in past year of avoided infrastructure generation	Possibly abroad and past years ⌀ ↔ ⇩	possibly all	Possibly in ETS1 scope and in past years ⌀ ↔ ⇩	Possibly in FI ESR scope and in past years ⌀ ↔ ⇩	Possibly in FI LULUCF scope and in past years ⌀ ↔ ⇩	Possibly in EU scope and in past years ⌀ ↔ ⇩	

[1] ⇩ symbol signifies avoided emissions in the context of substitution effects.

[2] Methane emissions only. Biogenic CO_2 released during biochar production is zero-rated.

[3] Methodology guidance for inventory coverage of long-term carbon storage as cement additive is not yet available from the IPCC. Any methodology developed at national / EU level would need to pass UNFCCC technical inventory review. Note than Japan reports on biochar fixed in concrete in CRT category 4.H in its 2024 NID (https://unfccc.int/documents/637879) that has not yet been subject to UNFCCC technical review by June 2024.

[4] If FI would choose to report long-term carbon storage as cement additive as an industrial process in CRT 2.H.3, the present CRT tables would only allow to report stored amounts as ‘recovery/capture of biogenic CO_2’. If FI would report in category 6 ‘other’, the CRT tables would allow reporting this process as ‘removals’. For reporting in category 4.H (LULUCF – other) like indicated in the 2024 NID of Japan (see footnote 3) the present CRT does not offer an explicit option to report removals (The CRT IT implementation (not yet available by June 2024) might possibly facilitate to report a negative amount for 4.H CO_2 emissions. The choice of the category has implications for ESR, LULUCF & EU NDC coverage (see footnotes 5, 6 and 7).

[5] ⌀ in case the process would be reported in CRT 4.H or CRT 6 (see footnote 4). If reported in CRT 2.H.3, the present ESR rules can be interpreted to allow for accounting such negative emission contributions. In the case of an EU-wide acknowledgement of such a reporting approach in inventories, however, it should be expected that the ESR rules would be amended in analogy to the 2024 amendment of IR 2020/1208 in order to exclude ESR accounting of such negative emission contributions.

[6] ⇩ in case the process would be reported in CRT 4.H (see footnote 4), else ⌀.

[7] ⌀ for the EU NDC in case the process would be reported in CRT 6 (see footnote 4) as CRT 6 is not included in the NDC scope. ⇩ for the ECL scope (‘regulated by Union law’) if ⇩ is reported at all in the inventory (footnote 3).

[8] Negative emissions for the application of biochar in soils would be reported in importing countries’ inventories. Negative emissions for other durable storage approaches could be reported in importing countries’ inventories subject to the limitations discussed in footnotes 3 and 4.

[9] For application as cement additive, subject to restrictions discussed in footnote 5.

[10] For application in mineral soils. For application as cement additive in case the importing country would report this in CRT 4.H (see footnote 4).

[11] ⇩ for application in mineral soils. ECL / NDC coverage of application in as cement additive subject to the restrictions discussed in footnote 7.

[12] As a pre-requisite to overall environmental integrity, avoided emissions due to substitution effects should exceed total additional emissions accounted for the removal measure.

[13] The net balance of emissions (without substitution effects) depends on the size of associated emissions in relation to domestic durable biochar application reported in the inventory (footnote 3).

[14] A net negative ESR balance is conceivable only in case of domestic biochar application as cement additive where inventory reporting takes place in CRT 2.H.3 and the ESR rules would NOT be amended to exclude negative inventory emissions assigned to carbon capture for e-fuel production (see footnotes 3, 4 & 5).

[15] The net balance of emissions (without substitution effects) depends on the size of associated emissions in relation to domestic durable biochar application reported in the inventory (footnote 3). For a potential difference between ECL and NDC coverage in case of application as a cement additive see footnote 7.

[16] Note that avoided emissions / substitution effects were assessed in comparison to fossil alternatives.

Table 9 Case study #6: Biochar production for short-term carbon storage (coal substitution in industry)

NET case study #6 (neutral): Biochar production for short-term carbon storage (coal substitution in industry)		Negative (⇩ [1]), zero (⌀) or positive (⇧) emissions accounted for the mitigation measure for the year of biochar application (where not indicated otherwise):						
		National GHG Inventory		ETS Directive	ESR	LULUCF Regulation	ECL / NDC	CRCF units
Process steps	settings & high / low GHG options	Net GHG emissions	CRT	ETS 1 verified emissions	ESR target	LULUCF target	EU net GHG target	
Biomass production / harvest	Use of sustainable biomass waste feedstock assumed	⌀	4	⌀	⌀	⌀	⌀[3]	Short-term carbon storage in biochar for coal substitution is excluded from the scope of the CRCF.
Biochar production	GHGs released from biomass feedstock during the pyrolysis / torrefication process: Occurring vs not occurring	⇧ ↔ ⌀ [2]	1.B	⌀	⇧ ↔ ⌀ [2]	⌀	⇧ ↔ ⌀ [2]	
Energy supply for pyrolysis / torrefication	Fossil fuel vs from used biomass	⇧ ↔ ⌀	1.A / 1.B	⇧ ↔ ⌀	⇧ ↔ ⌀	⌀	⇧ ↔ ⌀	
Energy supply replacing 'lost' energy use of waste biomass feedstock	May be relevant for some waste streams, possibly additional biomass harvest	⇧ ↔ ⌀	1.A / 1.B / 4	⇧ ↔ ⌀	⇧ ↔ ⌀	⇧ ↔ ⌀	⇧ ↔ ⌀	
Fuel GHG emissions from biomass feedstock and biochar distribution	fossil vs sustainable fuel, zero-emission vehicles	⇧ ↔ ⌀	1.A.3	⌀	⌀⇧ ↔ ⌀	⌀	⇧ ↔ ⌀	
Biochar combustion / process use in domestic industry	Without substitution effects	⌀ [3]	1.A.2 / 2	⌀ [3]	⌀ [3]	⌀	⌀ [3]	
Export of biochar (for short-term applications) to EU	for avoided emissions due to substitution effects see lower part of table	Out of FI scope		⌀ [3]	EU outside FI: ⌀ [3]	EU outside FI: ⌀	⌀	
Export of biochar (for short-term applications) to non-EU				Out of EU scope				
Other associated GHG emissions, incl. biochar infrastructure	Possibly abroad, possibly in past year of infrastructure generation	Possibly abroad and past years ⇧ ↔ ⌀	possibly all	Possibly in ETS1 scope and in past years ⇧ ↔ ⌀	Possibly in FI ESR scope and in past years ⇧ ↔ ⌀	Possibly in FI LULUCF scope and in past years ⇧ ↔ ⌀	Possibly in EU scope and in past years ⇧ ↔ ⌀	
Total mitigation measure without substitution effects [4]		⇧ ↔ ⌀		⇧ ↔ ⌀	⇧ ↔ ⌀	⇧ ↔ ⌀	⇧ ↔ ⌀	Out of scope
Total substitution effects[4, 5] related to the use of biochar (avoided emissions)		⌀ ↔ ⇩		⌀ ↔ ⇩	⌀ ↔ ⇩	⌀ ↔ ⇩	⌀ ↔ ⇩	Out of scope
Avoided emissions[5] from domestic industry	In case of biochar application as coal replacement in industry processes	⌀ ↔ ⇩	1.A.2 / 2	⌀ ↔ ⇩	⌀ ↔ ⇩	⌀	⌀ ↔ ⇩	Out of CRCF scope
Avoided industry emissions[5], biochar export to EU		Out of FI scope		EU outside FI: ⌀ ↔ ⇩	EU outside FI: ⌀ ↔ ⇩	⌀	⌀ ↔ ⇩	
Avoided industry emissions[5], biochar export to non-EU				Out of EU scope				
Other associated avoided emissions[5], incl. infrastructure	Possibly abroad, possibly in past year of avoided infrastructure generation	Possibly abroad and past years ⌀ ↔ ⇩	possibly all	Possibly in ETS1 scope and in past years ⌀ ↔ ⇩	Possibly in FI ESR scope and in past years ⌀ ↔ ⇩	Possibly in FI LULUCF scope and in past years ⌀ ↔ ⇩	Possibly in EU scope and in past years ⌀ ↔ ⇩	

[1] ⇩ symbol signifies avoided emissions in the context of substitution effects.

[2] Methane emissions only. Biogenic CO_2 released during biochar production is zero-rated.

[3] Zero-rated emissions of biogenic CO_2

[4] As a pre-requisite to overall environmental integrity, avoided emissions due to substitution effects should exceed total additional emissions accounted for the mitigation measure.

[5] Note that avoided emissions / substitution effects were assessed in comparison to fossil alternatives.

Table 10 Case study #7a: BECCU e-fuel production using carbon from municipal waste incineration (CCU downstream approach in inventory)

NET case study #7a (neutral / delayed emission[1]): **BECCU e-fuel production using carbon from municipal waste incineration** **CCU *downstream* approach** assumed for GHG inventory (& consequently for ESR, ECL/NDC & Finnish Climate Act)		Negative (⇩ [2]), zero (⌀) or positive (⇧) emissions accounted for the mitigation measure for the year of carbon capture (where not indicated otherwise):						
		National GHG Inventory *CCU downstream approach*		ETS Directive	ESR	LULUCF Regulation	ECL / NDC	CRCF units
Process steps	settings & high / low GHG options	Net GHG emissions	CRT	ETS 1 verified emissions	ESR target	LULUCF target	EU net GHG target	
CO_2 capture at point source, biogenic share	Municipal waste incineration eventually moving from ESR to ETS coverage [3]	⇩	1.A.1 / 5.C [4]	⌀	⌀ / ⇩ ? [5]	⌀	⇩	Short-term carbon storage in e-fuels is excluded from the scope of the CRCF.
CO_2 capture at point source, fossil share [6]		⇩	1.A.1 / 5.C [4]	⌀	⌀ / ⇩ ? [7]	⌀	⇩	
Energy supply for CO_2 capture	Additional nuclear or non-biomass renewables [8]	⌀	1.A	⌀	⌀	⌀	⌀	
Energy / hydrogen supply for e-fuel production								
Fuel GHG emissions from e-fuel distribution	fossil vs sustainable fuel, zero-emission vehicles	⇧ ↔ ⌀	1.A.3	⌀	⇧ ↔ ⌀	⌀	⇧ ↔ ⌀	
E-fuel use in domestic transport	Without substitution effects For avoided emissions due to substitution effects see lower part of table	⇧	1.A.3	⌀	⇧	⌀	⇧	
E-fuel use in international transport		⇧	1.D.1.b (not included in national total)	⌀ [9]	⌀	⌀	⇧ / ⌀ [18]	
E-fuel use after export to EU		Out of FI scope [10]		⌀ [9]	EU outside FI: ⇧ / ⌀ [11]	EU outside FI: ⌀	⇧ / ⌀ [19]	
E-fuel use after export to non-EU				Out of EU scope				
Other associated GHG emissions, incl. energy and CO_2 infrastructure	Possibly abroad, possibly in past year of infrastructure generation	Possibly abroad and past years ⇧ ↔ ⌀	possibly all	Possibly in ETS1 scope and in past years ⇧ ↔ ⌀	Possibly in FI ESR scope and in past years ⇧ ↔ ⌀	Possibly in FI LULUCF scope and in past years ⇧ ↔ ⌀	Possibly in EU scope and in past years ⇧ ↔ ⌀	
Total mitigation measure without substitution effects [12]		⇧ ↔ ⌀ ↔ ⇩ [13]		⇧ ↔ ⌀	⇧ ↔ ⌀ (↔⇩ ?[14])	⇧ ↔ ⌀	⇧ ↔ ⌀ ↔ ⇩ [13]	Out of scope
Total substitution effects[12, 17] related to the use of e-fuels (avoided emissions)		⌀ ↔ ⇩		⌀ ↔ ⇩	⌀ ↔ ⇩	⌀ ↔ ⇩	⌀ ↔ ⇩	Out of scope
Avoided emissions[17], domestic transport	E-fuel use assumed to replace fossil fuel, vs sustainable biofuel / electricity or efficiency / sufficiency gains	⌀ ↔ ⇩	1.A.3, 1.A.1	⌀	⌀ ↔ ⇩	⌀	⌀ ↔ ⇩	Out of CRCF scope
Avoided emissions[17], international transport		⌀ ↔ ⇩	1.D.1.b (not included in national total)	⌀ ↔ ⇩	⌀	⌀	⌀ ↔ ⇩	
Avoided emissions[17], e-fuel export to EU		Out of FI scope		EU outside FI: ⌀ ↔ ⇩ [15]	EU outside FI: ⌀ ↔ ⇩ [16]	EU outside FI: ⌀	⌀ ↔ ⇩	
Avoided emissions[17], e-fuel export to non-EU				Out of EU scope				
Other associated avoided emissions[17], incl. infrastructure	Possibly abroad, possibly in past year of avoided infrastructure generation	Possibly abroad and past years ⌀ ↔ ⇩	possibly all	Possibly in ETS1 scope and in past years ⌀ ↔ ⇩	Possibly in FI ESR scope and in past years ⌀ ↔ ⇩	Possibly in FI LULUCF scope and in past years ⌀ ↔ ⇩	Possibly in EU scope and in past years ⌀ ↔ ⇩	

[1] 'delayed emission' in case of e-fuels containing carbon derived from fossil CO_2

[2] ⇩ symbol signifies avoided emissions in the context of substitution effects.

[3] ETS vs ESR coverage of municipal waste incineration is of no relevance for the accounting questions summarised in this overview, with the exception of accounting for capture of fossil carbon in non-ETS installations, see footnote 8.

[4] For waste incineration reported in category 5.C (relevant if without energy recovery), the present CRT reporting tables do not allow to report negative emissions.

[5] The present ESR rules can be interpreted to allow for accounting such negative emission contributions. In the case of an EU-wide acknowledgement of the CCU downstream approach in inventories, however, it should be expected that the ESR rules would be amended in analogy to the 2024 amendment of IR 2020/1208 in order to exclude ESR accounting of such negative emission contributions.

[6] Fossil CO_2 emissions from the MWI plant are not considered in this overview as constant fossil waste input is assumed for an add-on CCU / GHG mitigation measure.

[7] The present ESR rules can be interpreted to allow for accounting such negative emission contributions. In the case of an EU-wide acknowledgement of the CCU downstream approach in inventories, however, it should be expected that the ESR rules would be amended in analogy to the 2024 amendment of IR 2020/1208 in order to exclude ESR accounting of such negative emission contributions, if MWI installations would be included in the ETS1. If MWI installations would remain outside ETS, such negative emission contributions (= temporary avoidance of fossil CO_2 emissions) can be expected to remain in the ESR scope.

[8] E-fuel production is assumed to meet RFNBO standards under the RED or comparable 'low-carbon fuel' standards (yet to be defined under EU law) relying on nuclear energy instead of renewables.

[9] Zero-rating of CO_2 from RFNBOs & 'low-carbon fuels (see footnote 8) expected under upcoming 2024 amendment of Monitoring & Reporting Regulation (MRR) under EU ETS.

[10] Respective CO_2 emissions from the use of exported e-fuels would be reported in importing countries' inventories only if those would adopt the 'CCU downstream approach', as well.

[11] ⇧ if exported e-fuels are used in domestic transport of importing EU Member State. ⌀ If used in international transport.

[12] As a pre-requisite to overall environmental integrity, avoided emissions due to substitution effects should exceed total additional emissions accounted for the mitigation measure.

[13] The net balance of emissions (without substitution effects) depends on the size of distribution and other associated / infrastructure emissions in relation to the carbon content of e-fuels supplied to international transport or exported.

[14] A net negative ESR balance is conceivable only in case the ESR rules would NOT be amended to exclude negative inventory emissions assigned to carbon capture for e-fuel production (see footnotes 5 & 7).

[15] ⇩ possible only if avoiding fossil emissions from international transport of importing EU Member State.

[16] ⇩ possible only if avoiding fossil emissions from domestic transport of importing EU Member State.

[17] Note that avoided emissions / substitution effects were assessed in comparison to fossil fuel alternatives. A comparison e.g. involving electric drive motors would result in differing assessments.

[18] ⇧ if e-fuels are used in international transport covered under the EU NDC. ⌀ If used in international transport not covered under the EU NDC.

[19] ⇧ if exported e-fuels are used in domestic transport of importing EU Member State or in international transport covered under the EU NDC. ⌀ If used in international transport not covered under the EU NDC.

Table 11 Case study #7b: BECCU e-fuel production using carbon from municipal waste incineration (CCU upstream approach in inventory)

NET case study #7b (neutral / delayed emission[1]): **BECCU e-fuel production using carbon from municipal waste incineration** **CCU up*stream* approach** assumed for GHG inventory (& consequently for ESR, ECL/NDC & Finnish Climate Act)		Negative (⇩ [2]), zero (⌀) or positive (⇧) emissions accounted for the mitigation measure for the year of carbon capture (where not indicated otherwise):						
		National GHG Inventory *CCU upstream approach*		ETS Directive	ESR	LULUCF Regulation	ECL / NDC	CRCF units
Process steps	settings & high / low GHG options	Net GHG emissions	CRT	ETS 1 verified emissions	ESR target	LULUCF target	EU net GHG target	
CO_2 capture at point source, biogenic share	Municipal waste incineration eventually moving from ESR to ETS coverage [3]	⌀	1.A.1 / 5.C	⌀	⌀	⌀	⌀	Short-term carbon storage in e-fuels is excluded from the scope of the CRCF.
CO_2 capture at point source, fossil share [4]		⌀	1.A.1 / 5.C	⌀	⌀	⌀	⌀	
Energy supply for CO_2 capture	Additional nuclear or non-biomass renewables [5]	⌀	1.A	⌀	⌀	⌀	⌀	
Energy / hydrogen supply for e-fuel production								
Fuel GHG emissions from e-fuel distribution	fossil vs sustainable fuel, zero-emission vehicles	⇧ ↔ ⌀	1.A.3	⌀	⇧ ↔ ⌀	⌀	⇧ ↔ ⌀	
E-fuel use in domestic transport	Without substitution effects For avoided emissions due to substitution effects see lower part of table	⌀	1.A.3	⌀	⌀	⌀	⌀	
E-fuel use in international transport		⌀	1.D.1.b (not included in national total)	⌀ [6]	⌀	⌀	⌀	
E-fuel use after export to EU		Out of FI scope [7]		⌀ [6]	EU outside FI: ⌀	EU outside FI: ⌀	⌀	
E-fuel use after export to non-EU				Out of EU scope				
Other associated GHG emissions, incl. energy and CO_2 infrastructure	Possibly abroad, possibly in past year of infrastructure generation	Possibly abroad and past years ⇧ ↔ ⌀	possibly all	Possibly in ETS1 scope and in past years ⇧ ↔ ⌀	Possibly in FI ESR scope and in past years ⇧ ↔ ⌀	Possibly in FI LULUCF scope and in past years ⇧ ↔ ⌀	Possibly in EU scope and in past years ⇧ ↔ ⌀	
Total mitigation measure without substitution effects [8]		⇧ ↔ ⌀		⇧ ↔ ⌀	⇧ ↔ ⌀	⇧ ↔ ⌀	⇧ ↔ ⌀	Out of scope
Total substitution effects[8, 11] related to the use of e-fuels (avoided emissions)		⌀ ↔ ⇩		⌀ ↔ ⇩	⌀ ↔ ⇩	⌀ ↔ ⇩	⌀ ↔ ⇩	Out of scope
Avoided emissions[11], domestic transport	E-fuel use assumed to replace fossil fuel, vs sustainable biofuel / electricity or efficiency / sufficiency gains	⌀ ↔ ⇩	1.A.3, 1.A.1	⌀	⌀ ↔ ⇩	⌀	⌀ ↔ ⇩	Out of CRCF scope
Avoided emissions[11], international transport		⌀ ↔ ⇩	1.D.1.b (not included in national total)	⌀ ↔ ⇩	⌀	⌀	⌀ ↔ ⇩	
Avoided emissions[11], e-fuel export to EU		Out of FI scope		EU outside FI: ⌀ ↔ ⇩ [9]	EU outside FI: ⌀ ↔ ⇩ [10]	EU outside FI: ⌀	⌀ ↔ ⇩	
Avoided emissions[11], e-fuel export to non-EU				Out of EU scope				
Other associated avoided emissions[11], incl. infrastructure	Possibly abroad, possibly in past year of avoided infrastructure generation	Possibly abroad and past years ⌀ ↔ ⇩	possibly all	Possibly in ETS1 scope and in past years ⌀ ↔ ⇩	Possibly in FI ESR scope and in past years ⌀ ↔ ⇩	Possibly in FI LULUCF scope and in past years ⌀ ↔ ⇩	Possibly in EU scope and in past years ⌀ ↔ ⇩	

[1] 'delayed emission' in case of e-fuels containing carbon derived from fossil CO_2
[2] ⇩ symbol signifies avoided emissions in the context of substitution effects.
[3] ETS vs ESR coverage of municipal waste incineration is of no relevance for the accounting questions summarised in this overview.
[4] Fossil CO_2 emissions from the MWI plant are not considered in this overview as constant fossil waste input is assumed for an add-on CCU / GHG mitigation measure.
[5] E-fuel production is assumed to meet RFNBO standards under the RED or comparable 'low-carbon fuel' standards (yet to be defined under EU law) relying on nuclear energy instead of renewables.
[6] Zero-rating of CO_2 from RFNBOs & 'low-carbon fuels (see footnote 5) expected under upcoming 2024 amendment of Monitoring & Reporting Regulation (MRR) under EU ETS.
[7] Respective CO_2 emissions from the use of exported e-fuels would not be reported in importing countries' inventories only if those would adopt the 'CCU upstream approach', as well.
[8] As a pre-requisite to overall environmental integrity, avoided emissions due to substitution effects should exceed total additional emissions accounted for the mitigation measure.
[9] ⇩ possible only if avoiding fossil emissions from international transport of importing EU Member State.
[10] ⇩ possible only if avoiding fossil emissions from domestic transport of importing EU Member State.
[11] Note that avoided emissions / substitution effects were assessed in comparison to fossil fuel alternatives. A comparison e.g. involving electric drive motors would result in differing assessments.

Table 12 Case study #8a: DACCU e-fuel production using carbon from direct air capture in Finland (CCU downstream approach in inventory)

NET case study #8a (neutral): **DACCU e-fuel production using carbon from direct air capture in Finland** **CCU *downstream* approach** assumed for GHG inventory (& consequently for ESR, ECL/NDC & Finnish Climate Act)		Negative (⇩ [1]), zero (⌀) or positive (⇧) emissions accounted for the mitigation measure for the year of carbon capture (where not indicated otherwise):						
		National GHG Inventory *CCU downstream approach*		ETS Directive	ESR	LULUCF Regulation	ECL / NDC	CRCF units
Process steps	settings & high / low GHG options	Net GHG emissions	CRT	ETS 1 verified emissions	ESR target	LULUCF target	EU net GHG target	
CO_2 capture at DAC plant	DAC & e-fuel production in Finland	⇩	6 / 2.H.3 [2]	⌀	⌀ / ⇩ ? [3]	⌀	⌀ / ⇩ ? [4]	Short-term carbon storage in e-fuels is excluded from the scope of the CRCF.
Energy supply for CO_2 capture Energy / hydrogen supply for e-fuel production	Additional nuclear or non-biomass renewables [5]	⌀	1.A	⌀	⌀	⌀	⌀	
Fuel GHG emissions from e-fuel distribution	fossil vs sustainable fuel, zero-emission vehicles	⇧ ↔ ⌀	1.A.3	⌀	⇧ ↔ ⌀	⌀	⇧ ↔ ⌀	
E-fuel use in domestic transport	Without substitution effects For avoided emissions due to substitution effects see lower part of table	⇧	1.A.3	⌀	⇧	⌀	⇧	
E-fuel use in international transport		⇧	1.D.1.b (not included in national total)	⌀ [6]	⌀	⌀	⇧ / ⌀ [16]	
E-fuel use after export to EU		Out of FI scope [7]		⌀ [6]	EU outside FI: ⇧ / ⌀ [8]	EU outside FI: ⌀	⇧ / ⌀ [17]	
E-fuel use after export to non-EU				Out of EU scope				
Other associated GHG emissions, incl. energy and CO_2 infrastructure	Possibly abroad, possibly in past year of infrastructure generation	Possibly abroad and past years ⇧ ↔ ⌀	possibly all	Possibly in ETS1 scope and in past years ⇧ ↔ ⌀	Possibly in FI ESR scope and in past years ⇧ ↔ ⌀	Possibly in FI LULUCF scope and in past years ⇧ ↔ ⌀	Possibly in EU scope and in past years ⇧ ↔ ⌀	
Total mitigation measure without substitution effects [9]		⇧ ↔ ⌀ ↔ ⇩ [10]		⇧ ↔ ⌀	⇧ ↔ ⌀ (↔⇩ ? [11])	⇧ ↔ ⌀	⇧ ↔ ⌀ ↔ ⇩ [12]	Out of scope
Total substitution effects [9, 15] related to the use of e-fuels (avoided emissions)		⌀ ↔ ⇩		⌀ ↔ ⇩	⌀ ↔ ⇩	⌀ ↔ ⇩	⌀ ↔ ⇩	Out of scope
Avoided emissions [15], domestic transport	E-fuel use assumed to replace fossil fuel, vs sustainable biofuel / electricity or efficiency / sufficiency gains	⌀ ↔ ⇩	1.A.3, 1.A.1	⌀	⌀ ↔ ⇩	⌀	⌀ ↔ ⇩	Out of CRCF scope
Avoided emissions [15], international transport		⌀ ↔ ⇩	1.D.1.b (not included in national total)	⌀ ↔ ⇩	⌀	⌀	⌀ ↔ ⇩	
Avoided emissions [15], e-fuel export to EU		Out of FI scope		EU outside FI: ⌀ ↔ ⇩ [13]	EU outside FI: ⌀ ↔ ⇩ [14]	EU outside FI: ⌀	⌀ ↔ ⇩	
Avoided emissions [15], e-fuel export to non-EU				Out of EU scope				
Other associated avoided emissions [15], incl. infrastructure	Possibly abroad, possibly in past year of avoided infrastructure generation	Possibly abroad and past years ⌀ ↔ ⇩	possibly all	Possibly in ETS1 scope and in past years ⌀ ↔ ⇩	Possibly in FI ESR scope and in past years ⌀ ↔ ⇩	Possibly in FI LULUCF scope and in past years ⌀ ↔ ⇩	Possibly in EU scope and in past years ⌀ ↔ ⇩	

[1] ⇩ symbol signifies avoided emissions in the context of substitution effects.

[2] Methodology guidance for Direct air capture coverage in inventories is not yet available from the IPCC. If FI would choose to report DAC as an industrial process in CRT 2.H.3, the present CRT tables would only allow to report captured amounts as 'recovery/capture of biogenic CO_2'. Only if FI would report in category 6 'other', the CRT tables would allow reporting DAC as 'removals'. The choice of the category has implications for ESR & EU NDC coverage (see footnotes 3, 4, 11 & 12)).

[3] ⌀ in case DAC would be reported in CRT 6 (see footnote 2). If reported in CRT 2.H.3, the present ESR rules can be interpreted to allow for accounting such negative emission contributions. In the case of an EU-wide acknowledgement of the CCU downstream approach in inventories, however, it should be expected that the ESR rules would be amended in analogy to the 2024 amendment of IR 2020/1208 in order to exclude ESR accounting of such negative emission contributions.

[4] ⌀ for the EU NDC in case DAC would be reported in CRT 6 (see footnote 2) as CRT 6 is not included in the NDC scope. ⇩ for the ECL scope ('regulated by Union law').

[5] E-fuel production is assumed to meet RFNBO standards under the RED or comparable 'low-carbon fuel' standards (yet to be defined under EU law) relying on nuclear energy instead of renewables.

[6] Zero-rating of CO_2 from RFNBOs & 'low-carbon fuels (see footnote 5) expected under upcoming 2024 amendment of Monitoring & Reporting Regulation (MRR) under EU ETS.

[7] Respective CO_2 emissions from the use of exported e-fuels would be reported in importing countries' inventories only if those would adopt the 'CCU downstream approach', as well.

[8] ⇧ if exported e-fuels are used in domestic transport of importing EU Member State. ⌀ If used in international transport.

[9] As a pre-requisite to overall environmental integrity, avoided emissions due to substitution effects should exceed total additional emissions accounted for the mitigation measure.

[10] The net balance of emissions (without substitution effects) depends on the size of distribution and other associated / infrastructure emissions in relation to the carbon content of e-fuels supplied to international transport or exported.

[11] A net negative ESR balance is conceivable only in case DAC inventory reporting takes place in CRT 2.H.3 and the ESR rules would NOT be amended to exclude negative inventory emissions assigned to carbon capture for e-fuel production (see footnotes 2 & 3).

[12] A net negative EU NDC balance is conceivable only in case DAC inventory reporting takes place in CRT 2.H.3 (footnote 2). No such limitation for the purpose of the ECL net GHG target. Else, the net balance of emissions (without substitution effects) depends on the size of distribution and other associated / infrastructure emissions in relation to the carbon content of e-fuels supplied to international transport or exported.

[13] ⇩ possible only if avoiding fossil emissions from international transport of importing EU Member State.

[14] ⇩ possible only if avoiding fossil emissions from domestic transport of importing EU Member State.

[15] Note that avoided emissions / substitution effects were assessed in comparison to fossil fuel alternatives. A comparison e.g. involving electric drive motors would result in differing assessments.

[16] ⇧ if e-fuels are used in international transport covered under the EU NDC. ⌀ If used in international transport not covered under the EU NDC.

[17] ⇧ if exported e-fuels are used in domestic transport of importing EU Member State or in international transport covered under the EU NDC. ⌀ If used in international transport not covered under the EU NDC.

Table 13 Case study #8b: DACCU e-fuel production using carbon from direct air capture in Finland (CCU upstream approach in inventory)

NET case study #8b (neutral): **DACCU e-fuel production using carbon from direct air capture in Finland** **CCU *upstream* approach** assumed for GHG inventory (& consequently for ESR, ECL/NDC & Finnish Climate Act)		Negative (⇩ [1]), zero (⌀) or positive (⇧) emissions accounted for the mitigation measure for the year of carbon capture (where not indicated otherwise):						
		National GHG Inventory *CCU upstream approach*		ETS Directive	ESR	LULUCF Regulation	ECL / NDC	CRCF units
Process steps	settings & high / low GHG options	Net GHG emissions	CRT	ETS 1 verified emissions	ESR target	LULUCF target	EU net GHG target	
CO_2 capture at DAC plant	DAC & e-fuel production in Finland	⌀	6 / 2.H.3	⌀	⌀	⌀	⌀	Short-term carbon storage in e-fuels is excluded from the scope of the CRCF.
Energy supply for CO_2 capture	Additional nuclear or non-biomass renewables [2]	⌀	1.A	⌀	⌀	⌀	⌀	
Energy / hydrogen supply for e-fuel production								
Fuel GHG emissions from e-fuel distribution	fossil vs sustainable fuel, zero-emission vehicles	⇧ ↔ ⌀	1.A.3	⌀	⇧ ↔ ⌀	⌀	⇧ ↔ ⌀	
E-fuel use in domestic transport	Without substitution effects For avoided emissions due to substitution effects see lower part of table	⌀	1.A.3	⌀	⌀	⌀	⌀	
E-fuel use in international transport		⌀	1.D.1.b (not included in national total)	⌀ [3]	⌀	⌀	⌀	
E-fuel use after export to EU		Out of FI scope [4]		⌀ [3]	EU outside FI: ⌀	EU outside FI: ⌀	⌀	
E-fuel use after export to non-EU				Out of EU scope				
Other associated GHG emissions, incl. energy and CO_2 infrastructure	Possibly abroad, possibly in past year of infrastructure generation	Possibly abroad and past years ⇧ ↔ ⌀	possibly all	Possibly in ETS1 scope and in past years ⇧ ↔ ⌀	Possibly in FI ESR scope and in past years ⇧ ↔ ⌀	Possibly in FI LULUCF scope and in past years ⇧ ↔ ⌀	Possibly in EU scope and in past years ⇧ ↔ ⌀	
Total mitigation measure without substitution effects [5]		⇧ ↔ ⌀		⇧ ↔ ⌀	⇧ ↔ ⌀	⇧ ↔ ⌀	⇧ ↔ ⌀	Out of scope
Total substitution effects[5, 8] related to the use of e-fuels (avoided emissions)		⌀ ↔ ⇩		⌀ ↔ ⇩	⌀ ↔ ⇩	⌀ ↔ ⇩	⌀ ↔ ⇩	Out of scope
Avoided emissions[8], domestic transport	E-fuel use assumed to replace fossil fuel, vs sustainable biofuel / electricity or efficiency / sufficiency gains	⌀ ↔ ⇩	1.A.3, 1.A.1	⌀	⌀ ↔ ⇩	⌀	⌀ ↔ ⇩	Out of CRCF scope
Avoided emissions[8], international transport		⌀ ↔ ⇩	1.D.1.b (not included in national total)	⌀ ↔ ⇩	⌀	⌀	⌀ ↔ ⇩	
Avoided emissions[8], e-fuel export to EU		Out of FI scope		EU outside FI: ⌀ ↔ ⇩ [6]	EU outside FI: ⌀ ↔ ⇩ [7]	EU outside FI: ⌀	⌀ ↔ ⇩	
Avoided emissions[8], e-fuel export to non-EU				Out of EU scope				
Other associated avoided emissions[8], incl. infrastructure	Possibly abroad, possibly in past year of avoided infrastructure generation	Possibly abroad and past years ⌀ ↔ ⇩	possibly all	Possibly in ETS1 scope and in past years ⌀ ↔ ⇩	Possibly in FI ESR scope and in past years ⌀ ↔ ⇩	Possibly in FI LULUCF scope and in past years ⌀ ↔ ⇩	Possibly in EU scope and in past years ⌀ ↔ ⇩	

[1] ⇩ symbol signifies avoided emissions in the context of substitution effects.

[2] E-fuel production is assumed to meet RFNBO standards under the RED or comparable 'low-carbon fuel' standards (yet to be defined under EU law) relying on nuclear energy instead of renewables.

[3] Zero-rating of CO_2 from RFNBOs & 'low-carbon fuels (see footnote 2) expected under upcoming 2024 amendment of Monitoring & Reporting Regulation (MRR) under EU ETS.

[4] Respective CO_2 emissions from the use of exported e-fuels would not be reported in importing countries' inventories only if those would adopt the 'CCU upstream approach', as well.

[5] As a pre-requisite to overall environmental integrity, avoided emissions due to substitution effects should exceed total additional emissions accounted for the mitigation measure.

[6] ⇩ possible only if avoiding fossil emissions from international transport of importing EU Member State.

[7] ⇩ possible only if avoiding fossil emissions from domestic transport of importing EU Member State.

[8] Note that avoided emissions / substitution effects were assessed in comparison to fossil fuel alternatives. A comparison e.g. involving electric drive motors would result in differing assessments.

Table 14 Case study #9a: Net Import of e-fuels in Finland for use in domestic or international transport (CCU downstream approach in inventory)

NET case study #9a (neutral / delayed emission[1]): **Net Import of e-fuels in Finland for use in transport** **CCU *downstream* approach** assumed for GHG inventory (& consequently for ESR, ECL/NDC & Finnish Climate Act)		Negative (⇩ [2]), zero (⌀) or positive (⇧) emissions accounted for the mitigation measure for the year of fuel use (where not indicated otherwise):						
		National GHG Inventory *CCU downstream approach*		ETS Directive	ESR	LULUCF Regulation	ECL / NDC	CRCF units
Process steps	settings & high / low GHG options	Net GHG emissions	CRT	ETS 1 verified emissions	ESR target	LULUCF target	EU net GHG target	
Import of E-fuels	Energy content assumed to rely on additional nuclear or non-biomass renewables [3]	⌀	none [4]	⌀	⌀	⌀	⌀	Short-term carbon storage in e-fuels is excluded from the scope of the CRCF.
Fuel GHG emissions from e-fuel distribution	fossil vs sustainable fuel, zero-emission vehicles	⇧ ↔ ⌀	1.A.3	⌀	⇧ ↔ ⌀	⌀	⇧ ↔ ⌀	
E-fuel use in domestic transport	Without substitution effects For avoided emissions due to substitution effects see lower part of table	⇧	1.A.3	⌀	⇧	⌀	⇧	
E-fuel use in international transport		⇧	1.D.1.b (not included in national total)	⌀ [5]	⌀	⌀	⇧ / ⌀ [8]	
Other associated GHG emissions, incl. fuel distribution infrastructure	Possibly abroad, possibly in past year of infrastructure generation	Possibly abroad and past years ⇧ ↔ ⌀	possibly all	Possibly in ETS1 scope and in past years ⇧ ↔ ⌀	Possibly in FI ESR scope and in past years ⇧ ↔ ⌀	Possibly in FI LULUCF scope and in past years ⇧ ↔ ⌀	Possibly in EU scope and in past years ⇧ ↔ ⌀	
Total mitigation measure without substitution effects [6]		⇧ ↔ ⌀		⇧ ↔ ⌀	⇧ ↔ ⌀	⇧ ↔ ⌀	⇧ ↔ ⌀	Out of scope
Total substitution effects[6, 7] related to the use of e-fuels (avoided emissions)		⌀ ↔ ⇩		⌀ ↔ ⇩	⌀ ↔ ⇩	⌀ ↔ ⇩	⌀ ↔ ⇩	Out of scope
Avoided emissions[7], domestic transport	E-fuel use assumed to replace fossil fuel, vs sustainable biofuel / electricity or efficiency / sufficiency gains	⌀ ↔ ⇩	1.A.3, 1.A.1	⌀	⌀ ↔ ⇩	⌀	⌀ ↔ ⇩	Out of CRCF scope
Avoided emissions[7], international transport		⌀ ↔ ⇩	1.D.1.b (not included in national total)	⌀ ↔ ⇩	⌀	⌀	⌀ ↔ ⇩	
Other associated avoided emissions[7], incl. infrastructure	Possibly abroad, possibly in past year of avoided infrastructure generation	Possibly abroad and past years ⌀ ↔ ⇩	possibly all	Possibly in ETS1 scope and in past years ⌀ ↔ ⇩	Possibly in FI ESR scope and in past years ⌀ ↔ ⇩	Possibly in FI LULUCF scope and in past years ⌀ ↔ ⇩	Possibly in EU scope and in past years ⌀ ↔ ⇩	

[1] 'delayed emission' in case of e-fuels containing carbon derived from fossil CO_2

[2] ⇩ symbol signifies avoided emissions in the context of substitution effects.

[3] E-fuel production is assumed to meet RFNBO standards under the RED or comparable 'low-carbon fuel' standards (yet to be defined under EU law) relying on nuclear energy instead of renewables.

[4] Import does not cause emissions. Emissions are being reported for use/combustion.

[5] Zero-rating of CO_2 from RFNBOs & 'low-carbon fuels (see footnote 2) expected under upcoming 2024 amendment of Monitoring & Reporting Regulation (MRR) under EU ETS.

[6] As a pre-requisite to overall environmental integrity, avoided emissions due to substitution effects should exceed total additional emissions accounted for the mitigation measure.

[7] Note that avoided emissions / substitution effects were assessed in comparison to fossil fuel alternatives. A comparison e.g. involving electric drive motors would result in differing assessments.

[8] ⇧ if e-fuels are used in international transport covered under the EU NDC. ⌀ If used in international transport not covered under the EU NDC.

Table 15 Case study #9a: Net Import of e-fuels in Finland for use in domestic or international transport (CCU upstream approach in inventory)

NET case study #9b (neutral / delayed emission[1]): **Net Import of e-fuels in Finland for use in transport** **CCU *upstream* approach** assumed for GHG inventory (& consequently for ESR, ECL/NDC & Finnish Climate Act)		Negative (⇩[2]), zero (⌀) or positive (⇧) emissions accounted for the mitigation measure for the year of fuel use (where not indicated otherwise):						
		National GHG Inventory *CCU upstream approach*		ETS Directive	ESR	LULUCF Regulation	ECL / NDC	CRCF units
Process steps	settings & high / low GHG options	Net GHG emissions	CRT	ETS 1 verified emissions	ESR target	LULUCF target	EU net GHG target	
Import of E-fuels	Energy content assumed to rely on additional nuclear or non-biomass renewables [3]	⌀	none [4]	⌀	⌀	⌀	⌀	Short-term carbon storage in e-fuels is excluded from the scope of the CRCF.
Fuel GHG emissions from e-fuel distribution	fossil vs sustainable fuel, zero-emission vehicles	⇧ ↔ ⌀	1.A.3	⌀	⇧ ↔ ⌀	⌀	⇧ ↔ ⌀	
E-fuel use in domestic transport	Without substitution effects	⌀	1.A.3	⌀	⌀	⌀	⌀	
E-fuel use in international transport	For avoided emissions due to substitution effects see lower part of table	⌀	1.D.1.b (not included in national total)	⌀ [5]	⌀	⌀	⌀	
Other associated GHG emissions, incl. fuel distribution infrastructure	Possibly abroad, possibly in past year of infrastructure generation	Possibly abroad and past years ⇧ ↔ ⌀	possibly all	Possibly in ETS1 scope and in past years ⇧ ↔ ⌀	Possibly in FI ESR scope and in past years ⇧ ↔ ⌀	Possibly in FI LULUCF scope and in past years ⇧ ↔ ⌀	Possibly in EU scope and in past years ⇧ ↔ ⌀	
Total mitigation measure without substitution effects [6]		⇧ ↔ ⌀		⇧ ↔ ⌀	⇧ ↔ ⌀	⇧ ↔ ⌀	⇧ ↔ ⌀	Out of scope
Total substitution effects[6, 7] related to the use of e-fuels (avoided emissions)		⌀ ↔ ⇩		⌀ ↔ ⇩	⌀ ↔ ⇩	⌀ ↔ ⇩	⌀ ↔ ⇩	Out of scope
Avoided emissions[7], domestic transport	E-fuel use assumed to replace fossil fuel, vs sustainable biofuel / electricity or efficiency / sufficiency gains	⌀ ↔ ⇩	1.A.3, 1.A.1	⌀	⌀ ↔ ⇩	⌀	⌀ ↔ ⇩	Out of CRCF scope
Avoided emissions[7], international transport		⌀ ↔ ⇩	1.D.1.b (not included in national total)	⌀ ↔ ⇩	⌀	⌀	⌀ ↔ ⇩	
Other associated avoided emissions[7], incl. infrastructure	Possibly abroad, possibly in past year of avoided infrastructure generation	Possibly abroad and past years ⌀ ↔ ⇩	possibly all	Possibly in ETS1 scope and in past years ⌀ ↔ ⇩	Possibly in FI ESR scope and in past years ⌀ ↔ ⇩	Possibly in FI LULUCF scope and in past years ⌀ ↔ ⇩	Possibly in EU scope and in past years ⌀ ↔ ⇩	

[1] 'delayed emission' in case of e-fuels containing carbon derived from fossil CO_2

[2] ⇩ symbol signifies avoided emissions in the context of substitution effects.

[3] E-fuel production is assumed to meet RFNBO standards under the RED or comparable 'low-carbon fuel' standards (yet to be defined under EU law) relying on nuclear energy instead of renewables.

[4] Import does not cause emissions. Emissions are being reported for use/combustion.

[5] Zero-rating of CO_2 from RFNBOs & 'low-carbon fuels (see footnote 2) expected under upcoming 2024 amendment of Monitoring & Reporting Regulation (MRR) under EU ETS.

[6] As a pre-requisite to overall environmental integrity, avoided emissions due to substitution effects should exceed total additional emissions accounted for the mitigation measure.

[7] Note that avoided emissions / substitution effects were assessed in comparison to fossil fuel alternatives. A comparison e.g. involving electric drive motors would result in differing assessments.