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Quantifying and Deploying Responsible Negative Emissions in Climate Resilient Pathways

Stocktaking of scenarios with negative emission technologies and practices - Documentation of the vision making process and initial NEGEM vision

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Executive Summary

Negative emission technologies and practices (NETPs) have a significant role in the Intergovernmental Panel on Climate Change's (IPCC) 1.5°C and 2°C climate change mitigation scenarios, but what is the realistic potential for NETPs when taking into account environmental, social and political constrains? The primary objective of the WP8 of the NEGEM project is to create a clear and shared medium-to-long-term vision on the sustainable potentials of the NETPs and their role in the greenhouse gas (GHG) mitigation at the European Union (EU) level and globally. Secondly, the objective is to create an analysis framework, which will give a guidance on how to create, select, analyse and disseminate pathways to reach the climate targets of the United Nation's Paris Agreement (1) in a broader perspective including renewable energy, nature-based solutions and carbon capture and storage.

The aim of Deliverable 8.1 of *Task 8.1 Scenario Selection* is to present a preliminary NEGEM vision, based on a literature review and the first NEGEM Vision workshop organized virtually on 18th December 2020. D8.1 demonstrates the formulation of the vision and the scenario selection as a first steps included in the analysis framework. The research and analysis reported in D8.1. will support other WPs in NEGEM during the 1st phase of the project.

In this report we review the most recent peer reviewed climate and energy scenarios, recent extensive literature reviews on NETPs, as well as selected scenarios published in the "grey literature" by the European Commission, international organisations, research institutes, stakeholders, NGOs and governments. The literature analysed will be used as a starting point for the scenario work in NEGEM, allowing to explore the analysis methods, data and aims of the scenarios. In addition, we report the NEGEM vision making process, including the results of the 1st NEGEM vision workshop and the background questionnaire sent to stakeholders.

The D8.1. draws the picture on existing knowledge, expectations and concerns on NETPs to reach the global and EU level climate targets, in line with the Paris Agreement. In addition, the report gives some country level examples, how NETPs have been considered in their climate and energy strategies.

Literature review

Based on extensive recent scientific literature reviews on climate change mitigation scenarios, NETPs are needed to reach the 1.5 °C mitigation goal. For achieving 2 °C target, the need for NETPs can be limited with ramping up the near-term ambition for mitigation. A portfolio of NETPs has lower sustainability risks than application of just one NETP technology (e.g. bioenergy with carbon capture and storage (BECCS)). The future need for NETPs significantly depends on the assumed future socio-economic conditions.

The IAMC 1.5°C Scenarios Database (2) contains results for almost about 350 climate change mitigation scenarios that have NETPs represented, and at least 275 of those have NETPs active in their solution at notable levels (≥ 1 $GtCO_2$/year.) Looking at the median estimates in the IAMC 1.5°C Scenarios Database for all NETPs combined, we arrive at a total estimate of almost 12 $GtCO_2$/year negative emissions in 2050 and 30 $GtCO_2$/year in 2100 respectively. The corresponding median value for BECCS was above 3 $GtCO_2$/year in 2050 and nearby 11 $GtCO_2$/year in 2100. The median amount for 2100 would thus correspond to over 100 EJ of bioenergy being utilized with CCS in 2100 (total global bioenergy use today accounts about 50 EJ). Unfortunately, IAMC database does not include EU or European level data but OECD would account for around 30% of the global BECCS both in 2050 and 2100. Work on the EU level scenarios to analyse the realistic and sustainable potentials of NETPs will continue during the NEGEM project.

Many of the estimates for the potential of the NETPs in the grey literature seem to be lower than the demand modelled in e.g. in the IPCC scenarios with Integrated Assessment Models (IAM). In grey literature, BECCS is the NETP most often included, while direct air capture (DAC) is included in a few scenarios. The scenarios do not often include the development of the land use sector, which can limit their ability to describe the total development of GHG emissions.

In the European country level long-term climate strategies quantitative estimations on NETPs potentials are presented only by a few countries (e.g. France, Austria, Finland). Some countries have published specific studies on NETPs (e.g. Netherlands, Ireland, UK). Many countries mention NETPs, and especially afforestation and land management measures for enhancement of soil carbon stocks are widely discussed. The scientific literature shows the urgency for deployment of NETPs to reach the modelled demand for NETPs in 1.5 °C mitigation scenarios. However, the country level long-term climate plans mostly have vague plans related to NETPs, showing clearly a gap in the potential NETPs demand for mitigation, and the actual level of action.

Vision workshop and pre-questionnaire

The first Vision workshop was organized virtually on 18th December 2020, with over 80 participants. Before the workshop, a pre-questionnaire had been sent to stakeholders, attaining 39 responses.

The pre-questionnaire was built to gather viewpoints on the following aspects:

- The level of awareness on different NETPs;
- The role of different NETPs in global and European perspectives in medium and long term;
- Respondent's own vision on NETPs from their professional viewpoint (e.g. technology preferences, relation of NETPs in respect of emission reductions, timing);
- The main barriers for their NETPs vision foreseen by the stakeholders.

The questionnaire was complemented with on-line polls during the Vision workshop. The workshop and the questionnaire helped to include the stakeholder views to the NEGEM vision work. For example, three different roles for NETPs were identified, reflecting different emphasises:

1. NETPs can be seen as a complementary measure to emission reductions, giving high priority to concerns of them replacing the emission reduction efforts.
2. If the urgency of climate change mitigation is highlighted, fast employment of NETPs can be considered justified.
3. NETPs can be seen as a tool to raise the ambition of climate change mitigation.

Preliminary Vision

The initial NEGEM vision was compiled based on the literature review, taking into account the views of the wider audience by the Vision workshop and the results of the pre-questionnaire. The initial vision will guide the work carried out by different WPs in NEGEM project, and is summarized as follows:

NEGEM should increase the holistic understanding of NETPs, including co-benefits and trade-offs and eventually enlarge the portfolio for NETPs. NEGEM will consider techno-economics and commercialisation pathways, environmental impacts, social aspects and risks in its analysis of "realistic potentials" of NETPs to reach the climate goals of Paris Agreement. NEGEM will make those accountable for decision-making beyond only looking into negative CO_2 emission balance accounting.

It is acknowledged and recognized in the vision-building work that there are many definitions and different understandings of the term "vision". In general, the work presented in this deliverable builds on a definition of a vision representing a desirable outcome or goal. As desirable outcome, the vision for the role of NETPs may differ according to values of individuals or organisations they present, or differences in geographical or stakeholder positions, etc. The preliminary vision formulated above strongly builds on a promise of neutral scientific results that NEGEM as a research project delivers. This approach makes it possible to a significant extent meet the identified criteria for the vision: wide acceptability among stakeholders; inclusion of concrete, evidence-based information on the role of NETPs; environmental sustainability; instrumental for European policymaking; and significant contribution in European climate change mitigation efforts.

The work carried out in WP8 will continue by framework and pathway creation (Task 8.3) by selecting the scenarios for the NEGEM analysis. During the second phase of the NEGEM project, realistic global and EU level potentials of NETPs will be modelled with TIMES-VTT IAM by using the data and results from WP1-WP7. Results of these quantitative assessments will be published in D8.2. In the end of the project, Task 8.5 will formulate recommendations based on the WP1-WP8 analysis and conclusions will be drawn on realistic and sustainable potentials of the NETPs. The NEGEM recommendations will be reported in D8.4. As described in the report, the vision will be updated though the project lifetime. The next updated vision will be presented in D8.7 and the final NEGEM medium-to-long-term vision will be documented in D8.3.

Policy relevant messages

- To reach the climate targets of the Paris Agreement, carbon dioxide removal (CDR) is needed but as a complementary measure to greenhouse gas emission reductions. NEGEM scenarios would consider all the mitigation options to reach the climate targets of the EU and globally.
- Due to urgency of climate change mitigation, fast deployment of NETPs is justified. NETPs can also be seen as a tool to raise the ambition of climate change mitigation. Scenario analysis carried out in NEGEM would consider the alternative levels of ambition in GHG mitigation at the EU and global levels.
- There is lack of knowledge to make definite conclusions on the sustainable potentials of NETPs at the EU and global levels. There are especial concerns on environmental sustainability of NETPs. NEGEM results would support in elaborating sustainable potentials by considering both the demands and sustainable supply of NETPs taken into account the planetary boundaries.
- Based on the 1st vision workshop results, the major barriers for the implementation are the economic performance of NETPs and lack of common EU policy framework. NEGEM would create new and synthesized information on the economic performance, commercialisation pathways and formulate policy recommendations for NETP deployment.
- There is a lack of social awareness and low commitment of people to foster the CDR. NEGEM will investigate the perceived socio-economic potential of NETPs and its social license to operate.

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Introduction

The primary objective of the WP8 of the NEGEM project is to create a clear and shared medium-to-long-term vision on the sustainable potentials of the Negative Emission Technologies and Practices (NETPs) and their role in the greenhouse gas (GHG) mitigation at the EU level and globally. Secondly, the objective is to create an analysis framework, which will give a guidance on how to create, select, analyse and disseminate pathways to reach the climate targets of the United Nation's Paris Agreement (1) in a broader perspective including renewable energy, nature-based solutions and carbon capture and storage.

The aim of Deliverable 8.1 of *Task 8.1 Scenario Selection* is to present a preliminary NEGEM vision, based on literature review and the first NEGEM Vision workshop organized virtually on 18th December 2020. In this report we review the most recent peer reviewed climate and energy scenarios, recent extensive literature reviews on NETPs in peer reviewed articles, as well as selected scenarios published in the "grey literature" by the European Commission, international organisations, research institutes, stakeholders, NGOs and governments. The literature and data were gathered during the fall 2020 so that initial findings were presented in the vision workshop. During the 2nd phase of the NEGEM project, we will partly update the review with the new literature when it comes to global and EU level scenario modelling, e.g. in D3.9, D8.2 and D8.6.

We can describe the literature analysis more like illustrative, as it does not give a comprehensive review or analysis of the available literature. Literature analysis of the peer review articles have recently been published and, on the other hand, we wanted include examples of the recent scenarios, which have been published by the most reviewed organisations, like the IEA. The illustrative nature of the review is especially valid in the national level analysis, which should be kept in mind while reading the report. However, the motivation to include also some examples of the grey literature on global and national scenarios was to test and demonstrate the first steps the of the NEGEM framework for scenario selection. The NEGEM framework is formulated in the Task 8.3 during the whole project lifetime.

The scenarios analysed will be used as a starting point for the scenario work in NEGEM, allowing to explore the analysis methods, data and aims of the scenarios. In addition, we report the NEGEM vision making process, including the results of the 1st NEGEM vision workshop and the background questioner sent to stakeholders.

During the 1st phase of the NEGEM project the research will be based on analysis of the existing scenarios. This selected "scenario framework" should represent different storylines with different assumptions on NETPs, and different objectives of the scenario analysis. With a literature review on recent scientific and grey literature, the D8.1. draws the picture on existing knowledge, expectations and concerns of the role of NETPs in reaching the global and EU level climate targets, in line with the Paris Agreement. In addition, the report gives some country level examples on how NETPs have been considered in their climate and energy strategies. The literature analysis provided background information for the Vision workshop and preliminary vision formulation. In addition, literature analysis guides the scenario selection for NEGEM analysis during its 1st phase, which will be carried out in collaboration with WP3, WP4, WP7 and WP8.

Based on the internal interviews of the NEGEM partners, the mitigation scenarios relevant for the NEGEM analysis and quantitative modelling were identified together with WP3, WP4, WP7 and WP8. Based on the interviews, the scenarios reported by the IPCC (Intergovernmental Panel of Climate Change) Special Report on Global Warming of 1.5 °C (3) were assumed to be the most relevant for the NEGEM analysis. Therefore, we have included a data analysis of the IPCC scenarios, which are included in the IIASA database for peer reviewed 1.5 °C scenarios (2). However, we were not yet able to define the exact 1.5°C-consistent pathways, e.g. the so called shared socio-economic pathways (SSPs), which are defined by different

assumptions on future population levels, secular trends in economic growth and income convergence, behavioral change and technological progress (IPCC SR 1.5, 2019). Some findings on this are discussed in recent scientific literature reviews summarized in Section 1.1., and this work will continue in NEGEM. The final scenario selection will be done in collaboration with WP3, WP4, WP7 and WP8 in 2021 as soon as the work of all these WPs has proceeded.

D8.1 describes the start of the vision work in NEGEM. The aim of the vision work is to set the ground for a clear, shared, medium-to-long term vision on NETPs, with a focus on their sustainable potentials and on their role in contributing to the climate targets at EU and global levels. The aim of the initial vision (or vision statement) is also to guide the NEGEM work done during the first stages of the project by concretizing the existing expectations, knowledge by the policymakers, stakeholders, researchers, etc. In addition to the literature review, the formulation of the preliminary vision is based on the 1st NEGEM vision workshop and the background questioner sent to stakeholders. The results of these are described in detail in the latter part of the report. The vision work will be on-going throughout the project, and the vision will be complemented with the findings from other WPs.

This report has been organised in five chapters. In Chapter 1, the summary of recent extensive literature reviews on peer reviewed articles with NETPs as well as the scenario analysis with NETPs reported in the IIASA database are shown. Chapter 2 summarises the scenarios with NETPs in “grey literature”. The results of the web-based questionnaire and 1st vision workshop are given in Chapter 3. The preliminary NEGEM Vision is formulated in the Chapter 4, and in Chapter 5 the report concludes with next steps.

1 Summary of the peer reviewed articles with NETPs

Increasing amount of articles is reporting on the role of NETPs to reach the 1.5 °C mitigation goal of the Paris Agreement (PA), which is the primary scope of the NEGEM research. To support the scenario and vision work of the NEGEM project a literature stocktake is done. We concentrate on extensive recent literature reviews done on climate change mitigation scenarios with NETPs and on "grey literature", which is often left out from literature studies for NETPs. In addition, a short data analysis of the IPCC scenarios, which are included in the IIASA database for peer reviewed 1.5 °C scenarios (2) is completed. The D1.1 of the NEGEM project included the more in-depth analysis of different NETPs, including estimations on their costs and potentials, which is therefore beyond the scope of this report.

1.1 Findings from earlier literature reviews on mitigation scenarios with NETPs

Recently, extensive scientific literature reviews on NETPs have been published and some of them are shortly summarised here.

Hilaire et al. (2019) (4) analysed the role of NETPs in 1.5 °C and 2 °C scenarios based on scientific literature published by 2018, and altogether 138 studies were reviewed. They present the first review of the NETPs scenarios, where also the qualitative findings of individual studies are considered (excel with synthesis of the 138 studies on NETPs into 66 summary statements). They link the systematic assessment of individual findings to the literature base and evidence from scenario data. They conclude that a rapid large-scale deployment of NETPs is needed to keep warming below 1.5 °C and found no scenarios where warming could be limited below 1.5 °C by 2100 without NETPs. For 2 °C target the need for NETPs can be limited with ramping up the near-term ambition for mitigation. They state that: "Temporal discounting is the main factor driving these dynamics. Indeed, by giving a lower weight to the costs of future mitigation actions, the use of a constant discount rate (generally 5%) during the twenty-first century makes the use of NETPs in the second half of the century an economically attractive mitigation option that allow costly near-term emissions reductions to be postponed."

Hilaire et al. (2019) (4) also highlight that BECCS is the only NETP available in most of the mitigation scenarios. However, also other NETPs, especially afforestation, DAC, enhanced weathering are increasingly present in the scenarios. The availability of several NETPs, makes it easier to manage the NETPS related risks, which are often scale dependent. They highlight that NETPs should be studied under Planetary Boundaries and Sustainable Development Goals as well as from political and business perspectives. To these questions research done in NEGEM aims to provide answers.

Minx et al. (2018) (5) synthesize a large amount of NETPs literature and provide an in-depth assessment on the role of NETPs in climate change mitigation scenarios. They also discuss on the challenges involved in bringing NETPs to the market and scaling them up in time. Minx et al. (2018) (5) conclude that the introduction of NETPs in cost-optimising mitigation scenarios helps to reduce the costs of long-term mitigations. However, it makes the short-term emission reductions more challenging. In addition, they state that it will be difficult to reach the mitigation needs addressed for NETPs in scenarios with a single NETP solution. However, there is an asymmetry on the immediate availability, effectiveness and safe storage and costs and potentials across NETPs.

Minx et al. (2018) (5) also found out that the future dependence on NETPs in the mitigation scenarios (both 1.5 °C and 2 °C) significantly depend on future socio-economic conditions. They highlight that the need for NETPs is much lower in scenarios assuming a world with "sustainability narrative" for the social development (e.g. high levels of education, lower population, less inequality) compared to a world with fossil-fuel dependent development. Therefore, they recommend that in addition to climate policies

defining how to reduce GHG emissions, also non-climate policies should help in the transition between alternative future worlds.

Second part of the review series started by Minx et al. is by Fuss et al. (2018) (6), who have especially focused on costs, potentials and side effects of NETPs. They have recognised two major purposes for including NETPs in the mitigation scenarios: First, NETPs are used to compensate temporary exceed of carbon budget. However, this compensation can come with a penalty, as the cooling from negative emissions can only offset a part of the warming from earlier positive emissions. Second, especially in the second half of the century, NETPs are used to compensate between different sectors, e.g. to offset emissions that are difficult to abate in industry, agriculture or transportation.

In 2°C scenarios, high energy efficiency improvements and aggressive energy savings provide flexibility in achieving climate goal, and lower NETPs deployment is possible. Fuss et al. (2018) (6) state that the restriction of NETPs in 1.5°C scenarios often results to model infeasibility. However, recent findings have shown, that NETPs use can be restricted to some degree with specific socioeconomic scenarios including conditions such as low energy demand, sustainable consumption patterns and high crop yield improvements. Based on literature, Fuss et al. (6) have found new evidence that the socio-economic developments assumed significantly affect the role and importance of NETPs in the mitigation scenarios. They also highlight the need for the discussion on how the changes consumption patterns, energy demand and international cooperation can affect the mitigation trajectories and demand for NETPs. Fuss et al. (6) conclude that "The window of opportunity for limiting NETs dependence is closing rapidly due the cumulative warming effect of CO_2 in the atmosphere and the lock-in of large-scale carbon-intensive infrastructure."

Third part of the literature review series is by Nemet et al. (2018) (7) on innovation and upscaling of NETPs. They highlight the urgency for developing NETPs, as results from integrated assessment models show that the major period of new NETPs deployment is already between 2030 and 2050, even though their major contribution would be after 2050. This urgency seems to be highly unrecognised, even though it is known that generally long time periods are required for widespread adaptation of new technologies. They recognise important issues that will need to be addressed for faster upscaling of NETPs, such as including incentives for early deployment, niche markets, and public acceptance. Nemet et al. (7) divide the innovation activities in two categories: Supply side activities relate to improvements and demonstration of costs and performance of the technology, while demand side activities involve the marker developments, how NETPs are used and by whom, and the broader public acceptance. They conclude that "The heterogeneity of these technologies, especially in their limitations and adverse side effects, strongly suggests a portfolio-based risk management approach to scaling up NETs, rather than a singular focus." Nemet et al. highlight that meeting the removal potentials that are required from NETPs in the mitigation scenarios, hundreds of large scale BECCS facilities should be established each year, DACCS would involve transporting CO_2 to thousands of storage facilities, and soil C enhancement and biochar would require actions of millions of farmers. Thus, the attitudes and preferences of these actors are essential.

1.2 Scenarios with NETPs reported in the IIASA database

NETPs are relatively well represented in scenarios that have been studied by Integrated Assessment Models over the recent years. One of the most recent scenario databases hosted by the IIASA is the IAMC 1.5°C Scenarios Database (2), which contains results for almost about 350 scenarios that have NETPs

represented, and at least 275 of those have NETPs active in their solution at notable levels (≥ 1 $GtCO_2$/year), as summarized in Table 1.

One can clearly see from the IAMC 1.5°C Scenarios Database that according to many IAM models, the role of NETPs would become quite large under stringent climate policies. Among the 275 scenarios that were found to manifest over 1 $GtCO_2$/year of NETPs in 2100, the median value for BECCS was 3,300 $MtCO_2$/year in 2050 and 10,840 $MtCO_2$/year in 2100. The median amount for 2100 would thus correspond to over 100 EJ of bioenergy being utilized with CCS in 2100. In comparison to the current global use of primary biomass for energy (about 50 EJ), the utilization under CCS applications would need to be double as large. That could possible with a significant expansion in dedicated energy crop production, and with the extensive use of biomass in power and heat generation, fuel refineries and industrial processes with modern energy conversion technologies. Nonetheless, the *median* by itself may already be considered a somewhat optimistic estimate, and any projections with over 15 $GtCO_2$/year of BECCS can be assessed to entail significant uncertainties.

For afforestation, the database also included a good number of scenarios, showing a median value of nearly 5 $GtCO_2$/year removal potential by 2100. The variation among the afforestation projections is somewhat smaller than that for BECCS, which may thus indicate less uncertainty in the economic potentials. Interestingly, the spread of the estimates was higher in the shorter term (until 2060) than in 2100.

Concerning the DACCS (Direct Air Capture with carbon capture and storage), the database included only 8 scenarios, and thus does not yet give a very good picture of the possible role of DAC as a NET option. However, the uncertainties for DACCS are inherently smaller than for BECCS. Finally, for enhanced weathering and soil carbon management options, the database included only one scenario for each, and thus gives minimal information about their potentials.

Table 1 Summary of scenarios having each NETP active in the solution in the IAMC 1.5°C Scenarios Database.

NETP	Number of scenarios	Median value in 2050, $MtCO_2$/yr	Median value in 2100, $MtCO_2$/yr
BECCS	266	3,300	10,840
DACCS	8	50	6,420
Afforestation	51	3,790	4,740
Enhanced weathering	1	1,200	2,500
Soil carbon / biochar	1	3,600	3,500
Total NETPs	**275**	**11,940**	**27,950**

Looking at the median estimates in the IAMC 1.5°C Scenarios Database for all NETPs combined, we arrive at a total estimate of almost 30 $GtCO_2$/year negative emissions in 2100 (Figure 1). One can immediately see that such an amount would have an extremely important role in the total climate change mitigation measures. Although one should bear in mind that this total is obtained only from the median values, it seems that the highest estimates for BECCS (> 20 $GtCO_2$/year) are most likely unrealistically high. However, none of the IAMC scenarios exceed 20 $GtCO_2$/year of BECCS before 2065.

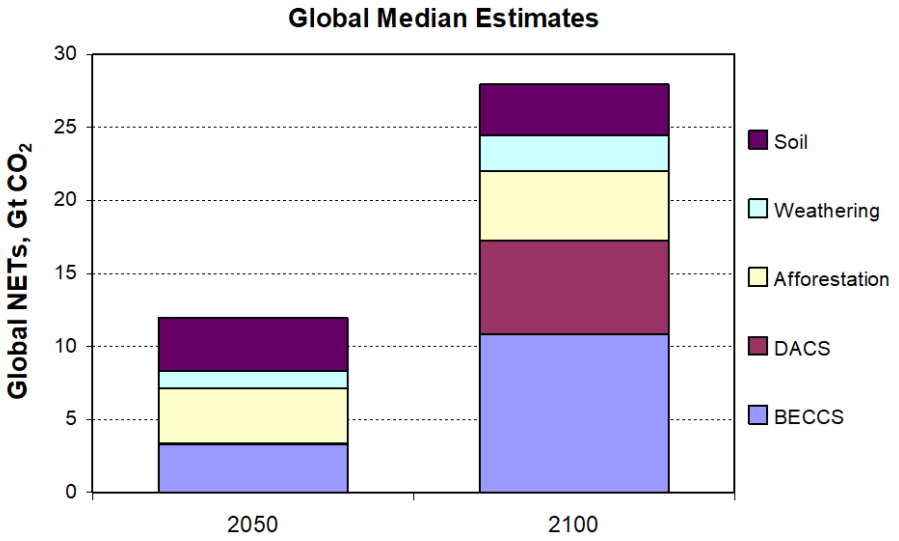


Figure 1 Scale of NETP deployment per year in the IAMC 1.5°C Scenarios Database, median values over all scenarios having each NETP active in the results.

It is also important to note that both BECCS and DACCS depend on CO_2 storage systems, the potential of which may become the limiting factor for both. However, if sufficient and both economically and environmentally viable storage capacity can be identified, DACCS would actually not have other significant constraints for sustainable deployment at any perceivable scales in the scenarios. However, DAC is very energy intensive, so it can be questioned, if the available low carbon energy is prioritized for the use of DAC.

Due to the fact that BECCS has been usually the most important NETP in integrated assessment modelling, and still is by such in the IAMC 1.5°C Scenarios Database, it is also useful to have a closer look at the distribution of the BECCS utilization levels among the various scenarios until 2050, which is the crucial timeframe for successful climate change mitigation. As shown in Figure 2, by 2050 the role of BECCS is projected to be within the range of 0–15 $GtCO_2$/year and in most scenarios the scale of deployment lies within 1–6 $GtCO_2$/year by 2050. How these amounts may be distributed among world regions is another interesting matter, in particular concerning Europe. Unfortunately, the IAMC database does not include EU or Europe as a region, but Figure 3 shows the BECCS deployment for OECD total. According to the regional projections, OECD would account for around 30% of the global BECCS deployment by 2050, and slightly less by 2100. In further scenario work of the NEGEM project, a more in-depth analysis on the background assumptions on the scenarios, as well as on European level data will be continued.

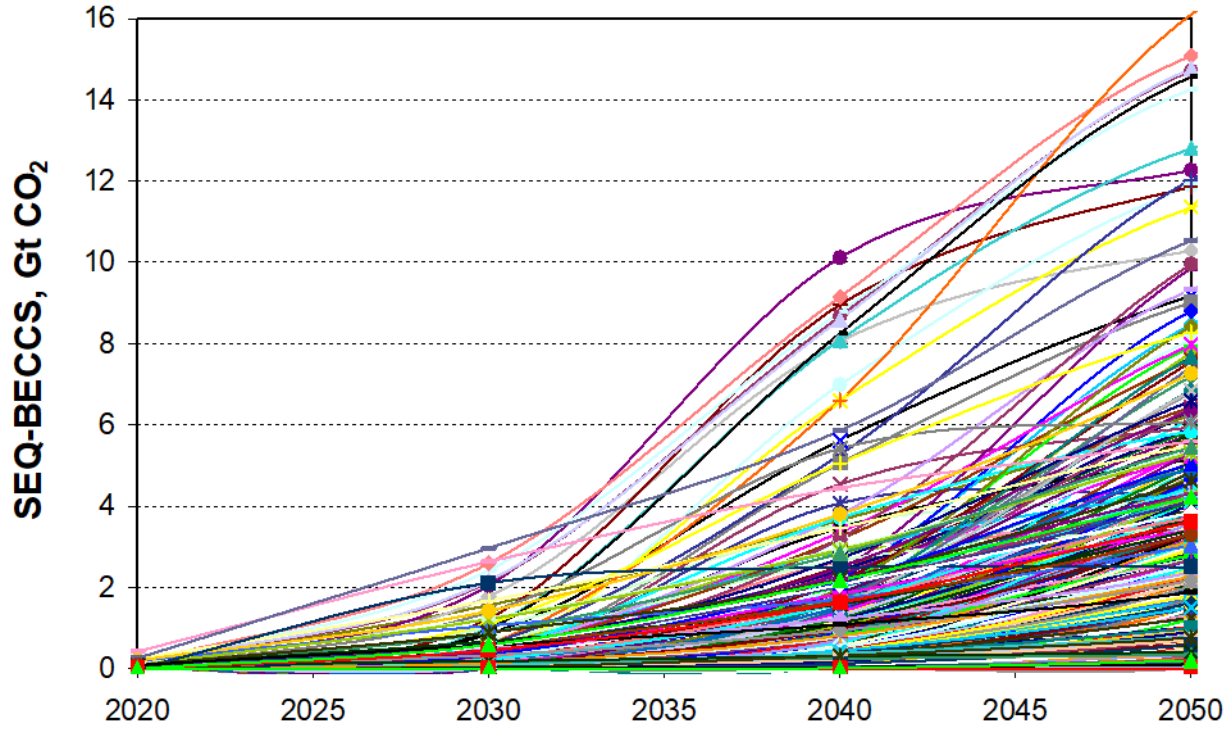


Figure 2 Set of BECCS deployment curves on the global scale until 2050, as projected in the global IAMC scenarios ($GtCO_2$/year).

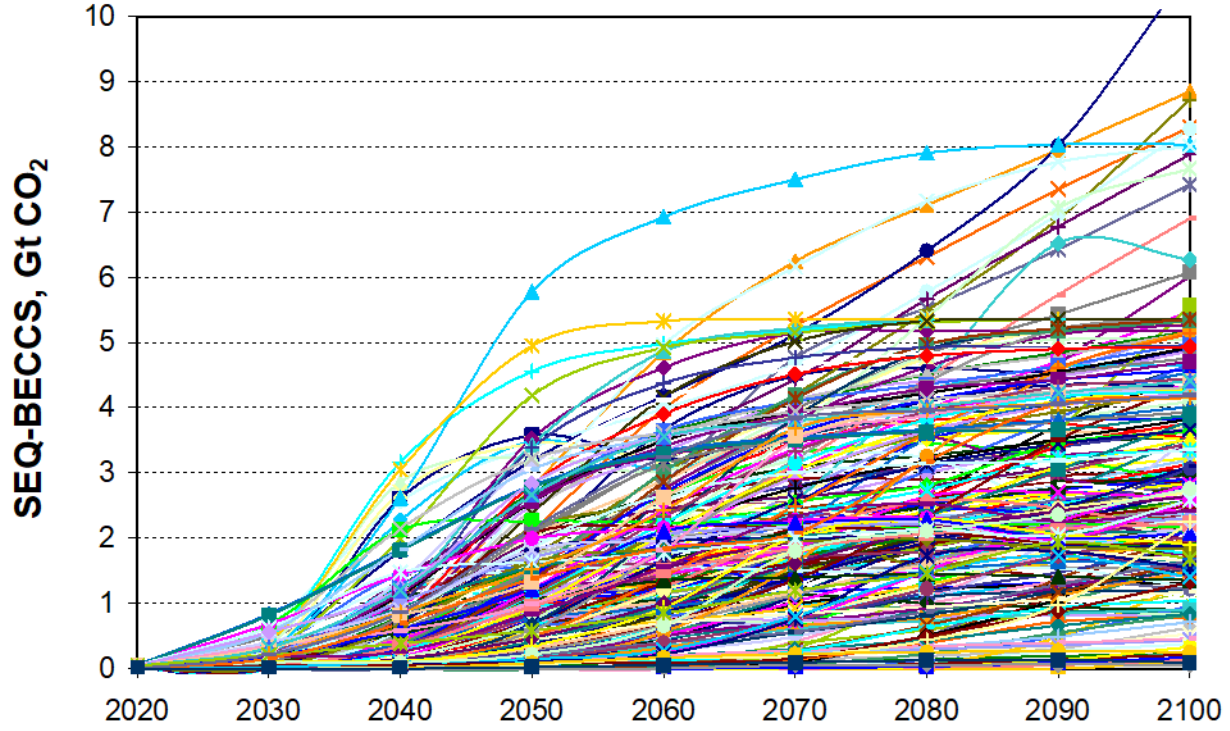


Figure 3 Set of BECCS deployment curves for the OECD until 2100, as projected in the global IAMC scenarios ($GtCO_2$/year).

2 Summary of the role of NETPS in grey literature

To complement the findings from scientific literature, we studied NETPs in grey literature. We made an illustrative review of recent reports from known international and EU organisations, NGOs and companies to track the role of NETPs in climate change mitigation scenarios. In addition, we went through several national long-term climate strategies to see how frequently and with what accuracy NETPs are mentioned in the national level planning. The review is based on the materials available at the time of collecting the data and literature between September and December 2020. As the scope of the review is illustrative, it is acknowledged that e.g. modelling analyses to be completed later will benefit from inclusion of updates on the evolvement of national medium and long-term climate strategies. Hence, the upcoming NEGEM WP8 scenario modelling analyses will be completed with up-to-date information in when appropriate.

For the global scenarios, we have selected examples, which have been prepared and reported by commonly known and/or mostly reviewed organisations or companies, like International Energy Agency (IEA), International Renewable Energy Association (IRENA), WWF and Shell. In addition, global scenarios by the EU's Joint Research Centre (JRC) were included in this comparison. For the EU level analysis, we have reviewed long-term scenarios reported by the European Commission. In addition, we have included a summary of the National Energy and Climate Plans (NECPs) of the EU Member States (MSs), which gives a good overview of the status of the NECPs in more official national energy and climate scenarios. The progress reports of the NECPs need to be delivered by the Member States to the EU in 2022 meaning that there will be new information available during the second phase of the NEGEM project.

The results of the review were documented in an Excel file, which can be found from Annex 2 (added as a separate Excel file).

In the Excel file, the scenarios and the reports were reviewed based on the following points (Table 2), and below we discuss on findings from the bolded sections:

Table 2 Structure of the literature review

Structure of the literature review
- Author of the report (organisation / country)
- Year published
- Name of the report
- Approach used (e.g. policy support, aim of the report)
- Models used
- Scale (Global, EU, other?)
- Name of the scenario
- **Climate target of the scenario**
- **Role of NETPS in Gt**
o at 2030, 2040, 2050, 2060, 2070, 2100
- Emission reduction by negative emission **technologies mentioned** (x) / their contribution (Gt)
o BECCS Afforestation/soil C; Biochar; DACCS; Ocean based; Enhanced weathering; Other
- **How is land use/C stock development included?**
- **Capacity of CO_2 storage infra mentioned?**
- **Conclusion on NETPS**
- Other remarks
- Available

2.1 The role of NETPS in global scenarios

The role of NETPs in climate change mitigation scenarios at global level was studied from reports of IEA (8–10), IRENA (11), JRC (12), Shell (13), and BP (14). The scenarios generally target either to net-zero emissions after 2050 or to Paris Agreement's targets (2°C or 1.5°C warming). BECCS and DAC are the NETPs technologies most often included, but also afforestation, biochar and carbon capture and utilisation (CCU[1]) technologies are mentioned. Figure 4 shows that before 2050 the potential of NETPs in different scenarios is clearly under 2 GtCO2/year. After 2050 their role is expected to grow in the global scenarios. In the JRC scenarios the difference in NETPs use between 1.5°C and 2°C scenarios occurs in years 2060-2080, where NETPs (especially DAC) are adopted faster in the 1.5°C scenario. However, the final contribution of NETPs in 2100 is similar in both scenarios.

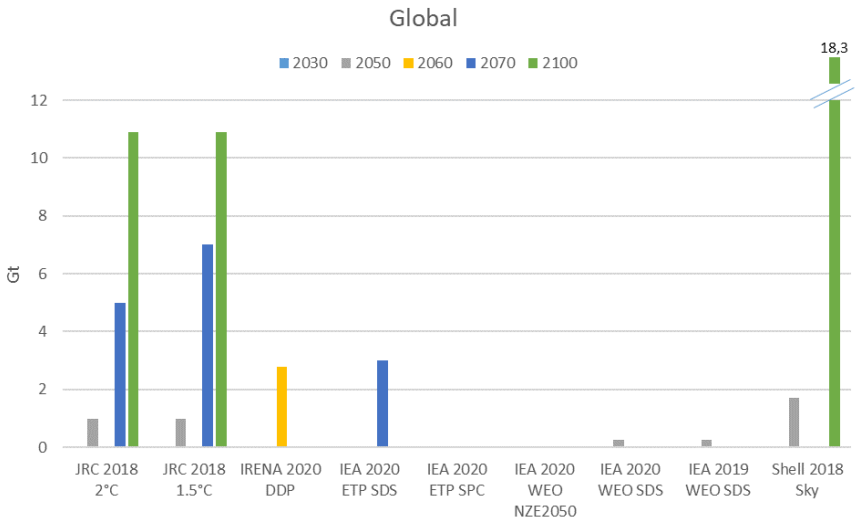


Figure 4 Examples of the NETPs potential estimates in global scenarios.

Several general conclusions on the NETPs were gathered from the reports. It seems that all agree that deep emission cuts are needed and that there is a need for NETPs. JRC (12) and IEA (8,9) both agree on the need on NETPS but are somewhat careful when it comes to estimating their potential. JRC states that negative emissions technologies will be restricted by constraints such as biodiversity limits to biomass use, saturation of LULUCF sink, and energy cost of DAC. Therefore, the NETPS are not mobilised much more in 1.5°C scenario than in 2°C scenario. The IEA WEO 2020 (9) concluded that "the amount of CO_2 captured with CCUS in 2030 in the NZE2050 (1 150 Mt) is less than the level captured in half of the IPCC 1.5 °C scenarios. The 35 Mt CO_2 captured through BECCS in 2030 in the NZE2050 is less than the level captured in 60% of the scenarios." The IEA WEO 2019 concluded that : "The Sustainable Development Scenario uses around 80 EJ (1 900 Mtoe) of bioenergy in total in 2050, and around 0.25 Gt CO_2 is absorbed from the atmosphere in that year through the use of BECCS, compared to a median of 4.7 Gt from scenarios in the IPCC SR1.5 database of scenarios (IPCC, 2018)." It seems clear, that IEA estimates much lower potential for NETPs than the median estimates on NETPs demand in the IPCC scenarios.

BP (14) did not include quantitative estimation on NETPs potential but they estimated that by 2040 CO_2 emissions from energy use fall by around 45% relative to current levels, and around 18 $GtCO_2$ emissions

[1] CCU may be sometimes considered to create negative emissions, if CO_2 used as raw material is permanently stored in the material produced (e.g. for over 100 years, or in closed recycling cycle).

would still remain in the sector. Similarly, Shell Sky scenarios (13) show that even if the whole current energy system has changed or is in transition in 2070, remaining fossil fuel use leads to emissions of around 15 $GtCO_2$ per year, reducing to 11 $GtCO_2$ by 2100. Therefore, both conclude that CO_2 sinks and negative emissions are needed.

In IEA ETP 2020 (8) the role of CCUS (carbon capture use and storage) is discussed. It is stated that the role of CCUS changes over time. First, the focus is on decarbonising the power sector and heavy industries whereas later the focus in on CO_2 removal from atmosphere to offset emissions that are hard to abate otherwise.

Even though BECCS is generally seen as the most promising NETPs option, the models do not always capture the developments in the land use (LULUCF) sector. Some of the models cover bioenergy supply and demand, and may give restrictions on the biomass availability, but they do not capture the possible impacts on land and forest carbon (C) sinks and storages due to increased bioenergy use. Many of the global scenarios are aimed to study the development of the energy and industrial systems, so modelling of the land use sector has not been in their scope. However, this limits the ability of the scenarios to illustrate the possible trade-offs between bioenergy use and the development of C stocks and sinks.

The CO_2 storage facilities are discussed by JRC and IEA. JRC (12) remarks that global estimates on the storage vary significantly, between 1,700 $GtCO_2$ and 10 times that figure. They also highlight that as the storage capacity greatly varies between countries and the storage facilities are often situated in remote locations, an industrial-scale cross-border CO_2 transport needs to be established. Several possible barriers are recognised by JRC: CO_2 transport and storage infrastructure costs; uncertainty over storage capacity; uncertainty of the long-term management of storage, with potential environmental concerns in case of leakages; and general public acceptance.

In addition to the global scenario studies, EASAC (2018) (15) has published a literature review and a system-wide overview of candidate negative emission technologies. Their report includes also a critical analysis of future potential of NETPs (included in Annex 2 excel). E.g. the estimation for BECCS and DACS potential post 2050 are both 3.3 $GtCO_2$/year They conclude that scenarios without NETPs show great difficulty in reaching net zero emissions of CO_2 by 2050. However, they also conclude that the limited potential for CO_2 removal underlines the need for significant efforts to mitigate emissions in order to make the need for NETPs more manageable.

WWF (NGO) has gathered background data on NETPs in their discussion paper on “Carbon Dioxide Removal and the 1.5°Climate target” (16). They discuss on different scenarios and different ways to get to the 1.5°C target. They also summarise information on radical change scenarios, where 1.5°C target could be achieved without NETPs (apart from afforestation) based on (17,18). These scenarios demand radical changes such as low carbon energy, renewable electrification, agricultural intensification, education rise and reduced fertility, and lifestyle changes taking place simultaneously, or radical changes such as digitalisation of global south and lifestyle changes in global north combined with overall sustainable development.

2.2 The role of NETPs in the EU

The role of NETPs in climate change mitigation scenarios at European level was studied from reports of European Commission. In 2018 Commission published In-Depth Analysis in Support of the Commission

Communication COM(2018) 773 “A Clean Planet for all A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy” (19) and in 2020 impact assessment accompanying the document "Stepping up Europe’s 2030 climate ambition" SWD(2020) 176 final was published (20) (here NETPs referred to as “carbon removal technologies”). In 2018 report, the scenarios aim to 80-100% emission reduction in the EU at 2050 compared to 1990 including or excluding the sinks, whereas in 2020 report the target is climate neutrality in the EU at 2050. BECCS, afforestation and DAC are the NETPs technologies mostly discussed. Figure 5 shows that the role of NETPs (BECCS) vary between 0.05 - 0.25 $GtCO_2$/year in EU at 2050. The Commission report 2018 (19) concludes that carbon dioxide removal technologies are part of the solution and should not be disregarded. The EU’s role could be to test and develop the NETP solutions to serve the global needs.

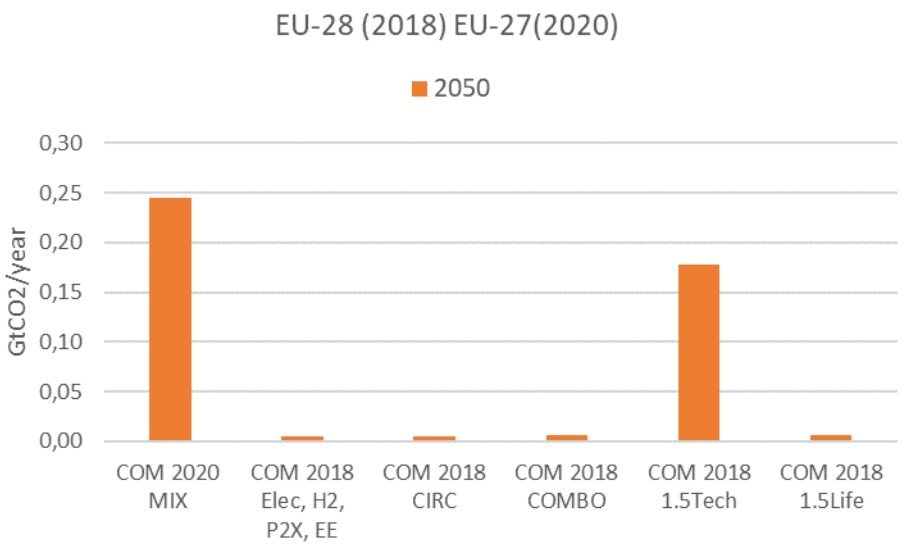


Figure 5 Examples of the BECCSs potential estimates in the EU scenarios. (Value for COM MIX scenario is estimated from a figure, thus being illustrative.)

The EU Commission 2020 impact assessment (20) concludes that in the EU the total negative emissions including LULUCF sector and NETPS needs to be around 0,5 $GtCO_2$/year by 2050, in order to enable climate neutrality. In the EU level scenarios the land use sector is included, so also the development of the natural C sink can be followed. When looking at the scenario results, it seems that in the 1.5 Tech scenarios where more BECCS is used, the natural C sink stays at lower level than in the 1.5 Life scenario, where less BECCS is used. Similar behaviour of the scenarios can be noticed from some national assessments (see below). However, there are several assumptions changing simultaneously between the scenarios, so no direct conclusions on possible trade-off between BECCS and natural C sinks can be drawn. In 1.5 Life scenario, there are more dietary changes assumed, letting more land available for afforestation. This reduces the reliance on BECCS. In addition, in 1.5 Tech scenario, more bioenergy is produced from lignocellulosic grass and short rotation coppice, and less forest land and non-productive grassland and shrub is available than in 1.5 Life scenario. Thus, many assumptions impact the results, and one cannot directly conclude that increased use of BECCS would cause a trade-off with the enhancement of the natural C sink.

The EU Commission Impact Assessment 2020 (20) highlights the importance of enhancement of the LULUCF sinks in the EU. Currently, the development is towards decreasing sinks (Figure 6), based on the Member States reports on the LULUCF developments (21) (i.e. the development of the forest C sinks based on submitted Forest Reference Levels). It is stated that the need for the C sinks depends on the availability of the NETPs (or in other words, the need for NETPs depends on the development of the sink).

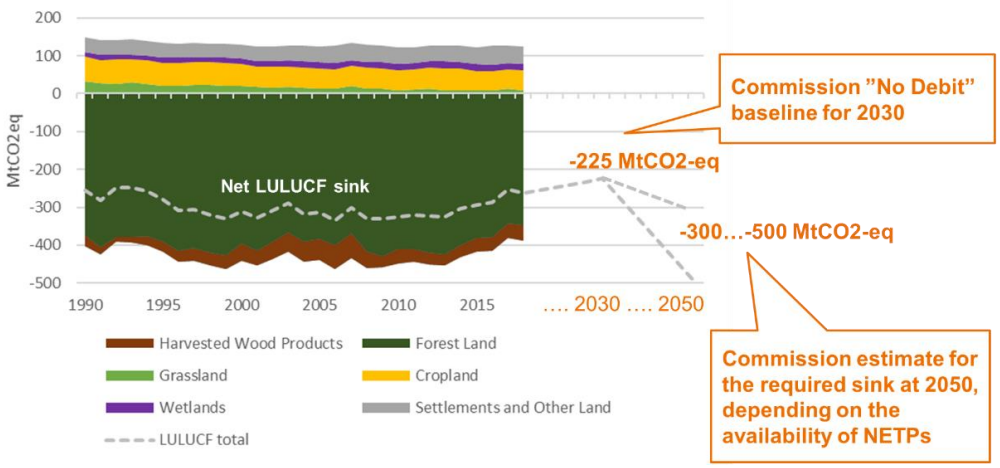


Figure 6 Development of the LULUCF sink in the EU Member States (future projections based on COM 2020)

Commission reports mention the CO_2 storage facilities and especially the acceptability issues related to long-term CO_2 storage. It is concluded that the social acceptance for onshore storage sets a barrier for its development in Europe. Therefore, CCS projects under development plan to store CO_2 offshore, e.g. in storages below seabed. Public consultation included in the Commission 2018 study indicated preference for carbon capture and long-term utilization rather than carbon capture and underground storage. In the consultation, significant concerns on BECCS were found related to the actual emissions savings achievable, the energy inputs needed and the diversion of resources from other technologies.

In addition, a 1.5 °C energy scenario by Climate Action Network Europe and The European Environmental Bureau (NGOs) was also reviewed (22). This Paris Agreement compatible (PAC) scenario suggests a pathway with at least 65% greenhouse gas emission reductions in the energy sector by the year 2030 and a 100% renewable energy supply by 2040. Thus, it shows a scenario, where zero emissions on energy sector are reached without application of NETPs. However, it assumes radical reduction in energy consumption and increase of renewable energy production (especially solar, wind and ocean energy, as well as ambient and geothermal energy for heating).

2.3 NETPs in European long-term climate strategies

The EU Member States need to prepare national long-term climate strategies every 10 years, and the first set of the long-term strategies is currently being published by the EU Commission[2]. Here we shortly reviewed the role of NETPS in the national strategies submitted by 11 December 2020 (except the Greek strategy due to limited language skills). For English versions, also the UNFCCC[3] site on long-term strategies was used.

[2] The national strategies available from: https://ec.europa.eu/info/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-long-term-strategies_en

[3] The national strategies available from: https://unfccc.int/process/the-paris-agreement/long-term-strategies

In the EU national strategies, only Austria, France and Finland had included quantitative estimates on NETPs demand (19, 10, 14 $MtCO_2$/year by 2050, respectively). The national estimations on NETPs potential seem to be on a similar magnitude, even though relatively higher estimates for smaller forestry intensive countries such as Austria and Finland are made. France and Austria discuss also on the CO_2 storage capacity, whereas Finland generally assumes that captured CO_2 will be exported for storage. BECCS and afforestation were the NETPs mentioned by most of the Member States (Table 3). However, e.g. Germany did not allow for CCS in its qualitative scenarios due to lack of acceptance, high costs and uncertainty about long-term ecological effects. For Netherlands (23) and Ireland (24), a separate study on NETPs was published at 2018. For Netherlands the estimated potential for NETPS was 34-150 $MtCO_2$/year and for Ireland the potential varied from 23-270 $MtCO_2$/year by 2100. (It is possible that these types of studies are published for other countries as well but were not yet found).

Table 3 Role of NETPS in the European long-term strategies

Country	Year	$GtCO_2$/y 2050	BECCS	Afforestation/ soil C	Biochar	DACCS	Ocean based	Enhanced weathering	Other	Ref
France	2020	0,01	0,01	x		x				(25)
Germany	2016			x						(26)
Spain	2020			x						(27)
Finland	2020	0,014	0,014							(28)
Sweden	2020		x							(29)
Denmark	2019									(30)
Belgium	2020		x	x						(31)
Czech	2017		x	x						(32)
Estonia	2017									(33)
Latvia	2019									(34)
Portugal	2019			x						(35)
Slovakia	2020			x						(36)
Austria	2019	0,0187	x						CCU	(37)
Netherlands	2019		x	x					wood products	(38)
Netherlands[4]	2018	0,034	0,017	0,0012	0,001	0,034		0,0014		(23)
Ireland[5]	2018		0,025	0,017	0,015	0,015		0,076		(24)
UK	2020	0,053	0,051	x	x	0,005		x	0,00044 (additional wood in construction)	(39)

Most of the Member States discuss on the enhancement of the natural C sinks. For example, sustainable forest management, fire prevention and improved agricultural practises are discussed in many of the reports. In some Member States, declining forest C sink is foreseen (often due to urban development or due to age structure of forests), putting even more pressure on other emission reduction measures.

Both, the Austrian and Finnish scenarios show again a selection of assumptions, where scenarios with increased use of CCS technologies are combined with lower forest C sinks, and scenarios with less CCS

[4] The realistic potential evaluated for NETPs is shown, also technical potential was reported.
[5] Average potential calculated used here, high and low potential reported.

with higher natural sinks. E.g. in the Finnish scenarios, the net LULUCF sink reached by 2050 is 15 Mt CO_2-eq larger compared to the WEM scenario under the scenario with less BECCS, and 10 Mt CO_2-eq smaller than in WEM under the scenario with more intensive use of BECCS. Again, as in the EU scenarios above, the Finnish scenario with higher sink and less BECCS use includes e.g. the assumption of more radical dietary changes. As several assumptions change between the scenarios simultaneously, their comparison is not straightforward.

In addition to EU Member States, Norway has submitted its long-term low-emission strategy for 2050 to UNFCCC. The target is to achieve emission reductions of the order of 80–95% from the level in the reference year 1990 by 2050. The strategy does not include analysis on NETPs. However, Norway discusses on a plan to develop a CO_2 storage site with considerably more capacity than is needed for emissions of Norway. If the project is realised, it will make possible for other industrial operators to store their captured CO_2 in the same facility rather than having to develop their own storage sites.

In 2019 UK Committee on Climate Change has published a Net Zero Technical report (40), which accompanies the 'Net Zero' advice report which is the Committee's recommendation to the UK Government and Devolved Administrations for a net zero emissions target in the UK by 2050. This report presents a quantitative analysis on need for NETPS. These analyses were updated in 2020 (39) and are shown in Table 3. Compared to 2019, the potential for DAC has been slightly increased due to new cost estimates. In addition, the 2020 report represents several scenarios with different storylines, and the variation for the need for NETPs is estimated between 45-112 MtCO2/year in 2050. The level of NETPs in the pathways "is dictated by the amount of remaining emissions needed to be offset, in addition to nature-based sinks, to reach Net Zero, and the pace of the transition to Net Zero, including the need to demonstrate engineered removals at scale". Again, the lowest need for NETPs is in scenario with highest levels of behavioural changes, e.g. in diets, reduced waste and reduced flying, leading to reduced residual emissions. The scenario also includes tree planting and higher natural removals than other scenarios.

2.4 NETPs in long-term climate strategies outside Europe

The UNFCCC[6] site on long-term strategies according to Paris Agreement was studied to find long-term strategies of other countries, and strategies of Japan (41), South-Africa (42) and USA (43) were reviewed.

- Japan's Long-term Strategy under the Paris Agreement aims for reduction of GHGs emissions by 80% by 2050. The NETPs technologies (BECCS, afforestation, biochar, DACCS, ocean-based technologies and enhanced weathering) are widely mentioned but no quantitative analysis is available. The report highlights that life-cycle assessment results on the effectiveness of NETPs are still limited and that e.g. DAC faces many challenges including significant energy input and need for cost reductions. Thus, more research and promoting of effectiveness and social acceptance is needed, as well as international collaboration. In addition, they discuss the CO_2 storage potential, which primarily located on the Pacific coast. Thus, the locations of CO_2 sources and suitable storage sites are not necessarily close to each other, and adequate business models are needed to enable safe and economically feasible CO_2 transport.
- South-Africa's Low Emission Development Strategy sets the target that "South Africa follows a low-carbon growth trajectory while making a fair contribution to the global effort to limit the

[6] The national strategies available from: https://unfccc.int/process/the-paris-agreement/long-term-strategies

average temperature increase, while ensuring a just transition and building of the country's resilience to climate change." The strategy discusses on afforestation, conservation agriculture farming methods and agroforestry as measures to increase C sinks, otherwise NETPS are not analysed. CCS is mentioned.

- USA's Mid-Century Strategy for Deep Decarbonization dates to 2016. It includes a separate section on the negative emissions, where decarbonization is studied with the negative emission technologies ("benchmark" scenario), and with scenarios where NETPs are limited ("No CO_2 Removal Technology", "Limited Sink"). The potential for NETPs in the benchmark scenario is around 0,6 $GtCO_2$/year by 2050, and in the "Limited sink" around 0,2 $GtCO_2$/year. In addition, a large section on the role of land and forest carbon sink enhancement is included. Role of BECCS is highlighted in the report. However, it seems that the CO_2 storage capacity is not discussed.

China has not submitted its long-term plan on the UNFCCC site, but recent information and studies on China's plans and the role of NETPs has been published. China has recently released its target to become carbon-neutral by 2060[7]. Tsinghua University Institute for Climate Change and Sustainable Development (ICCSD) and 18 other Chinese research institutes released their new scenarios on "China Low-Carbon Development Strategy and Transformation Pathways" of which an English presentation is available[8]. In these scenarios, the role of BECCS in China seems to vary between 0.51– 0.88$GtCO_2$/year in 2050, in 2°C and 1.5°C scenarios, respectively. Earlier, e.g. Pan et al. (2018) (44) have studied the role of biomass in China's long-term mitigation scenarios and foresee BECCS application of similar magnitude 0,01-1,4 $GtCO_2$/year at 2050. In their scenarios, 0.7-4.1$GtCO_2$/year of BECCS could be used in China at 2100, but no limitations are applied on biomass availability. Fuhrman et al. 2020 (not peer reviewed) (45) have estimated that China's 2060 carbon-neutrality target would require up to 2.5 $GtCO_2$/year of negative emissions technology deployment (including BECCS, DAC, afforestation).

2.5 Key findings from the literature review

Several key findings from the literature review can be listed:

- General conclusion is that NETPs are needed but there might be significant technological, sustainability and acceptability constraints related to them. A portfolio of NETPs has lower risks than application of just one NETP technology (e.g. BECCS).
- The recent literature reviews on mitigation scenarios conclude that achieving 1.5 °C target without NETPs seems to be unfeasible. For achieving 2 °C target, the need for NETPs can be limited with ramping up the near-term ambition for mitigation.
- The future need for NETPs significantly depend on the assumed future socio-economic conditions. The need for NETPs is much lower in scenarios assuming a world with "sustainability narrative" for the social development (e.g. high levels of education, lower population, less inequality) compared to a world with fossil-fuel dependent development.
- Many of the estimates for the potential of the NETPs in the grey literature seem to be lower than the demand modelled e.g. in the IPCC scenarios with Integrated Assessment Models (IAM).

[7] https://www.bbc.com/news/science-environment-54256826
[8] https://mp.weixin.qq.com/s/S_8ajdq963YL7X3sRJSWGg

- BECCS is the negative emission technology that is most frequently included in the quantitative scenarios. DAC is also analysed quantitively, but to a lesser extent. In the IAM scenarios, a good number of scenarios include also afforestation. Enhanced weathering or soil carbon are hardly included in any scenarios.
- The country level long-term climate strategies do not often include a quantitative analysis on NETPs. However, the NETPs are often mentioned and discussed.
- In the quantitative mitigation scenarios on EU and country level, GHG mitigation with behavioural assumptions behind the scenarios (e.g. dietary changes towards more vegetarian based diets) seem to have important impact on the demand of NETPs in the scenarios.
- The scientific literature shows the urgency for NETPs deployment to reach the targets modelled on the demand of NETPs. However, e.g. the country level long-term climate plans mostly have vague plans related to NETPs, showing clearly a gap in the potential NETPs demand for mitigation, and the actual level of action.
- Enhancement of forest and soil C sinks is discussed widely especially in the country and also EU level long-term strategies. In the quantitative estimates, it is hard to separate the general development of the LULUCF sector from the "additional" negative emission practises.

3 Formulation of the NEGEM vision – Vision workshop and pre-questionnaire

The formulation of the NEGEM vision is an iterative and interactive process, which will be carried out through the whole project lifetime. The aim of the vision work is to set the ground for a clear, shared, medium-to-long term vision on NETPs, with a focus on their sustainable potentials and on their role in contributing to the climate targets at EU and global levels. The aim of the initial vision (or vision statement) is also to guide the NEGEM work done during the first stages of the project by concretizing the existing expectations, knowledge by the policymakers, stakeholders, researchers, etc.

It is acknowledged by the authors that there are many definitions and different understandings of the term "vision". In general, we define term vision representing desirable outcome or goal. Whereas it may not be realistic to build a vision for NETPs that can be for all parts accepted by "every" stakeholder and/or individual, there were principles identified that NEGEM as a research project should incorporate in its vision. As a first principle, the NEGEM vision should target to being shareable to the highest level possible. As a second principle, the NEGEM vision should target beyond vague general statements and should include concrete, evidence-based information on the role of NETPs specifically. In this respect, notably, research to be conducted in different parts of NEGEM contributes in identifying realistic potential of NETPs in technology-neutral, environmentally feasible and socially acceptable way. Hence, the results from the work of the WPs in NEGEM will represent natural components to be integrated in the vision as the project proceeds and results become increasingly available. Initial NEGEM vision presented in this deliverable is based on external sources, such as literature, and the information further elaborated in the first vision workshop.

Due to COVID19 situation, the vision workshop was organised virtually and therefore we were not able to use the planned foresight methods, like world café or future wheel, to collect the views and to co-create the initial vision. Therefore, for co-creation a pre-questionnaire, the discussions at the 1st vision workshop,

and on-line polls during the workshop collected the views of stakeholders and researchers outside NEGEM consortia.

Below, a summary of the results of the pre-questionnaire and the results of the vision workshop is presented.

3.1 Results of the pre-questionnaire

3.1.1 Background and methods

To integrate stakeholder views for the construction of vision for NETPs by NEGEM, a brief background questionnaire (Annex 1) was conducted in parallel with the first vision workshop which was arranged virtually on December 18th, 2020. The questionnaire was distributed to the targeted workshop participants in parallel with the invitation to the workshop. The distribution was organised through stakeholder and contact lists managed by NEGEM partner ETA Florence. Additionally, further distribution of the questionnaire was boosted through promoting it in expert channels e.g. in social media. Hence, the targeted answerer segment was experts working under NEGEM related themes in different stakeholder groups. Targets of the questionnaire were described to contribute in

- Co-operative integration of stakeholder views for the construction of Vision for NETPs
- Inspiration of further discussions in the Vision workshop; to enable this, initial results of the questionnaire available before were the workshop were used to prepare materials, and some insights from the initial results were presented the workshop.

Altogether, the questionnaire gathered 39 answers between December 11th and 18th, 2020. Geographically, most of the respondents reported their home region/country as Europe (64 % of the answers, 11 different countries), with Asia (20 %) as the second significant group. Other regions gathered not more than single or very limited number of answers. Distribution of stakeholder groups of the respondents were reported as follows: research, 51 %; industry: 28 %; public sector: 3 %; Non-Governmental Organisation: 8 %; other: 10 %. As stated above, it was presumed that vision of the role of NETPs may differ according to values of individuals, or organisations they present, or differences geographical or stakeholder positions, etc.

Based on the above principles, the background questionnaire was built to gather viewpoints on different NETP options and related issues to contribute. Specifically, the questions included likert scale and open questions to shed light in the following aspects:

- The level of awareness on different NETPs
- The role of different NETPs in global and European perspectives in medium and long term
- The question of how the respondents describe their own vision on NETPs from their professional viewpoint (e.g. technology preferences, relation of NETPs in respect of emission reductions, timing)
- The main barriers for their NETP vision foreseen by the stakeholders

Hence, the use of the questionnaire results combined with the forthcoming NEGEM phases and results supports the formulation of vision in at least the following aspects:

(i) Detecting issues/areas to be emphasized in communications of the vision and project outputs due to lack of awareness or perception of the potential of different NETPs (e.g. if in conflict or supporting NEGEM results)

(ii) Identifying respondent-dependent preferences for the vision to map a space of alternatives

3.1.2 Results

The results on awareness of different NETPs indicate differences (*Figure 7*) among participants. Of NETPs listed, ocean-based technologies appear the least familiar option (ocean alkalinisation: the sum of "Strongly agree" or "Agree": 26%; ocean fertilisation: 33%), followed by enhanced weathering (38%) and mineral carbonation (41%). The answerers report being considerably better informed on BECCS (79%), afforestation/reforestation (77%), soil carbon sequestration (74%), bio-char (72%). Also DACCS (55%) crosses the 50% mark.

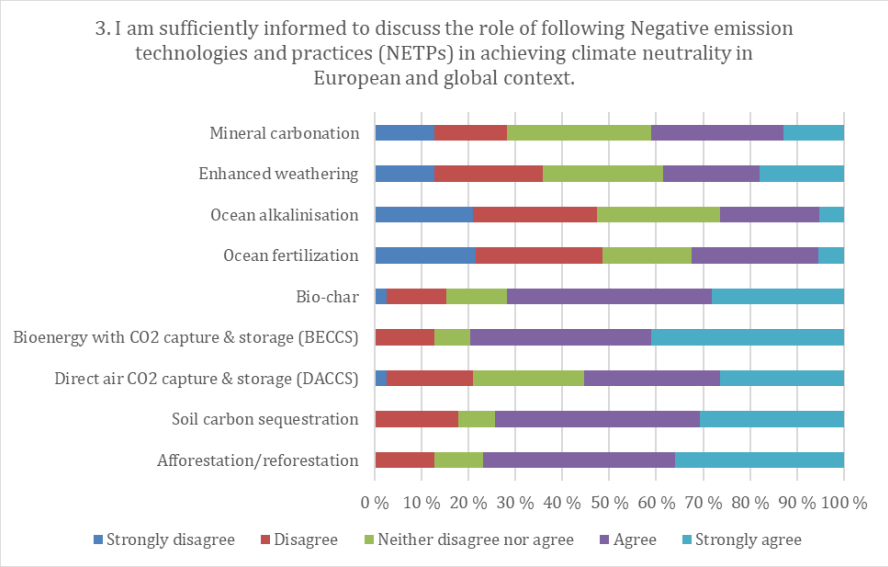
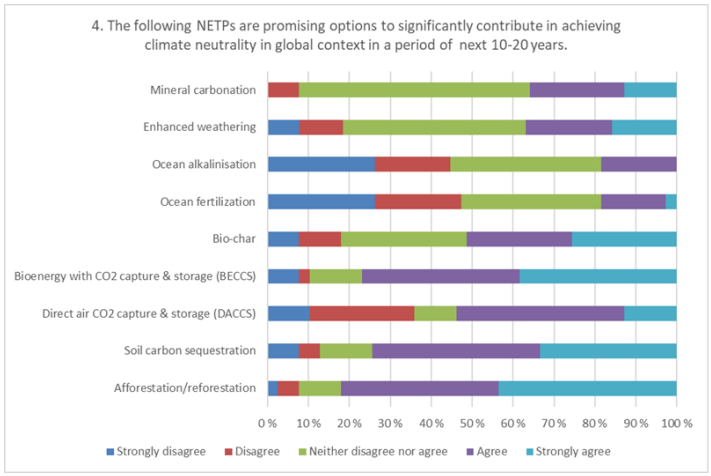


Figure 7 Distribution of answers to question on awareness of NETPs.

In global context, afforestation/reforestation (82% "Strongly agree" or "Agree"), BECCS (77%), and soil carbon sequestration (74%) appear as the most promising options to contribute on achieving the climate neutrality in medium term (10-20 years), whereas ocean fertilization (18%) and ocean alkalization (18%) scoring the lowest (*Figure 8*). Over time up to 2050 and beyond, there is on average 12% improvement in this metrics in the options, particularly, bio-char (74% long-term, 51% short-term) and DACCS (77% long-term, 54% short-term) appear as options with significantly large improvement, whereas afforestation/reforestation (84% long-term, 82% short-term) as notably small. In the long-term, BECCS is valued as the most promising option with the share of 87%. In addition to listed options, there was an open field to present supplementary option with e.g. restoring degraded lands, hydrogen economy, protection of ecosystems and forests, restoration of degraded ecosystems, prolonged logging cycles, seaweed, coastal carbon, CCU and carbon containing products e.g. wood buildings mentioned in the results.



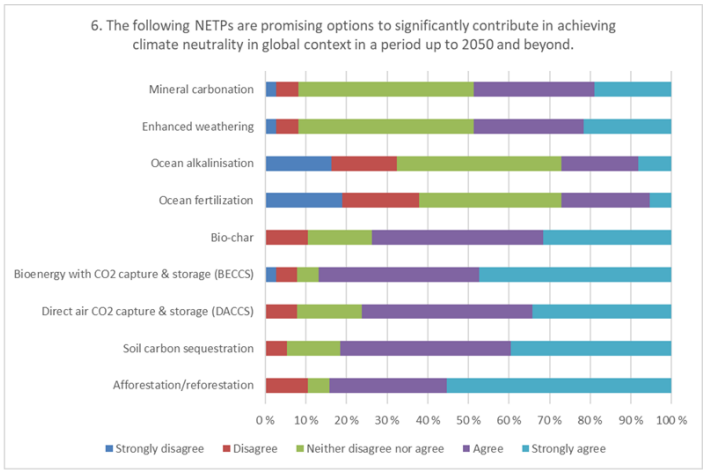
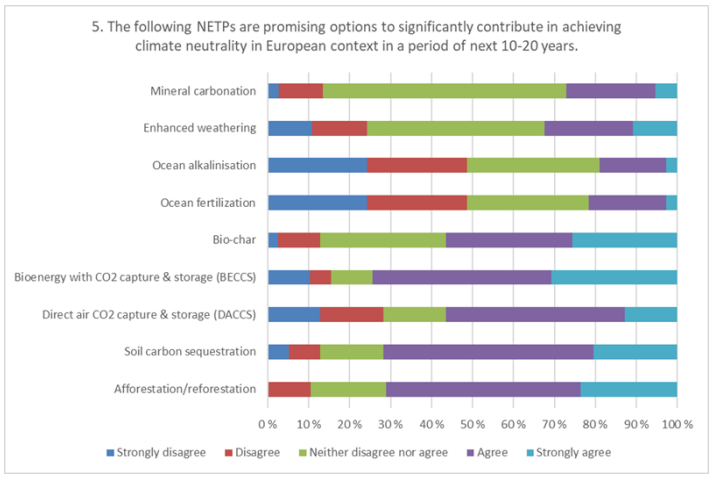


Figure 8 Distribution of answers to the question of promise of different NETPs in global context in medium term (left) and long-term (right).

In European context (*Figure 9*), BECCS (74%), soil carbon sequestration (72%) and afforestation/ reforestation (71%) appear as the most promising options to contribute on achieving the climate neutrality in medium term (10-20 years), whereas ocean fertilization (22%) and ocean alkalization (19%) scoring the lowest. Over time up to 2050 and beyond (long-term), BECCS appears the most promising option (89%), followed by DACCS (75%) and soil carbon sequestration (69%). mineral carbonation (49% long-term, 22% medium-term) and DACCS (75% long-term, 54% medium-term) appear as options with significantly large improvement, whereas afforestation/reforestation and soil carbon sequestration signalling a short decline (-2%). In the long-term, BECCS is valued as the most promising option with the share of 89%.



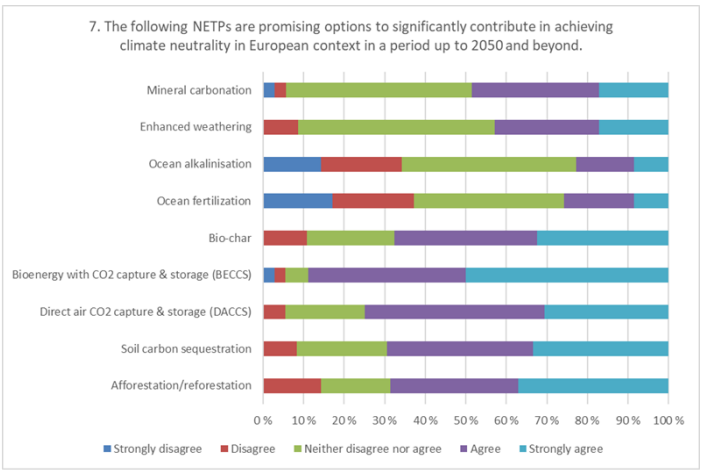


Figure 9 Distribution of answers to the question of promise of different NETPs in European context in medium-term (left) and long-term (right).

In the big picture, the differences in global and European contexts are relatively small. Perhaps the differences in promises of the options of afforestation/reforestation and bio-char in the global scale over European one can be mentioned as the most significant. The relative "readiness" of afforestation/reforestation with only slight signals of improving potential in time is also clearly visible in the results in distinction to many alternatives under technological deployment.

3.1.3 Summary of open answers

To shed light on answerers' preferences, two open answer questions were included. Based on answers to a question "From your professional perspective, please briefly describe your vision (desired outcome) on the role of the negative emissions and practices", it was remarked that preferences of NETPs in comparison with emission reductions were reflected in many answers. The answers represented two major tendencies as follows:

1. **NETPs are seen as a complementary measure to emission reductions, concerns of them replacing the emission reduction efforts.** This tendency was reflected in the answers e.g. as follows: *emission reductions* "should remain the focus", "overriding priority", whereas *NETPs* "should be the last option", "should not replace emission reduction", "should be seen complementary and additional tool", "should complement emission reduction options", "should help hard/expensive-to-abate sectors", "bridge technology till the end of the century, the need to moving to zero emission as soon as possible"
2. **The urgency of climate change mitigation is highlighted, justifying fast employment of NETPS** This tendency was reflected in the answers e.g. as follows: "we need to start employing these techniques", "both are needed, there should be no conflict between the two", "emission reductions and negative emissions are equally important and both has to start now in a big way".

As another observation, need for more information was flagged: it was concluded that it is too early to make definite conclusions on the potential of NETs. Part of the answers discussed on the role of singles technologies. As one group, preference in nature-based options was mentioned in many answers (reflected in raising issues as protection of ecosystems, restoration of degraded ecosystems, prolongation of harvest logging cycle, preference in "natural ones" like reforestation, biochar, or soil sequestration, maintenance of forest health and productivity in mature forests, microalgal). In technologies, BECCS was mentioned in many answers, in line with the message of the answers of likert scale answers.

A question on most important factors potentially limiting the realisation of answerers' visions raised factors categorised as follows:

- **Social:** awareness, lack of information, low commitment of people, social upheaval, rejection of science, strong fossil interest, differences between developed and developing countries
- **Technical:** overly techno-optimist assessment of CDR, technical aspects of biomass production
- **Political:** political corruption, low commitments, political resistance, failure of deep emissions reductions
- **Economic:** inadequate market mechanisms to incentivize, the NETs stated being too costly, CO_2 pricing too low, recognition of negative emission of BECCS as part of the existing regulations (such as ETS).
- **Environmental** considerations including biodiversity

Overall, the diversity of the answerers' descriptions of their visions and barriers made them attractive subjects for the live polls in the workshop discussed in section 3.2. On-line polls were created to shed light on preferences set for the vision to e.g. help guaranteeing their wide acceptance.

3.2 Documentation and findings of the 1st vision workshop

1st NEGEM Vision workshop was organised as virtual[9] (Zoom) event on December 18th, 2020. This first co-creation workshop was organised by VTT in collaboration with ETA Florence and gathered about 80 participants, chaired by Kati Koponen, NEGEM coordinator as of January 1st, 2021. All the materials and recording of the event are available at the NEGEM website[10].

The opening words of the workshop were provided by Timo Ritonummi, Deputy Director General, Energy Department, Ministry of Economic Affairs and Employment of Finland and representative of the External Advisory Board of NEGEM. This was followed by three presentations from NEGEM researchers:

- Carbon Dioxide Removal and the European Climate Law, David Reiner, UCAM
- Selection and Sustainability Assessment of NETPs , Selene Cobo Gutiérrez, ETH
- Introduction to NEGEM Vision: The Demand of NETPs Based on Literature and Results of Questionnaire, Tiina Koljonen, VTT

In order to make the workshop more interactive and to collect stakeholders' views, participants were involved on-line polls during the workshop. Four questions addressed dealt with goals, role of NETPs to define the NEGEM vision about NETPs derived based on the preliminary questionnaire (*Figure 10* and *Figure 11*). The following indications were derived from the live polls:

- The respondents expressed a strong preference concerning the role of NETPs. The alternative "In order to get the fastest impact on climate mitigation, maximal introduction of NETPs should be set in parallel with emission reductions", was clearly the most popular with a share of 68%.
- Supporting common European policymaking was considered as the primary goal for NEGEM vision to serve. But a high preference was granted also to ensure environmental sustainability of NETPs
- Financial instruments (taxes and subsidies) were considered as the most efficient policy instruments in supporting the deployment of NETPs (36%), closely followed by developing market mechanisms for NETPs (33%).
- Economic performance of NETPs was considered as the primary barrier for their breakthrough (37%), closely followed by lack of common European policy framework (33%).

[9] Originally planned physical workshop was not possible due to COVID-19 limitations.
[10] https://www.negemproject.eu/news/negative-emissions-technologies-and-practices-building-a-vision-towards-climate-neutrality/

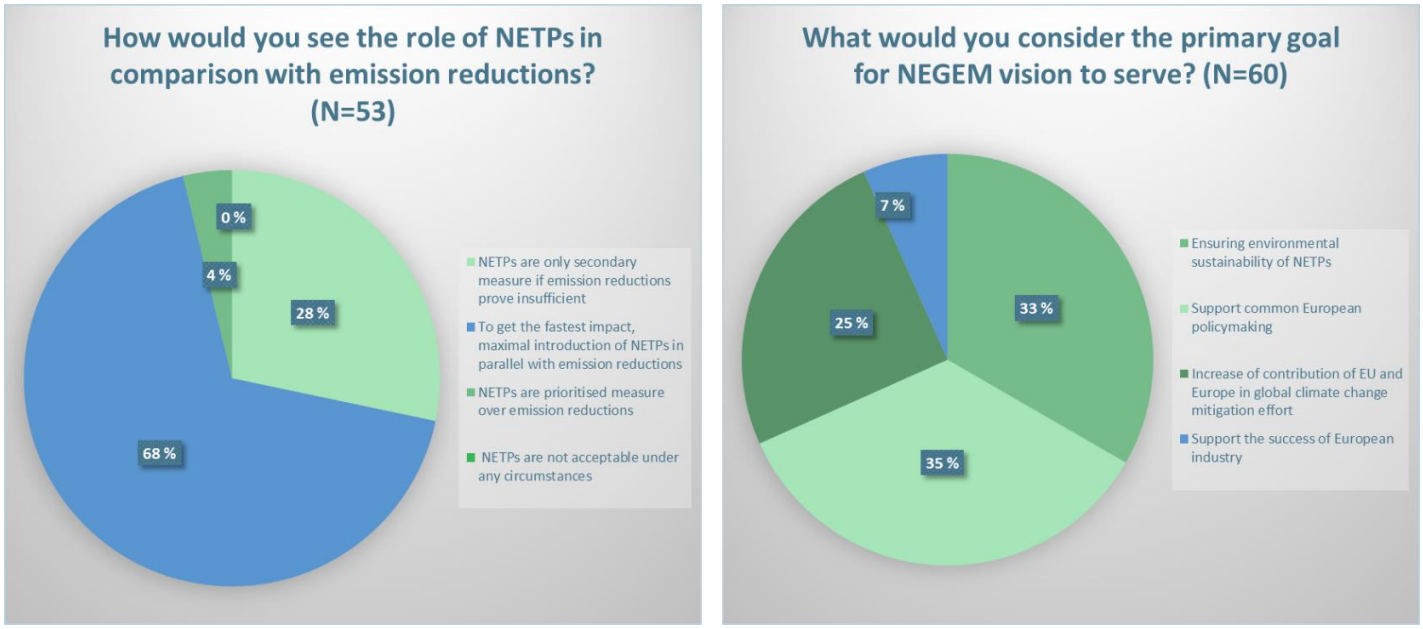


Figure 10 Distribution of answers to live poll questions on the role of NETPs and goals for NEGEM vision.

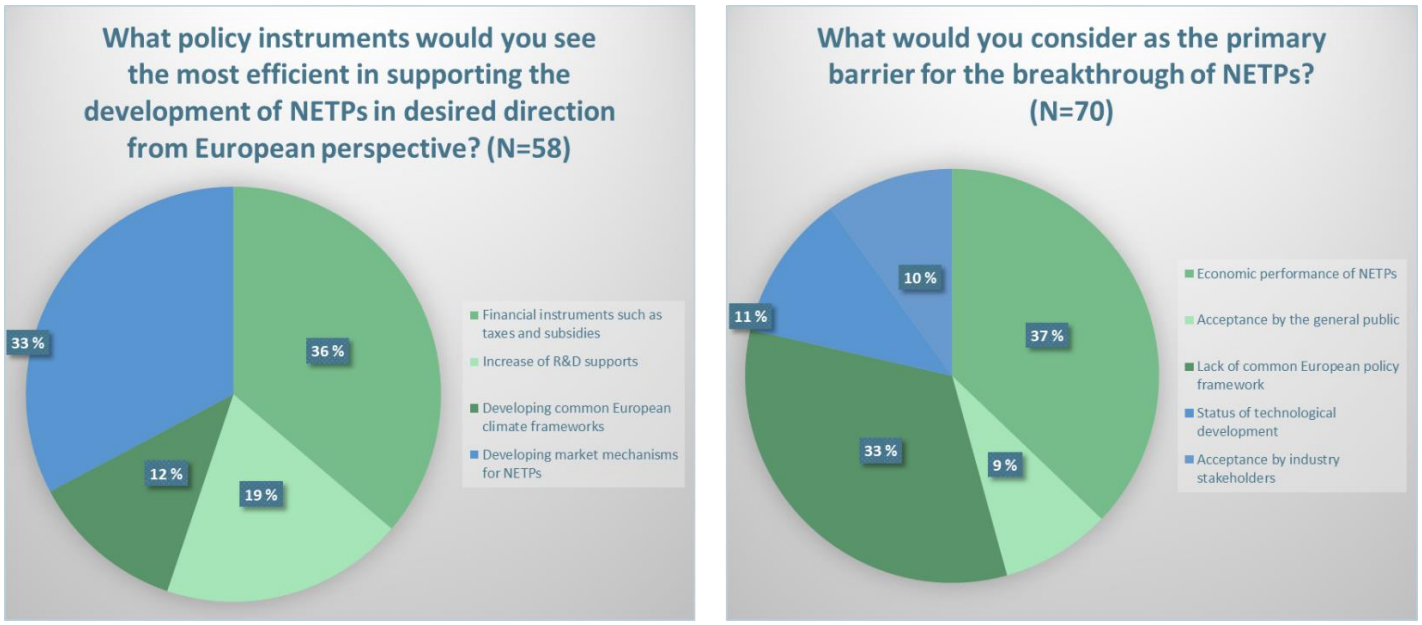


Figure 11 Distribution of answers to live poll questions on policy instruments and barriers for NETPs.

Discussion in the workshop was lively both in Q&A and in spoken word. Considerations were done about NETPs deployment, such as the necessity of a good policy framework, the opportunity of introducing taxes and the issue of NETPs acceptability. More detailed, the discussion included e.g. the following points:

- Individual questions and comments on single NETPs such as TRLs, costs (anaerobic digestion costs), life cycle assessment standards and methods used, inclusion of certain technologies (hydrothermal processing) were given.
- Definitional questions such as on permanence: how to address varying permanence (between e.g. soil/forest removals and underground storage). Relatedly, it was raised up by one participant that the key issue is liability and that might require the inclusion of legal experts.
- Politics: the details in policy targets, such as level of ambition greenhouse gas mitigation of the European Commission and Parliament targets (55 % and 60 % by 2030) were discussed, including tradability of land use storages and GHG reduction among themselves, and exclusion of international carbon credits and offsets between reductions and NETPs. In one comment, EU biofuel policy was raised as a good example how it has triggered certification and improvements in biofuels production.
- Some concerns on sustainability were raised as risk issues that need to be followed up. In one comment, need to align incentives for negative emission technologies and practices for maintaining ecosystem stability with paying was highlighted.

In more general level, the discussions in the workshop included some proposals for a structured definition of NETPs role: instead of only as a complementary measure for GHG reductions, they can also be seen as a tool to raise the ambition of climate mitigation. As another comment adding with general-level insights of NEGEM and NETPs, with NEGEM, there is an opportunity to bring a more holistic understanding of NETPs, including co-benefits and trade-offs and eventually enlarge the portfolio for NETPs, and make those accountable for decision-making beyond only looking into negative CO_2 accounting.

3.3 Key findings from the vision workshop including pre- questionnaire

1. As desirable outcome, the vision for the role of NETPs may differ according to values of individuals, or organisations they present, or differences geographical or stakeholder positions, etc.
2. In the first phase of the vision building process by NEGEM project, at least three different roles for NETPs are identified, reflecting different emphasises:
    - NETPs are seen as a complementary measure to emission reductions, giving high priority to concerns of them replacing the emission reduction efforts.
    - The urgency of climate change mitigation is highlighted, justifying fast employment of NETPs.
    - The NETPs are seen as a tool to raise the ambition of climate change mitigation.
3. NEGEM project can contribute to formulating realistic potentials for NETPs. Whereas the details evolve in line with the project results, several criteria to be met targeted the vision can already be identified for the vision, including:
    - Wide acceptability among stakeholders
    - The vision should include concrete, evidence-based information on the role of NETPs specifically
    - Environmentally sustainable
    - Instrumental for European policymaking
    - Significant contribution in European climate change mitigation efforts
4. The results of the preliminary questionnaire on awareness among stakeholders on different NETPs indicate differences. Of NETPs listed, ocean-based technologies appear the least familiar

option, followed by enhanced weathering and mineral carbonation. It seems that there is larger awareness on BECCS, afforestation/reforestation, soil carbon sequestration, and bio-char.

5. Different WPs of the NEGEM will bring a more holistic understanding of the above NETPs, including co-benefits and trade-offs and eventually enlarge the portfolio for NETPs.

As presented in this report, the scenarios reported by different organisations and countries show rather high variety of the role of NETPs to reach the 1.5-2 °C temperature limit and/or climate neutrality. From the perspective of vision building, this finding is in line with a message from the vision workshop suggesting it is too early to make definite conclusions on the potential of NETPs. More concretely, based on the vision workshop questionnaires, the different role for NETPs is reflected in varying preferences between the NETPs options. Here, preference on nature-based options like reforestation, biochar, or soil sequestration, maintenance of forest health and productivity in mature forests, microalgal, was mentioned by many. Regarding technological NETPs, BECCS appears having a promise of significant role in many envisaged futures, whereas ocean-based alternatives does not appear among the most promising options based on the survey answers.

The NEGEM vision aims at presenting a realistic role for NETPs. Wide variety of envisaged role for NETPs – in comparison with emission reductions and between the different NETPs options – can already be concluded based on the vision workshop organised in early phase of NEGEM. Therefore, formulation of the vision for the role of the NETPs, which would fulfil the criteria mentioned in the first key finding, can prove challenging. For that, we would need more holistic understanding (key finding 5) and, thus, better awareness of different NETPs (key finding 4) and analysis of the realistic potentials (key finding 3). Especially, the grey literature includes very little exact information on NETPs but it seems that NETPs are mostly modelled with BECCS. In scientific literature, also other NETPs are included in the modelling, especially DACCS. In the forthcoming WP8 reports on global and EU level scenario assessments, the aim is to fulfil these gaps in existing knowledge by including different types of NETPs in TIMES-VTT IAM scenario assessments, to include barriers and boundary conditions to model more realistic potentials (e.g. based on the results of WP3 on environmental impacts, WP7 on multi-dimensional potentials, and WP5 on the perspectives of stakeholder groups). In addition, WP8 work has a target to also combine the results of other WPs to bring more holistic understanding of NETPs.

4 Preliminary vision

The basic elements and statements for preliminary vision are listed below. However, it should be recognized that at this stage, the vision summarizes the most relevant and common findings at the situation, where we only have some very first results of the NEGEM project. The vision formulation will continue throughout NEGEM project.

- To reach the climate targets of the Paris Agreement, carbon dioxide removal (CDR) is needed but as a complementary measure to greenhouse gas emission reductions. NEGEM scenarios would consider all the mitigation options to reach the climate targets of the EU and globally.
- Due to urgency of climate change mitigation, fast deployment of NETPs is justified. NETPs can also be seen as a tool to raise the ambition of climate change mitigation. Scenario analysis carried out in NEGEM would consider the alternative levels of ambition in GHG mitigation at the EU and global levels.

- There is lack of knowledge to make definite conclusions on the sustainable potentials of NETPs at the EU and global levels. There are especial concerns on environmental sustainability of NETPs. NEGEM results would support in elaborating sustainable potentials by considering both the demands and sustainable supply of NETPs taken into account the planetary boundaries.
- Based on the 1st vision workshop results, the major barriers for the implementation are the economic performance of NETPs and lack of common EU policy framework. NEGEM would create new and synthesized information on the economic performance, commercialisation pathways and formulate policy recommendations for NETP deployment.
- There are lack of social awareness and low commitment of people to foster the CDR. NEGEM would investigate the perceived socio-economic potential of NETPs and its social license to operate.
- The 1.5 °C mitigation scenarios in scientific literature shows the urgency for NETPs deployment to reach the demand for NETPs. However, e.g. the country level long-term climate plans mostly have vague plans related to NETPs, showing clearly a gap in the potential NETPs demand for mitigation, and the actual level of action.

To summarize:

NEGEM should increase the holistic understanding of NETPs, including co-benefits and trade-offs and eventually enlarge the portfolio for NETPs. NEGEM will consider techno-economics and commercialisation pathways, environmental impacts, social aspects and risks in its analysis of “realistic potentials” of NETPs to reach the climate goals of Paris Agreement. NEGEM will make those accountable for decision-making beyond only looking into negative CO_2 emission balance accounting.

5 Conclusions and further steps

The D8.1. draws the picture on existing knowledge, expectations and concerns of NETPs to reach the global and EU level climate targets, which are in line with the Paris Agreement. In addition, the report gives some country level examples, how NETPs have been considered in their climate and energy strategies.

Our analysis is based on the most recent scientific and grey literature, questionnaires and the 1st vision workshop. The literature analysis served the background information for the vision workshop and preliminary vision formulation. In addition, literature analysis guides the scenario selection for NEGEM analysis during its 1st phase, which will be carried out in collaboration with WP3, WP4, WP7 and WP8.

Based on the literature analysis, NETPs are needed to reach the 1.5 °C mitigation goal. For achieving 2 °C target, the need for NETPs can be limited with ramping up the near-term ambition for mitigation. A portfolio of NETPs has lower sustainability risks than application of just one NETP technology (e.g. BECCS). The future need for NETPs significantly depends on the assumed future socio-economic conditions.

The IAMC 1.5°C Scenarios Database [3] contains results for almost about 350 scenarios that have NETPs represented, and at least 275 of those have NETPs active in their solution at notable levels (≥ 1 $GtCO_2$/year). Looking at the median estimates in the IAMC 1.5°C Scenarios Database for all NETPs combined, we arrive at a total estimate of almost 12 $GtCO_2$/year negative emissions in 2050 and 30 $GtCO_2$/year in 2100 respectively. The corresponding median value for BECCS was above 3 $GtCO_2$/year in 2050 and nearby 11 $GtCO_2$/year in 2100. The median amount for 2100 would thus correspond to over 100 EJ of bioenergy being utilized with CCS in 2100 (total global bioenergy use today accounts about 50 EJ). Unfortunately, IAMC database does not include EU or European level data but OECD would account for around 30% of the global BECCS both in 2050 and 2100.

Many of the estimates for the potential of the NETPs in the grey literature seem to be lower than the demand modelled in e.g. in the IPCC scenarios with Integrated Assessment Models (IAMs). The scientific literature shows the urgency for NETPs deployment to reach the modelled demand for NETPs. However, e.g. the country level long-term climate plans mostly have vague plans related to NETPs, showing clearly a gap in the potential NETPs demand for mitigation, and the actual level of action.

The first Vision workshop helped to include the stakeholder views to the NEGEM Vision work. Three different roles for NETPs were identified, reflecting different emphasises: First, NETPs can be seen as a complementary measure to emission reductions, giving high priority to concerns of them replacing the emission reduction efforts. Second, if the urgency of climate change mitigation is highlighted, fast employment of NETPs can be considered justified. And third, NETPs can be seen as a tool to raise the ambition of climate change mitigation.

The initial NEGEM vision will guide the work carried out by different WPs in NEGEM project taking into account the views and suggestions of the wider audience. The preliminary vision is summarized as follows:

NEGEM should increase the holistic understanding of NETPs, including co-benefits and trade-offs and eventually enlarge the portfolio for NETPs. NEGEM will consider techno-economics and commercialisation pathways, environmental impacts, social aspects and risks in its analysis of “realistic potentials” of NETPs to reach the climate goals of Paris Agreement. NEGEM will make those accountable for decision-making beyond only looking into negative CO_2 emission balance accounting.

The work carried out in WP8 will continue by framework and pathway creation (Task 8.3) by selecting the scenarios for the NEGEM analysis. During the second phase of the NEGEM project, realistic global and EU level potentials of NETPs will be modelled with TIMES-VTT IAM by using the data and results from WP1-WP7. Results of these quantitative assessments will be published in D8.2. In the end of the project, Task 8.5 will formulate recommendations based on the WP1-WP8 analysis and conclusions will be drawn on realistic and sustainable potentials of the NETPs. The NEGEM recommendations will be reported D8.4. As described in the report, the vision will be updated though the project lifetime. The next updated vision will be presented in D8.7 and the final NEGEM medium-to-long-term vision will be documented in D8.3.

For preparing this report, the following deliverable/s have been taken into consideration:

D#	Deliverable title	Lead Beneficiary	Type	Dissemination level	Due date (in MM)
D1.1	Justification of NETPs Chosen for the NEGEM project	ETH	R	[CO]	30.11.2020

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Annex 1: Background questionnaire

NEGEM vision workshop - background questionnaire

The quantitative potential, effectiveness and impacts of negative emission technologies and practices (NETPs), particularly taking into account physical, environmental, social and human sciences, are not so well understood.

NEGEM project will address to what extent NETPs are required to achieve climate neutrality and how their associated technical, economic, social, political or environmental impacts potentially limit their contribution. The result is a comprehensive analysis of the realistic, sustainably deployable potential of NETPs supporting EU's endeavours to implement the Paris Agreement within the frames of relevant UN Sustainable Development Goals.

This questionnaire has been built to integrate stakeholder views for the construction of Vision for NETPs by the NEGEM project. This part of the project is led by VTT Technical Research Centre of Finland Ltd. Answers submitted latest on December 16th, 2020, will be taken into account in design of the first vision workshop on December 18th, 2020. The results of the questionnaire and workshop will be documented in project Deliverables and other project outputs.

Response to the survey is voluntary. Privacy of the respondents will be secured and all respondents (individuals participating/organizations) stay anonymous and shall not be identifiable directly or indirectly. Responses to the survey will be used by VTT only for the research purpose identified above. The responses of the survey are combined with other responses and summarized in a report to further protect the anonymity of the respondents.

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1. Please select your main stakeholder group

- ◯ Research
- ◯ Industry
- ◯ Public sector
- ◯ Non-Governmental Organisation
- ◯ Other

2. What is your home region/country?

- ○ Europe, specify country ____
- ○ North America
- ○ South America
- ○ Asia
- ○ Africa
- ○ Australia
- ○ Antarctica

Below you will find statements regarding negative emission technologies and practices. Please indicate the extent of your agreement or disagreement with each statement.

3. I am sufficiently informed to discuss the role of following Negative emission technologies and practices (NETPs) in achieving climate neutrality in European and global context.

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
Afforestation/reforestation	○	○	○	○	○
Soil carbon sequestration	○	○	○	○	○
Direct air CO2 capture & storage (DACCS)	○	○	○	○	○
Bioenergy with CO2 capture & storage (BECCS)	○	○	○	○	○
Bio-char	○	○	○	○	○
Ocean fertilization	○	○	○	○	○
Ocean alkalinisation	○	○	○	○	○
Enhanced weathering	○	○	○	○	○
Mineral carbonation	○	○	○	○	○

4. The following NETPs are promising options to significantly contribute in achieving climate neutrality in global context in a period of next 10-20 years.

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
Afforestation/reforestation	○	○	○	○	○
Soil carbon sequestration	○	○	○	○	○
Direct air CO2 capture & storage (DACCS)	○	○	○	○	○
Bioenergy with CO2 capture & storage (BECCS)	○	○	○	○	○
Bio-char	○	○	○	○	○
Ocean fertilization	○	○	○	○	○
Ocean alkalinisation	○	○	○	○	○
Enhanced weathering	○	○	○	○	○
Mineral carbonation	○	○	○	○	○
Other, specify	○	○	○	○	○

5. The following NETPs are promising options to significantly contribute in achieving climate neutrality in European context in a period of next 10-20 years.

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
Afforestation/reforestation	○	○	○	○	○
Soil carbon sequestration	○	○	○	○	○
Direct air CO2 capture & storage (DACCS)	○	○	○	○	○
Bioenergy with CO2 capture & storage (BECCS)	○	○	○	○	○
Bio-char	○	○	○	○	○
Ocean fertilization	○	○	○	○	○
Ocean alkalinisation	○	○	○	○	○
Enhanced weathering	○	○	○	○	○
Mineral carbonation	○	○	○	○	○
Other, specify	○	○	○	○	○

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6. The following NETPs are promising options to significantly contribute in achieving climate neutrality in global context in a period up to 2050 and beyond.

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
Afforestation/reforestation	○	○	○	○	○
Soil carbon sequestration	○	○	○	○	○
Direct air CO_2 capture & storage (DACCS)	○	○	○	○	○
Bioenergy with CO_2 capture & storage (BECCS)	○	○	○	○	○
Bio-char	○	○	○	○	○
Ocean fertilization	○	○	○	○	○
Ocean alkalinisation	○	○	○	○	○
Enhanced weathering	○	○	○	○	○
Mineral carbonation	○	○	○	○	○
Other, specify	○	○	○	○	○

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7. The following NETPs are promising options to significantly contribute in achieving climate neutrality in European context in a period up to 2050 and beyond.

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
Afforestation/reforestation	○	○	○	○	○
Soil carbon sequestration	○	○	○	○	○
Direct air CO2 capture & storage (DACCS)	○	○	○	○	○
Bioenergy with CO2 capture & storage (BECCS)	○	○	○	○	○
Bio-char	○	○	○	○	○
Ocean fertilization	○	○	○	○	○
Ocean alkalinisation	○	○	○	○	○
Enhanced weathering	○	○	○	○	○
Mineral carbonation	○	○	○	○	○
Other, specify	○	○	○	○	○

8. From your professional perspective, please briefly describe your vision (desired outcome) on the role of the negative emissions and practices.

What role should NETPs have in achieving the Paris Agreement in your vision, e.g. their role compared with emission reductions globally or in Europe?
Do you see any priorities between the different type of NETPs in your vision?
What is the timescale to deploy different NETPs in your vision?

9. Please describe factors potentially limiting the realisation of vision you consider the most important.

Factors can be e.g. technical, economic, social, political or environmental. Could some factor prevent the realisation of your vision entirely?

Annex 2: A separate excel-file on the literature review of “grey literature”.