NEGEM

Quantifying and Deploying Responsible Negative Emissions in Climate Resilient Pathways

Updated NEGEM vision

Horizon 2020, Grant Agreement no. 869192

Number of the Deliverable	Due date	Actual submission date
D8.7	**30.11.2022**	**30.11.2022**

Work Package (WP): 8 – Vision and framework for pathways analysis

Task: T8.2 – Formulation of the medium-to-long-term vision

Lead beneficiary for this deliverable: VTT

Editors/Authors: Lassi Similä; Heidi Manninen; Tiina Koljonen; Antti Lehtilä

Dissemination level: Public

Call identifier: H2020-LC-CLA-02-2019 - Negative emissions and land-use based mitigation assessment

Document history

V	Date	Beneficiary	Author/Reviewer
1.0	2022-11-18	VTT	Lassi Similä; Heidi Manninen; Tiina Koljonen; Antti Lehtilä / Nixon Sunny (ICL)
1.1	2022-11-30	VTT	Lassi Similä; Heidi Manninen; Tiina Koljonen; Antti Lehtilä

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869192

NEGEM

Partners

VTT – VTT Technical Research Centre of Finland Ltd, Finland
PIK - Potsdam Institute for Climate Impact Research, Germany
ICL - Imperial College of Science Technology and Medicine, United Kingdom
UCAM - University of Cambridge, United Kingdom
ETH - Eidgenössische Technische Hochschule Zürich, Switzerland
BELLONA - Bellona Europa, Belgium
ETA - ETA Energia, Trasporti, Agricoltura, Italy
NIVA - Norwegian Institute for Water Research, Norway
RUG - University of Groningen, Netherlands
INSA - Institut National des Sciences Appliquées de Toulouse, France
CMW - Carbon Market Watch, Belgium
UOXF - University of Oxford, United Kingdom
SE - Stockholm Exergi, Sweden
St1 - St1 Oy, Finland
DRAX - Drax Power Limited, United Kingdom
SAPPI - Sappi Netherlands Services, The Netherlands

NEGEM

Executive Summary

Task 8.2 of the NEGEM project, *Formulation of the medium-to-long-term vision*, aims at creating a medium-to-long term vision concluding whether NETPs could be a responsible and rational option globally and for the European Union (EU) in mitigating climate change and to reach the climate targets set by the EU and the by the United Nations.

According to the NEGEM project plan, *Vision will be formulated in two stages: 1) The preliminary vision will be created in the beginning of the project based on the results of the task 8.1 for exploring alternative futures and by organising 1st vision workshop 2) final vision in the end of the project based on the NEGEM results and 2nd vision workshop. Foresight methods [will be used] for co-creation of the initial NEGEM vision, like world café or future wheel combined with analytical methods[1]. The initial vision (or vision statement) would guide the NEGEM work done during the first stages of the project by concretizing the existing expectations, knowledge by the policymakers,* stakeholders*, researchers, etc. The initial NEGEM vision and vision making process (incl. vision workshops) will be documented in D8.1. Updated vision will be presented in D8.7 and the final NEGEM medium-to-long-term vision will be documented in D8.3.*

At the stage of M30 (November 2022) of the 48-month-long NEGEM project, an **updated** vision compared to the initial vision first presented in Month 8 (M8, January 2021), is presented in this deliverable. As the aim of the vision during the project is to mostly guide the work, and the 2nd vision workshop, which will be based on NEGEM results, is to be arranged around M42-M46 (November 2023-March 2024), only minor updates to the wording of the preliminary vision have been completed. The updates to the vision (or vision statement) are based on internal discussions of the NEGEM consortium. An updated version of the vision is formulated as follows:

There is a risk that climate goals of Paris Agreement (PA) will not be met without NETPs. 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 PA goals. NEGEM will make those accountable for decision-making beyond only looking into negative CO_2 emission balance accounting.

The NEGEM vision aims at presenting a realistic contribution of NETPs to reach the climate goals of the PA. Wide variety of envisaged roles for NETPs was concluded based on the vision workshop organised in early phase of NEGEM, which was reported in D8.1. This view has been strengthened by the NEGEM results published by different WPs in between. Therefore, as concluded in the revised version of D8.1 (March 2022), more holistic understanding, better awareness of different NETPs, and analysis of the realistic potentials are needed to concretize the vision. 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

[1] World café and Futures Wheel (Glenn 2003) are participatory foresight methods often applied in workshops to facilitate and integrate views of a group around a question or problem dealt with. Analytical methods refer to quantitative models such as Integrated Assessment Model (IAM) TIMES-VTT (see NEGEM D8.6). The NEGEM vision work aims to build on research from both these fields of research.

more realistic and sustainable potentials of NETPs on a global and EU scales. Here, results of all the NEGEM WPs play key role. Particularly, the results of WP3 on environmental impacts, WP7 on multi-dimensional potentials, and WP5 on the perspectives of stakeholder groups, are applied in the scenario assessments. Hereby, these results supply the vision with more concrete ingredients based on the NEGEM results. As first steps of this work, initial insights of TIMES-VTT scenarios were completed in D3.9 (June 2022), and a report of the preliminary NEGEM scenarios (D8.6) is published at the time of this deliverable (November 2022). TIMES-VTT is a global Integrated Assessment Model with a representation of all the Kyoto greenhouse gases (GHGs). In addition, WP8 work has a target to also combine and use the results of other WPs and different analytical approaches to bring more holistic understanding of NETPs and its realistic potential.

As another methodological basis for this deliverable, internal NEGEM workshops have been organized attached to 3rd (M13) and 5th (M29) General Assemblies. These workshops have been designed to feed the scenario and storyline development for the NEGEM pathways. As the NEGEM pathways aim at to give a better insight on the "realistic potentials" of the NETPs, exploring the results of the workshops are natural components to feed the work on developing NEGEM vision.

Despite work of NEGEM is still in progress, the NEGEM results of the above-mentioned parts are applicable to update the vision. Hence, the core value of this interim update of the NEGEM vision is to present research-based ingredients from NEGEM WPs that can be used to supply the qualitative vision with more concrete research results to the extent allowed at the stage of the project. The process of achieving the final vision will be completed in second vision workshop that builds on final results of NEGEM and its WPs and incorporates views of different external stakeholders.

Policy relevant messages

- To update the NEGEM vision and make it more concrete, barriers and boundary conditions to model more realistic and sustainable potentials of NETPs on a global and EU scales, need to be included in its formulation.
- NEGEM results on potential of different NETPs by different approaches applied by WPs do not converge to a simple message. Complexity is inherent to the system.
- The most critical questions seem to relate to realistic and sustainable potentials of biomass based NETPs, e.g. especially BECCS, afforestation and reforestation. In addition, there are large uncertainties related to PyCCS, DACCS, and enhanced weathering
- In addition, the life cycle assessment results of various NETPs show trade-offs between various environmental impacts, while none of NETPs performs well in all impact categories.
- The current results indicate that when formulating the final vision, we need to accept trade-offs between targets such as environment and economy, and apply ranges for the level of deployment of different NETPs: no absolute realistic potentials, e.g. Mt $CO_{2\text{-eq}}$. removed, can be indicated.
- As another approach to incorporate variability, varying NEGEM scenarios will be studied, building on three different storylines, "Economy", "Environment", and "Security". These scenarios will delineate the roles of different NETPs and, thus, different total potentials of NETPs. Exploring different, realistic, storylines and pathways based on them enable way for efficient consideration of NETPs in European and global policymaking and strategy development by industries and other stakeholders.

- First quantitative results on corresponding scenarios are presented in D8.6. This provides with coherent reference to discuss the different NEGEM futures.
- Portfolio of NETPs will be needed according to NEGEM results and this may further help in achieving wide acceptance for the NEGEM vision.

Table of contents

Executive Summary 3
Introduction 6
1 Process of updating the NEGEM vision 8
2 Could NETPs be a responsible and rational option globally and for the EU? 10
2.1 Updated insights based on perspectives of stakeholder groups and social dimension 10
2.2 Updated insights based on commercialisation mechanisms 10
2.3 Updated insights based on environmental impacts 11
2.4 Updated insights based on multi-dimensional potentials 12
2.5 Updated insights based on scenario modelling 13
3 Ingredients to the Vision updates based on internal NEGEM workshop 14
3.1 Organization of the workshop 14
3.2 Dimension of technology and economy 16
3.2.1 Tailored storyline for the NEGEM vision 16
3.2.2 Opportunities and barriers 16
3.3 Dimension of nature conservation and biodiversity 17
3.3.1 Tailored storyline for the NEGEM vision 17
3.3.2 Opportunities and barriers 18
3.4 Dimension of security 19
3.4.1 Tailored storyline for the NEGEM vision 19
3.4.2 Opportunities and barriers 19
4 Key findings and policy relevant messages 21
5 Conclusions and further steps 25
References 27

Annex 1: Futures wheels created in the groupwork of internal NEGEM workshop

Introduction

Task 8.2 of the NEGEM project, Formulation of the medium-to-long-term vision, aims at creating a medium-to-long term *vision* concluding whether NETPs could be a responsible and rational option globally and for the EU. The NEGEM vision aims at being applicable for policymakers, industrial stakeholders and scientific community. Thereby, the vision can be used in consideration of realistic potentials of NETPs in European and global policymaking and strategy development and planning by these stakeholder groups.

According to the NEGEM project plan, *Vision will be formulated in two stages: 1) The preliminary vision will be created in the beginning of the project based on the results of the task 8.1 for exploring alternative futures and by organising 1st vision workshop 2) final vision in the end of the project based on the NEGEM results and 2nd vision workshop. Foresight methods [will be used] for co-creation of the initial NEGEM vision, like world café or future wheel combined with analytical methods. The initial vision (or vision statement) would guide the NEGEM work done during the first stages of the project by concretizing the existing expectations, knowledge by the policymakers, stakeholders, researchers, etc. The initial NEGEM vision and vision making process (incl. vision workshops) will be documented in D8.1. Updated vision will be presented in D8.7 and the final NEGEM medium-to-long-term vision will be documented in D8.3.*

Initial vision was presented as a vision statement in D8.1 at early stage if the project. Initial vision was backed up with discussion on different pathways on the role of NETPs. Hence, these results highly relied on a external literature and a virtual stakeholder workshop arranged by NEGEM in early stage of the project. Based on D8.1, several targets for the vision were identified:

- Wide acceptability among stakeholders
- Inclusion of concrete, evidence-based information on the role of NETPs
- Environmentally sustainable
- Instrumental for European policymaking
- Significant contribution in European climate change mitigation efforts

After the initial vision, the key goal is to update the vision and pathways beyond it to be more extensively based on the results of NEGEM project itself. At the stage of M30 (November 2022) of the 48-month-long NEGEM project, an **updated** vision compared to the initial vision first presented in M8 (January 2021), is presented in this deliverable D8.7. Despite work of NEGEM is still in progress, the NEGEM partners have achieved results that can be used for updating the vision. Hence, the core value of this interim update of the NEGEM vision is to present research-based ingredients from NEGEM WPs that can be used to supply the qualitative vision with research results. This process will be completed in the second vision workshop (M42-M44) that incorporates views of different stakeholders in the discussion, targeting at achieving a consensus for a medium-to-long term vision concluding whether NETPs could be a responsible and rational option globally and for the EU in reaching the medium and long-term climate targets.

The contents of the D8.7, “Updated NEGEM vision” to meet these target is organised as followed: Chapter 1 presents a process of updating the NEGEM vision and the key inputs of the NEGEM project applicable in the work. Chapter 2, building on a review of NEGEM results, explores the results achieved by different Work Packages to concretize the vision. In this update of the vision, selected results of the deliverables

published after the release of initial vision in D8.1, are applied. Chapter 3 explores the results achieved in internal NEGEM workshop on NEGEM storylines and their applicability to build a vision. Chapter 4 presents key findings and policy relevant messages, and Chapter 5 concludes with information on the next steps.

1 Process of updating the NEGEM vision

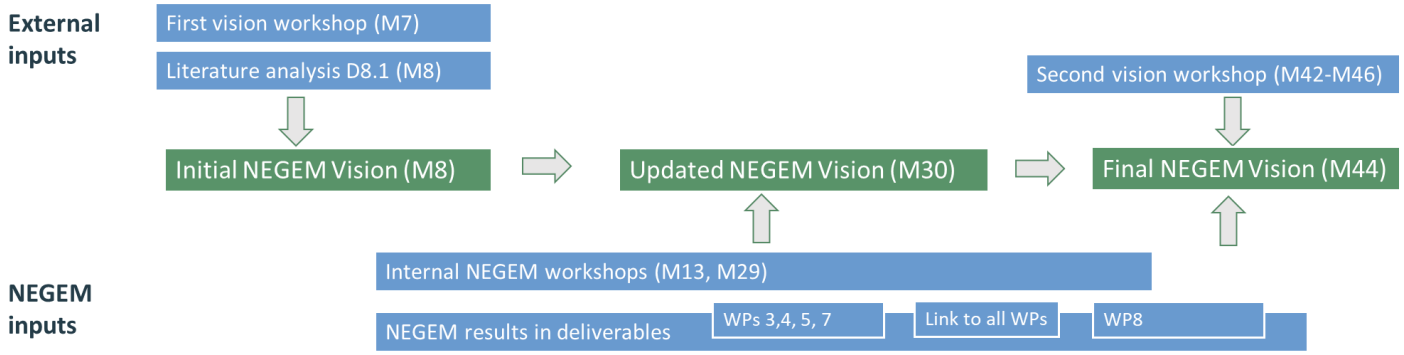


Figure 1 Process of the NEGEM vision work. Updated vision reported in this deliverable is in the stage of M30,and the initial vision, based on external inputs and external workshop, is being supplemented with messages from the NEGEM results achieved up to this point.

Figure 1 depicts the process of developing NEGEM vision throughout the project. The main milestones have been divided in *Initial NEGEM Vision*, *Updated NEGEM Vision* and *Final NEGEM Vision*. Each of the steps includes preparation of a deliverable. Noteworthy, external inputs from literature and NEGEM inputs based on results of the project, play different roles in developing different versions of the vision. Based on the project plan, initial vision (M8) aims at guiding the NEGEM work. Furthermore, the vision process as a whole "aims at creating a medium-to-long term vision concluding whether NETPs could be a responsible and rational option globally and for the EU" to reach their climate targets.

After the publication of initial NEGEM vision at early stage of project (Month 8, M8), several NEGEM outputs have been finalized during approximately M9-M30 that are applicable to develop the initial vision. The key outcomes include:

- Internal NEGEM workshops organized attached to 3rd (M13) and 5th (M29) General Assemblies. These workshops have been designed to feed the scenario and storyline development for the NEGEM pathways. Table 1 opens the role of different phases of NEGEM scenario work as an input for the updated NEGEM vision.
- Results of different NEGEM WPs (esp. WP3, WP5, WP7), on **barriers and boundary conditions** for the WP8 NEGEM scenario assessments. The preliminary results of WP8 scenario assessments, in turn, shed light on **holistic picture of the role of NETPs**.

In the context of process of updating the NEGEM vision, the purpose of this deliverable (D8.7) is in **concretizing and supplying the initial vision with NEGEM results and numbers available at M30 of the project**.

In the end of the project with final NEGEM results, the vision is to be presented and discussed in the 2nd vision workshop with external stakeholders. Incorporating external views serves to validate the vision, and/or it can lead in rewording or smaller or larger fine-tuning of the presented vision. Final vision and vision-making process will be documented in D8.3 (M44).

As an observation from the NEGEM work, the results can provide ideas as inputs for the NEGEM vision. Messages from different WPs are based on analytical work applying different methods and data, and thus can appear contradictory. Part of the results are be different as the base assumptions used by the WPs

are not always aligned. But if we start with the same set of assumptions and achieve contradicting results, then that needs increased scrutiny.Therefore, efforts to harmonize the results on NETPs between WPs of NEGEM have been launched. Even if full harmonization would prove not possible, identifying the points of differences in NEGEM results creates a platform for discussions to find a mutually agreed consensus. Collecting the NEGEM results in summarized format in this deliverable helps to identify the key questions for harmonization of sustainable and realistic potentials of the NETPs. This, in turn, helps to create coherent key messages of the whole project and therefore, paves the way towards a maximally shared vision of NEGEM consortium and external stakeholders, supported by evidence.

Partially, the differences in interim NEGEM results are explained by the design of the project work. The first phase of NEGEM elaborated the realistic potentials based on technological, environmental, acceptance-related, and commercial aspects of NETPs as well as model and database development to incorporate these tasks. The second phase aims to bring these assessments together to develop pathways on sustainable climate neutrality with credible reliance on NETPs. Hereafter, this deliverable presents a summarized set of results achieved by the NEGEM WPs by M30.

Table 1 Rough timeline of the NEGEM scenario work to supply the NEGEM vision with NEGEM results.

NEGEM PHASE 1 (~M1-18):	**NEGEM PHASE 2 (~M19-48):**
Scenario selection – analysis of existing scenarios with NETPs. Formulation of NEGEM scenario framework based on the analysis of existing scenarios & input from workshops. • Framework will define the drivers that need to be taken into account to formulate varying storylines for the NEGEM scenarios	Creation of NEGEM pathways • Definition of the qualitative storylines for the alternative pathways to reach the PA. • Inputs from other WPs (WP3, 4, 5, 7 related to assessments of sustainable and/or realistic potentials) IAM modelling for NEGEM scenarios with global TIMES-VTT and Pan-European TIMES (WP8) • NEGEM climate and energy scenarios (EU & Global) for 2050 and beyond.

2 Could NETPs be a responsible and rational option globally and for the EU?

As a guideline for the Vision work, the question "*Could NETPs be a responsible and rational option globally and for the EU?"* is formulated in the project plan. This question was addressed in early deliverable D8.1 with a preliminary vision building on literature, external research, questionnaires, and a workshop.

According to the results of D8.1, in the vision-building work, there are many definitions and different understandings of the term "vision". In general, the work in NEGEM builds on a definition of a vision representing a desirable outcome or goal. It was recognized that 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.

With NEGEM project having run for 30 months at the time of writing this deliverable, the results achieved by different Work Packages make it possible to concretize the vision. In this update of the vision, the selected results of the deliverables published in between, are applied. Especially, the following aspects have been paid attention to explore the results based on deliverables.

- Key messages to concretize the vision based on Deliverables completed / results achieved during M9-M30
- Barriers and boundary conditions for NETPs.

In sections 2.1-2.5, results of the NEGEM deliverables reviewed from the above viewpoints, are presented. The review of the deliverables confirmed that the messages based on research different approaches are partly contradictory. Partially, the fact that results "appear" contradictory is explained because NEGEM partners have all developed models and thinking tools independently, and the results have been an outcome of that effort. This must be kept in mind while reading the following sections. However, despite partially contradicting messages, even identifying these differences has value in developing the NEGEM vision.

2.1 Updated insights based on perspectives of stakeholder groups and social dimension

According to results of deliverables based on stakeholder consultations (D5.2, D5.3), regulatory frameworks need to be transformed to present clarity and long-term certainty at the EU level as well as within governments of individual Member States. Perception on which technologies should be applied vary between different stakeholders. Based on sample distribution used in D5.3, NGOs demand that EU policies should focus solely on reducing emissions and if CDR (Carbon Dioxide Removal) would be necessary, it should rely mostly on afforestation, reforestation and soil carbon sequestration. On the other hand, the private sector sees the deployment of a broader set of NETPs more favourably. Improving the awareness of less mainstream NETPs is needed to improve their perception. However, homogenous policies within the EU could fail because of different economic needs and resources of the territory as well as different degree of acceptance of NETPs in different geographical areas.

Key conclusions include:

- Clear regulatory frameworks are needed (D5.2);
- NGOs favor ecological solutions while private sector accepts broader deployment of NETPs (D5.3);
- Hard to implement homogenous policies within the EU (D5.3).

2.2 Updated insights based on commercialisation mechanisms

Based on work on commercialisation mechanisms (D2.1), currently, the commercialisation mechanisms in operation are under resourced and pay too little to enable a balanced portfolio of NETPs that could

support hard-to-abate sectors move to net zero. For Europe, a carbon contract-for-difference (CfD) is the most commonly suggested mechanism for BECCS and subsidy type payments are more likely for land-based NETPs. In most scenarios in EU, governments contribute the majority of financial resources in 2030, but the market surpasses them by 2050 due to the carbon price exceeding the cost of removals. Engineered removals (BECCS, DACCS) make up the vast majority of financial resource requirements in 2050 across scenarios. The resilience of regulatory arrangements, cap setting processes and market stability mechanisms need to be revised to absorb substantial volumes of CDR.

Key messages include:

- CDR supporting mechanisms are under resourced and payments are too low currently (D2.1);
- Carbon CfD for BECCS and subsidy payments for land-based NETPs are the most commonly suggested mechanism. (D2.1)
- Across mitigation scenarios, financial resources are allocated mostly to technical removals in 2050. (D2.1)
- Revision of regulatory arrangements, cap setting processes and market stability mechanisms need to be revised.

2.3 Updated insights based on environmental impacts

According to work on constraints on planetary boundaries (D3.2), biomass-based NETP potential is constrained by environmental limits, i.e. planetary boundaries (PB) for nitrogen (N) flows, freshwater use, and land system change.

The life cycle assessment results of various NETPs show trade-offs between various environmental impacts, while none of NETPs performs well in all impact categories (D3.8). Terrestial NETPs are vulnerable to unexpected events, such as droughts and fires, and should not be considered in isolation but as part of a portfolio of NETPs. However, afforestration and/or reforestation is the most promising terrestrial NETP in terms of CDR efficiency and the assessed environmental and socioeconomic KPIs (Key Performance Indicators) (D1.2).

Sustainability assessment of NETPs shows that coastal enhanced weathering and Low Temperature Solid Sorbent DACCS (LTSS-DACCS) are the most promising technologies generating net health and ecosystem co-benefits and low damage to resource availability (D3.8). Using cleaner energy and absorbents can minimise the climate change impacts associated with DACCS.

For BECCS, residual feedstocks are considered to have lower risk on climate and biodiversity. Maximum plantation-based BECCS potential is constrained by widespread and severe planetary boundary transgressions through current agricultural production and is reduced to almost zero if conversion of forests to biomass plantations is additionally precluded. There is a need for rapid socioeconomic transformation if risks associated with PB transgression are to be minimized. Reforestation on pasture areas could provide CDR while reducing pressure on planetary boundaries. However, it is subject to reversal and depends on reduced pasture areas for food supply (D3.2).

Biochar sequestration could be implemented without further pressure on land resources and food security when biochar-mediated yield increases are accounted for in land allocation for feedstock production. (D3.2)

When zero carbon technologies are deployed on a large scale, cobalt and dysprosium may be severely affected and copper and silver resources exhausted (D3.9).

Key messages include:

- Planetary boundaries for N flows, freshwater use and land system change will constrain biomass based NETPs. (D3.2)
- Portfolio of NETPs are needed. A/R are the most promising terrestrial NETP based on KPIs (D1.2).
- Coastal enhanced weathering and LTSS-DACCS perform best in sustainability assessment (D3.8)
- Residual feedstocks for BECCS have lower risks on climate and biodiversity (D3.2).
- Planetary boundaries may constrain plantation-based BECCS potential to almost zero. (D3.2)
- Need for rapid socioeconomic transformation to minimize the risk associated with PB transgression (D3.2)
- Reforestation potential on pasture areas are subject to reduced pasture areas for food supply (D3.2).
- Mineral demand may exhausts cobalt and dysprosium as well as copper and silver resources (D3.9)

2.4 Updated insights based on multi-dimensional potentials

According to work conducted on multi-dimensional potentials building on MONET-EU model aim at providing a whole-system analysis of a least cost portfolio of CDR pathways, the most cost-optimal way to meet the Paris Agreement relies on international cooperation especially due to restricted biomass resources, i.e it is not acceptable to base GHG mitigation efforts on permitted biomass import outside of the EU. By integrating NETs into an international market for negative emission trading, nations capable of generating CDR surplus relative to their individual CDR targets could provide this as a service to other nations with lower biomass and resource availability for NETs.

BECCS is the preferred technology and it is deployed at scale early on due to its lower removal cost. By 2040 around 12.5 $GtCO_2$ would be removed by BECCS in the EU, followed by afforestation contribution to around 2 $GtCO_2$. Biochar can either compliment BECCS or replace BECCS when CO_2 storage is not available nationally. Whereas the role of DACCS is more prominent during the second half of the century having potential to start deployment in 2040. Investing in DACCS technologies is essential in the mid-century to compensate for the constrained deployment of BECCS and afforestation.

Cumulative cost-optimal CO_2 removal in 2100 for the EU-28 is 80 Gt of CO_2, comprised of BECCS (59 Gt CO2), AR (16 Gt CO_2), biochar (4 Gt CO_2) and EW (2 Gt CO_2). However, it should be noted that here DACCS is not deployed owing to its costliness.

Key messages include:

- Integrating NETs into an international market for negative emission trading would be cost-optimal way to reach the PA. (D7.2)
- BECCS is the preferred technology, followed by afforestation (D7.2).
- DACCS investments in mid-century may compensate constraints in BECCS and afforestation (D7.2).

2.5 Updated insights based on scenario modelling

D8.6 published synchronously to this deliverable serves the vision update by fulfilling the 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. Furthermore, these assessments aim at increasing holistic understanding of the significance of NETPs.

The key messages based on the preliminary scenario assessments in D8.6 and D3.9. can be summarized as follows:

- NETPs would be needed to reach the 1.5-2.0°C mitigation goals and no NETP option should be excluded from mitigation portfolios at this stage. Considering the environmental constraints, DACCS seems be the most significant NETP option especially in the long-term.
- PyCCS and reforestration in our scenarios, are competitive and quite sustainable options in GHG mitigation, but under the assumed storylines their combined potential still seems far from sufficient for keeping the temperature change within 1.5-2.0 °C mitigation targets. However, especially PyCCS seems to be a potential mitigation option due to its several co-benefits but more research is needed to better analyse its global and regional potentials.
- The scenario modelling results reported in D3.9. showed that the clean energy transition may be constrained by a supply of cobalt and neodymium, copper and silver are used high amounts in renewable energy technologies but also in other sectors. If these boundary conditions are considered, the demand of NETPs could increase even further as the renewable energy implementation (solar, wind, batteries, etc.) may be constrained. The results e.g. showed that also non-renewable boundary conditions need to be considered in mitigation pathways.

3 Ingredients to the Vision updates based on internal NEGEM workshop

Based on the internal discussion with the NEGEM partners, the most critical questions for vision building on NETPs seem to relate on realistic and sustainable potentials of biomass based NETPs, e.g. especially BECCS, afforestation and reforestation. In addition, there are large uncertainties related to PyCCS, DACCS and enhanced weathering. If we especially focus on environmental constraints and planetary boundary limits, biomass based NETPs seem to have very low potentials compared with global scenario assessments with IAMs, where the techno-economic potential of especially BECCS seem to be much higher. Therefore, we selected two alternative pathways. One of the pathways focuses on building from the perspective of Environment and the other pathway on having the goals of Economy as the primary focus. In addition, we selected Security - energy security, self-sufficiency of food, goods, etc.- as the third sustainability pillar as after the Russian attack to Ukraine, the security issues need to be considered even more carefully.

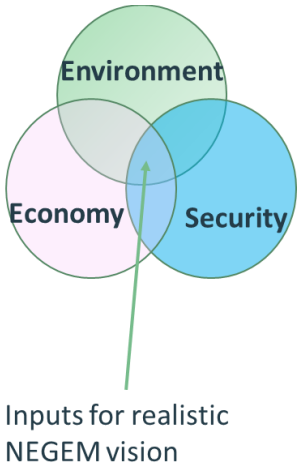


Figure 2 Inputs for realistic NEGEM vision. Internal NEGEM workshop arranged on October 6th, 2022, considered different types of worlds applying NETPs with three different emphases: Environment, Economy and Security. According to discussions in NEGEM events, views on appearance of different type NETPs differs between visions of individuals and stakeholders, e.g. according to how the three angles are valued. NEGEM aims at creating a highly shared vision on NETPs, meaning that these criteria should be fulfilled to an extent possible. Scenario work incorporating all the NEGEM WPs and harmonizing the results on NETPs by different WPs are the key tools to feed such a vision with NEGEM results.

3.1 Organization of the workshop

The internal NEGEM workshop arranged on October 6th, 2022, developed storylines for NEGEM scenarios. As the participants were instructed to base the ideas presented in the workshop on the results they've achieved in previous phases of NEGEM, the results should serve inputs (Figure 1) for the vision update based on NEGEM research.

The workshops was based on groupwork organized for three groups and on-line group with altogether 26 participants. The method of the workshop was based on *Futures wheel* method (Glenn 2003), preliminarily applied by VTT in earlier projects creating low-carbon pathways for society (e.g. Dufva et al. 2013).

Task for each group was to work on ideas of elements to be included in NEGEM storylines. Each of the storylines was instructed to be compatible with the 1.5…2 C goal of the Paris Agreement. However, it was underlined that none of the storylines represent forecasts. The aim was specified as to evaluate the role of NETPs in 2050 in different pathways, where different policies, norms and behaviour, and innovations define the pathways for NETP implementation.

Groups formulated alternative storylines with different assumptions on global and regional developments, including social norms and values, behaviour, policies, etc. In preparatory material supporting identifying relevant variables, the findings of a previous internal NEGEM workshop organized on M13, were applied. In the material, the primary emphasis of the alternatives storylines was defined as follows:

- **Environment**: Nature conservation and biodiversity
- **Economy**: Advanced clean technology implementation, global markets
- **Security**: Energy security and self-sufficiency of food, goods, etc.

Each of the emphases can be assumed to represent desirable futures for a large number individuals or stakeholder groups. For example, framework of the energy policy of the EU has been based on three pillars of security of supply, competitiveness and sustainability (e.g. EC 2015) paralleling the foci of three storylines dealt with in the internal NEGEM workshop. Therefore, the results of the workshop should be applicable for NEGEM vision from the viewpoint of desirability. However, according to NEGEM results completed (see e.g. Chapter 0 or NEGEM deliverables), fulfilment of all the targets simultaneously is seen challenging. For example, although BECCS is cost-effective, it can constrain the planetary boundaries significantly. Hence, defining a reasonable trade-off between the targets can increase the acceptance of a storyline. That is, even though it might prove challenging to define concrete pathways for NETPs with x Gt of certain technology preferred by "all", a widely accepted trade-off between the desirable futures is seen achievable. Figure 2 demonstrates this idea with the cross-section between the dimensions representing "Realistic NEGEM vision".

In the following, elements to meet the different targets, and therefore feeding the vision-building, are presented **based on the results of the workshop**. This includes both storylines tailored for vision-building, as well as more comprehensive workshop results classified on PESTEL tables. Importantly, it must be noted that the tables are based on the ideas of groups who worked independently. Therefore, there may be some inconsistencies and duplicate ideas included in the draft storylines built for the preliminary deliverables D8.6 and D8.7.

In the modified storylines, question of "what" is emphasized to present elements for updated vision. In PESTEL tables below, an effort is presented to divide the elements both as

- opportunities foreseen to be present in the worlds following the storyline and
- barriers prohibiting its materialisation.

It must be recognized that the division of elements between barriers and opportunities is not unambiguous. However, NEGEM vision should responsibly incorporate the the desired, positive aspects while considering barriers to represent realistic vision. In this deliverable, based on exploring the results of the workshops of different groups, key findings for the vision-building are presented in Chapter 4. Systematic quantitative approach with the forthcoming NEGEM IAM modelling exercises sheds additional light on this assessment (see e.g. D8.6 published synchronously to this deliverable). However, as quantitative modeling has its limitations, the ideas presented below, to a high degree relying on brainstorming complement the modeling results and back it up.

3.2 Dimension of technology and economy

3.2.1 Tailored storyline for the NEGEM vision

A massive NET scale-up takes place by 2050. This would be enabled by various business models and effective climate policies. The cost of technologies would go down and there would be internalisation of external costs as well as incentives to investing in more expensive solutions with early innovation funds. Large-scale, low-cost finance would allow fast-track deployment.

There would be a fundamental transformation of the energy system. The fossil fuel industry would need to be transformed in partnership with NETPs, CCS, CCU and renewables. However, geopolitical factors may a play a role, forcing a switch to coal or oil, and therefore increasing the need for CDR. Additionally, life cycle emissions would need to be reflected in increased costs and moving emissions abroad would have a cost.

Behavioural changes in wealthy nations are needed, as well as rapid implementation of technological solutions e.g. for sustainable aviation. Distributive fairness principles are agreed on at the global level, implicating support for low-income countries.

3.2.2 Opportunities and barriers

PESTEL	Advanced technology and global markets
Political & legal	Opportunities: • N_2O, CH_4 and other GHGs are valued emissions / removing • Policies ensure that NETPs are accounted similarly and comparable • Nature-based solutions won't have been incentivised purely through a carbon market / Nature-based solutions in a variety of mechanisms not just carbon market • Fossil fuel industry reconversion/partnership with NETPs/CCS/CCU/ renewables • Cooperation will be key to exploit regional advantages • A regional portfolio optimized depending on the location Barriers: • Non supporting EU politics • Competition for storage of CO_2 • Geopolitical factors may a play a role, forcing a switch to coal or oil, and therefore increasing the need for CDR
Economic	Opportunities: • NET scale-up by 2050--> Business models --> Verification and vast integration with CO_2 markets and CAP and trade system • Decline in voluntary carbon markets in favour of capital being channeled into direct solutions • Internalisation of external costs • Incentives to investing in more expensive solutions • Life cycle emissions cost more / moving emissions abroad has a cost • CAP reform to take in a broader scope of funding • Early innovation funds but large-scale, low-cost finance to fast-track deployment Barriers:

	• Allowing carbon markets to establish that do not meet high multi-dimensional sustainability criteria and then cannot be regulated well later (e.g. current pressure of bioenergy lobbies in the EU against sustainability criteria)
Socio-cultural	Opportunities: • Distributive fairness principles to agree on at the global level and support for low-income countries • Either changed habits from "rich" world, either more techs (e.g. "sustainable aviation"), or maybe a mix of both Barriers: • High vulnerability/ dependency on access to affordable renewable electricity
Technological	Opportunities: • Balancing fossil CO_2 emissions with geological storage, Balancing non-CO_2 GHGs with removals • Large distributed CO2 transport and storage networks • DACCS will take up a larger proportion of the balance than fossil CCS • Strong system integration of NETPs with low fossil C future (residual biomass to bio/syn-gas, heat recovery, renewable H_2) Barriers: • The scale-up of DAC will require a huge amount of renewable energy • Undersupply of CDR in relation to market demand --> miss net zero targets
Environmental	Opportunities: • Ocean capacity for sequestering CO_2 • Ocean liming & fertilization w up/downwelling • C farming schemes in place Barriers: • Competition for land will become an issue, particularly considering the need to feed a growing population • Ocean, conflict w other users

3.3 Dimension of nature conservation and biodiversity

3.3.1 Tailored storyline for the NEGEM vision

The need to increase global co-operation for efficient resource use is highlighted. In this world, planetary boundaries would be strictly followed, and the energy system would be totally renewable. Consumption of material and energy would be reduced and become more efficient. In this storyline, NETPs are viewed skeptically due to the concerns of environmental impacts attached. As NETPs are not highly accepted, deployment of rapid and stringent emission reductions has an increased need. Moreover, there is support for indigenous and local communities to discourage deforestation

All available NETPs which do not violate the planetary boundaries would be needed. For non-permanent GHG emission storage, an insurance should be paid to ensure longer time horizon removals of at least 100 years. Monetary value would be given for biodiversity and ecosystem services could be monetarized to finance nature-based solutions (NBS), SCS, PyCCS (i.e. soil resilience and water holding capacity). Nature-based solutions, SCS and PyCCS would be prioritized NETPs due to other benefits and ecosystem services. DACCS would be needed sooner for emission reduction. There would be incentives

for circular economy to enable highly efficient management of material streams and efficient use of NETPs.

3.3.2 Opportunities and barriers

PESTEL	Nature conservation and biodiversity
Political & legal	Opportunities: • Need for global co-operation to use the available resources efficiently • "Keep it in the ground" + "best CDR is no CDR" --> rapid & stringent emission reductions • Support indigenous / local communities to discourage deforestation
Economic	Opportunities: • For "non-permanent" C storage: pay the insurance of longer time horizons (100 years?) • Monetarization of ecosystem services to finance NBS, SCS, PyCCS (i.e. soil resilience, water holding capacity etc.) • Incentives for circular economy Barriers: • Vested interests want to see near-term use of CDR • Energy intensive industry in problems
Socio-cultural	Opportunities: • Change in behavior, reduced consumption, diet change • Enable emerging economies to implement CDR technologies • More dense population centres and much lower population growth Barriers: • Difficult to engage population to change due to effects elsewhere in the future • Inertia of effective energy systems, population patterns etc.
Technological	Opportunities: • Use agricultural land for BECCS--> change diets--> use biochar to improve soil • Highly efficient management of material streams + efficient use for NETPs (BECCS, PyCCS, etc.) • Need for more DACCS --> even more aggressive RES deployment • Nature-based solution +SCS+PyCCS prioritized NETPs due to other benefits / ecosystem services
Environmental	Opportunities: • Active collaboration and polling of resources • Stop deforestation • Very intensive agriculture & bio-based products (including urban agriculture) Barriers: • Land use change for biomass-based NETPs only within current bounds of agr. land + where compatible with i.e. planetary boundaries • No ocean-based CDR • No further land use expansion (especially not for NETPs)

3.4 Dimension of security

3.4.1 Tailored storyline for the NEGEM vision

Nations and areas turn more to themselves, meaning increased significance of local production chains and local food supply. World operates more in clusters through regional development rather than global, market-based co-operation. In this set-up, the priority of 1.5 C target and if it can be achieved globally is questionable. In this type of world, technological development in general is seen challenging, and maybe even more so with NETPs.

Trust to build CO_2 pipelines between areas and countries is seen imperfect. This has consequences to portfolio and volume of NETPs foreseen. The role of NETPs development would materialise within the boundaries of land and clean energy availability. Energy independence would be essential to ensure self-sufficiency as NETPs such as DACCS which requires a lot of energy. DACCS would be limited by local renewable energy supply, BECCS to be implemented only in countries with CO_2 storage capacity and feedstock availability. Solutions with side benefits and that could be implemented within local circumstances would be emphasized. PyCCS would be based on residues and waste.

Dietary changes would be needed to reduce pressure on land use and energy. There could be also consequent revolutionary agricultural processes, with less energy and water requirements. As a positive opportunity from European perspective, energy independence can be increased and exportable technological solutions could be implemented from the locally developed NETPs applications

3.4.2 Opportunities and barriers

PESTEL	Security and self-sufficiency
Political & legal	Opportunities: • Clustered regional co-operation • NETPs implemented with reductions in GHG emissions Barriers: • CCS+CCU deployment will increase energy price in regions where climate targets are being achieved --> reduces energy security of citizens? • Low-tech NETPs, climate change mitigation not the key target, will 1.5 C be a priority?
Economic	Opportunities: • Act on the Supply side --> incentives • Act on the Demand side: efficiency, behavioral actions
Socio-cultural	Opportunities: • Revolutionary agricultural processes (less energy, water) + different food consumption habits (insects?) --> land allocated to NETPs without compromising food security • Energy independent • Some degree of diet change to allow for BECCS/PyCCS feedstock production?/ reforestation • Energy consumption reduce as population grows
Technological	Opportunities: • PyCCS based on residues & waste

	• BECCS, CO_2 utilization in food production etc.local supply chains • Exportable technological solutions • CO_2 pipelines connecting countries, countries with geopolitical threats are avoided • Forestation is scaled up as it imposes less geopolitical threats Barriers: • DACCS limited by local renewable energy supply • CO_2 pipelines-will there be trust to build infra • BECCS only in countries with a) CO2 storage capacity b) feedstock availability
Environmental	Barriers: • A/R may face some opposition from farmers if taking too many lands • Risk: biodiversity

4 Key findings and policy relevant messages

The summarized NEGEM vision statement, including the minor update in wording made after the release of D8.1 (January 2021), is formulated as follows:

> There is a risk that climate goals of Paris Agreement (PA) will not be met without NETPs. 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 PA goals. NEGEM will make those accountable for decision-making beyond only looking into negative CO_2 emission balance accounting.

The core value of the interim update of the NEGEM vision presented in this deliverable is to present research-based ingredients from NEGEM WPs that can be used to supply the highly qualitative vision above with more concrete research result.

Table 2 summarizes the key findings to update the NEGEM vision based on the outputs of internal NEGEM storyline workshop from October 6th, 2022 (see Chapter 3). Table 2 includes elements interpreted more or less desirable from the different possible futures focusing on viewpoints of Economy, Environment, and Security. Accordingly, somewhat different roles for the role of NETPs, are envisaged. That is, "Economy" storyline incorporates a wide variety and massive scale-up of NETPs, whereas "Environment" storyline includes a more conservative approach and emphasis of nature-based solutions such as SCS, and PyCCS.

As central characteristics related to the "Security" storyline discussions of the workshop, trust to build CO_2 pipelines between areas and countries is seen imperfect. Conclusively, in a portfolio NETPs foreseen in "Security" storyline, solutions with side benefits and that could be implemented within local circumstances would be emphasized. Noteworthy, the workshop discussions of "Security" storyline built on a continuing crisis mode, echoing the current geopolitical situation. Thereby, the results of this storyline must be considered carefully for vision-building. In further development of the security aspect in vision, it must be remembered that a focus on energy or resource security does not imply isolationism.

As another main source for concretizing the vision, ideas on concrete elements to be added to the qualitative NEGEM vision based on NEGEM results from M9-M30, are presented in Table 3. According to a review of results of other WPs in NEGEM deliverables conducted for this deliverable, there are differences in the messages of the role of NETPs according to results. BECCS, whose potential is seen low based on WP3 results, but on the other hand, preferred in the results based on cost-optimality assessments by WP7 and WP8. Also, there different results and views on DACCS, afforestation and reforestation. In WP8, the preliminary scenario results show also different dynamics in NETP investments. As an example, more strict constraints in BECCS will lead to earlier investments in DACCS.

In addition to the messages of different types of NETPs, results on regulatory and social issues feed the vision and parallel scenario work. As an example, realization of the difficulty to implement homogenous policies (D5.3) is recognized but the call for international co-operation and clear regulatory frameworks (D5.2, D7.2). These elements quite smoothly match with the storylines of "Security" with limited, and "Economy" and "Environment" building on co-operation, respectively. This message, alongside with

others with seemingly straightforward inclusion in NEGEM vision, is included in row "Straightforward messages for vision-building" of Table 3.

Conclusively, the key findings suggest co-developing the NEGEM vision and NEGEM scenarios incorporating differences in:

- Realistic and sustainable potentials of BECCS, afforestation and reforestation as well as DACCS.
- Uncertainties in PyCCS and enhanced weathering.
- The level of international co-operation in NETP related policies and measures.

Table 2. Elements to update the NEGEM vision based on outputs from internal NEGEM storyline workshop outputs. The selected outputs represent desirable elements for concretizing the vision from different emphases applied in group work of the workshop.

Economy	• A massive NET scale-up takes place by 2050. • Various business models and effective climate policies. • Cost of technologies down, internalisation of external costs • Incentives to investing in more expensive solutions with early innovation funds. • Fundamental transformation of the energy system. Fossil fuel industry transformed and in partnership with NETPs, CCS, CCU and renewables. • Geopolitical factors may a play a role, forcing a switch to coal or oil, and therefore increasing the need for CDR. • Life cycle emissions would need to be reflected in costs and exporting emissions abroad would have a cost. • Changed habits from the rich world and more of better technological solutions e.g. sustainable aviation. • Distributive fairness principles are agreed on at the global level, implicating support for low-income countries.
Environment	• Increased global co-operation for efficient resource use. • Planetary boundaries would be strictly followed. • Energy system totally renewable. • Consumption of material and energy would be reduced and become more efficient. • Indigenous and local communities supported to discourage deforestation • While NETPs will be deployed it is important to deploy rapid and stringent emission reductions. • All available NETPs which do not violate the planetary boundaries would be needed. • Monetary value would be given for biodiversity and ecosystem services could be monetarized to finance nature-based solutions (NBS), SCS, PyCCS (i.e. soil resilience and water holding capacity). • SCS and PyCCS would be prioritized NETPs due to other benefits and ecosystem services. • DACCS needed sooner for emission reduction. • Incentives for circular economy to enable highly efficient management of material streams and efficient use of NETPs.
Security	• Nations and areas turn more to themselves • Increased significance of local production chains and local food supply. • Regional development rather than global, market-based co-operation. • Technological development in general challenging, and maybe even more so with NETPs. • Trust to build CO_2 pipelines between areas and countries imperfect with consequences to portfolio and volume of NETPs foreseen. • The role of NETPs development within the boundaries of land and clean energy availability. • Energy independence would be essential to ensure self-sufficiency as NETPs such as DACCS which requires a lot of energy. • DACCS would be limited by local renewable energy supply, BECCS to be implemented only in countries with CO_2 storage capacity and feedstock availability.

	• Solutions with side benefits implementable within local circumstances emphasized. • PyCCS would be based on residues and waste. • Dietary changes reduce pressure on land use and energy. There could be also consequent revolutionary agricultural processes, with less energy and water requirements. • As a positive opportunity from European perspective, energy independence can be increase and exportable technological solutions could be implemented from the locally developed NETPs applications

Table 3 Key findings for vision developing based on NEGEM results up to M30.

Ambiguous messages for vision-building calling for further discussions	**Role of BECCS** • BECCS the preferred technology, followed by afforestation (D7.2) • Residual feedstocks for BECCS • Planetary boundaries for N flows, freshwater use and land system change will constrain biomass based NETPs. (D3.2) **Role of A/R** • A/R the most promising terrestrial NETP based on KPIs • Reforestation potential on pasture areas subject to reduced pasture areas for food supply **Role of DACCS and enhanced weathering** • Coastal enhanced weathering and LTSS-DACCS perform best in sustainability assessment • DACCS investments in mid-century to compensate for constraints in BECCS and AR
Straightforward messages for vision-building	• International cooperation the most cost-optimal way • Clear regulatory frameworks needed • NGOs favor ecological solutions while private sector accepts broader deployment of NETPs • Portfolio of NETPs needed • Hard to implement homogenous policies within EU • Need for rapid socioeconomic transformation (with PBs) • Mineral demand may exhaust cobalt and dysprosium as well as copper and silver resources • Biochar-mediated yield increases should be accounted for in land allocation for feedstock production • Focus on energy or resource security does not imply isolationism

<u>Policy relevant messages</u>

- An updated NEGEM vision statement has been formulated as follows: “There is a risk that climate goals of Paris Agreement (PA) will not be met without NETPs. 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 PA goals. NEGEM will make those accountable for decision-making beyond only looking into negative CO_2 emission balance accounting.”

- To update the NEGEM vision and make it more concrete, barriers and boundary conditions to model more realistic and sustainable potentials of NETPs on a global and EU scales, need to be included in its formulation.
- NEGEM results on potential of different NETPs by different approaches applied by WPs do not converge to a simple message.
- The most critical questions seem to relate to realistic and sustainable potentials of biomass based NETPs, e.g. especially BECCS, afforestation and reforestation. In addition, there are large uncertainties related to PyCCS, DACCS and enhanced weathering.
- As a vision based on NEGEM results is aimed at, the differing messages indicate a need for measures such as a) accepting a trade-off between targets such as environment and economy b) applying ranges for the level of deployment of different NETPs.
- As another approach to incorporate variability, NEGEM scenarios have been started to be developed building on three different storylines, “Economy”, “Environment”, and “Security”.
- First quantitative results on corresponding scenarios are presented in D8.6. This provides with coherent reference to discuss the different futures with NETPs having a significant role.
- Portfolio of NETPs will be needed according to NEGEM results and this may further help in achieving wide acceptance for the vision.

5 Conclusions and further steps

As a part of NEGEM, WP8 work has a target to also combine the results of other WPs to bring more holistic understanding of NETPs. The efforts to incorporate the results of other WPs in building the NEGEM vision and scenario assessments completed in this deliverable pave the way towards this target. Preliminary quantitative scenario assessments of M30 (November 2022) are reported alongside this deliverable in D8.6.

According to a review of results of other WPs in NEGEM deliverables conducted for this deliverable, there are differences in the messages of the role of NETPs. Partially, there are natural reasons, as the results are based on different methods. However, in order to develop a vision, further discussions are needed to achieve wide acceptability backed up by NEGEM results. At least the following points of discrepancies were identified based on the NEGEM results and internal discussions:

- The most critical questions for vision building on NETPs seem to relate on realistic and sustainable potentials of biomass based NETPs, e.g. especially BECCS, afforestation and reforestation.
- In addition, there are large uncertainties related to PyCCS, DACCS and enhanced weathering.

To address the uncertainties and incorporate conflicting messages, NEGEM scenario work was launched based on building storylines on three different worlds. Even if a single scenario *both* incorporating all the aspects in NEGEM results *and* seen desirable by every member of the consortium could not achieved, the results of the NEGEM scenarios improve the knowledge basis to formulate the vision more concretely. NEGEM scenarios in progress emphasizing aspects of Economy, Environment or Security, respectly, open up the discussion on different roles of NETPs seen parts of the possible futures. D8.6 with preliminary results on “Economy” and “Environment” scenarios, presents a starting point for increasing the mutual understanding and for formulating the final NEGEM vision.

Wide acceptability and the goal of being based on research results belong to targets for NEGEM vision identified in D8.1. Based on the work done for this deliverable, partially ambiguous research-based messages based on different approaches and models make it not straightforward to append the vision with NEGEM results. This aspect needs to be taken in account in forthcoming work. The following measures can be identified to pave the way towards these targets:

- Identifying the differences in underlying data/assumptions and harmonize them when feasible.
- Developing scenario variants to develop a vision addressing different possible futures, e.g. embracing targets on Economy, Environment, or Security.
- Applying ranges for the amounts of NETPs included in the vision to capture uncertainty.
- Finding trade-offs between the desired outcomes.
- Fine-tuning the expressions in summarized NEGEM statements, e.g. making them more general to increase acceptability.
- In addition to application of NEGEM results, options to reword the vision will be explored based on key literature available (e.g. IPCC). For example, it could be collectively considered if a stronger

statement “It is unlikely, that climate goals of Paris Agreement (PA) will be met without NETPs" could be included in the vision.

Conclusively, the measures listed above are applicable as the key guidelines for further development work of the vision and paralleling scenario work. The Final NEGEM vision is to be completed, tested and analyzed by forthcoming NEGEM work and externals in the Final vision workshop (M42-M46).

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)
D1.2	Comprehensive sustainability assessment of terrestrial biodiversity NETPs	ETH	R	PU	12
D2.1	Quantitative survey of commercialisation mechanisms	UOXF	R	PU	18
D2.2	Interactions and trade-offs between nature-based and engineered climate change solutions	UOXF	R	PU	17
D3.1	Upgraded LPJmL5 version	PIK	R	PU	12
D3.2	Report on Global NETP biogeochemical potential and impact analysis constrained by interacting planetary boundaries	PIK	R	PU	24
D3.8	Report on comparative life-cycle sustainability assessment of NETPs for impacts on human health, ecological functions and resources	ETH	R	PU	24
D3.9	Report on assessment of impacts on key non-renewable resource chains: case study on global demand, supply and trade-offs for selected metals and minerals in global mitigation pathways	VTT	R	PU	25
D5.2	Stakeholder views on the business case for NETPs	UCAM	R	PU	24
D5.3	Stakeholder views on NETP governance	UCAM	R	PU	18

D7.2	Extended MONET-EU	ICL	R	PU	17
D8.1	Stocktaking of scenarios with negative emission technologies and practises. Documentation of the vision making process and initial NEGEM vision	VTT	R	PU	8
D8.6	Quantitative assessments of NEGEM scenarios with TIMES-VTT, preliminary results	VTT	R	PU	30

References

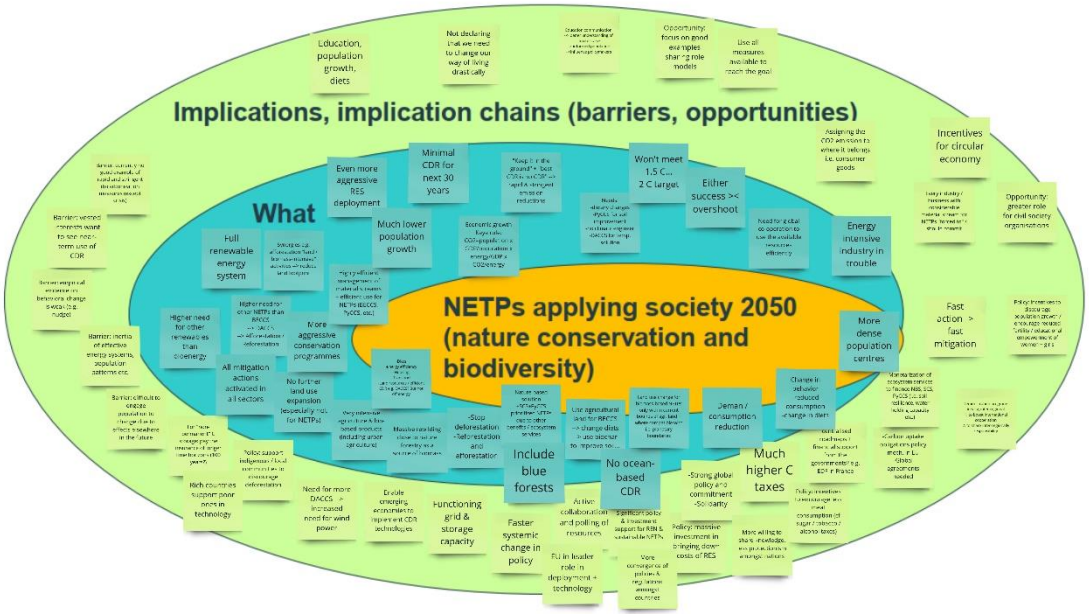
Dufva, M. Wessberg, N., Similä, L., Koljonen, T. (2013). Low Carbon Finland 2050 –platform. Ennakointiprosessin kuvaus. (in Finnish) Tutkimusraportti VTT-R-03302-13. https://www.vttresearch.com/sites/default/files/julkaisut/muut/2013/VTT-R-03302-13.pdf

EC (2015). A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy. Communication from the European Commission COM/2015/080 final. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52015DC0080&from=EN

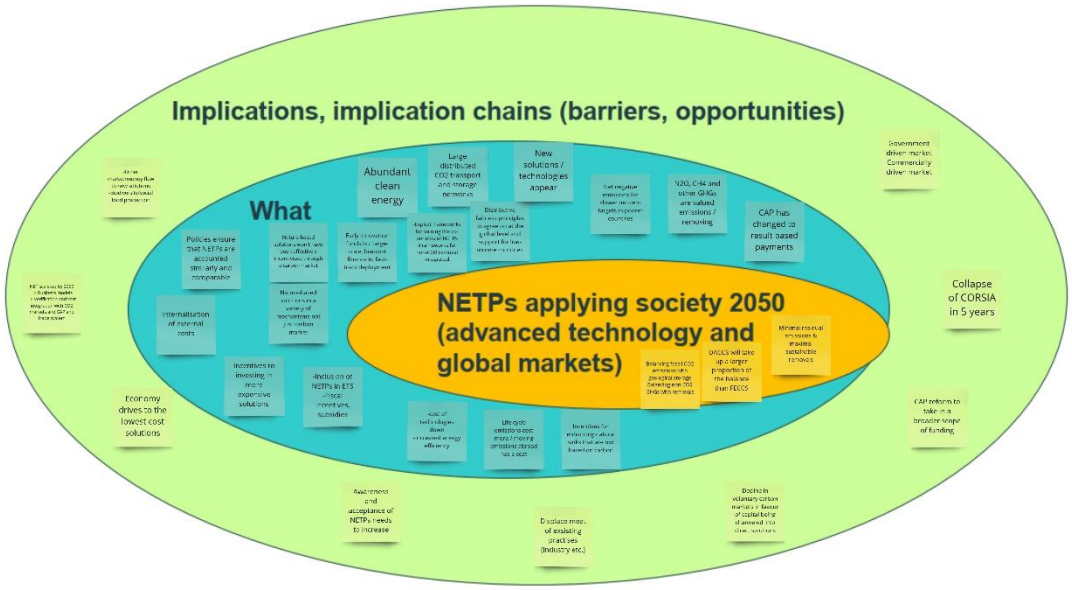
Glenn, J. (2003). The Futures Wheel. In Futures Research Methodology–V2.0. The United Nations University, The Millennium Project.

Annex 1: Futures wheels created in the groupwork of internal NEGEM workshop

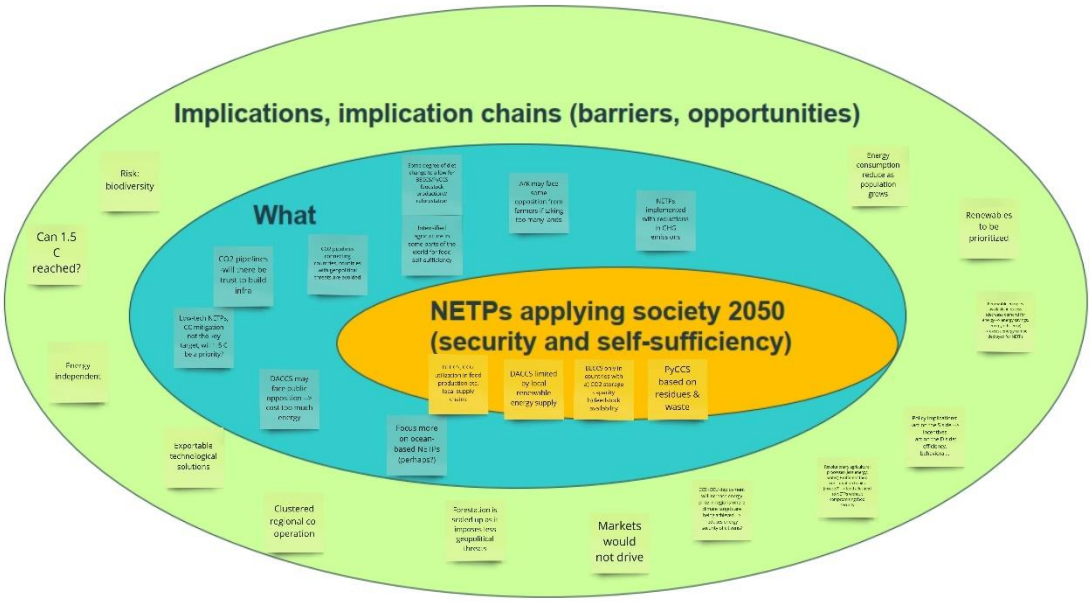
Futures wheel – group A



Futures wheel – group B



Futures wheel – group C



Futures Wheel - Group B