



## D 5.6 Policy recommendations report at EU level WP5 - Modelling framework and policy recommendations

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## Abbreviation and Acronyms

Acronym	Description
CAP	Common Agricultural Policy
CH <sub>4</sub>	Methane
CO <sub>2</sub>	Carbon Dioxide
CRCF	Carbon Removals Certification Framework
EJ	Exajoule (10 <sup>18</sup> joule)
EROI	Energy Return on Investment
EU	European Union
EU27	European Union composed of 27 member states
FE	Final Energy
GHG	Greenhouse Gas
GW	Gigawatt (10 <sup>9</sup> watt)
IAM	Integrated Assessment Model
KPI	Key Performance Indicator
LAMS	Land-based Adaptation and Mitigation Solutions
LULUCF	Land Use, Land Use Change and Forestry
NECP	National Energy and Climate Plan
NO <sub>2</sub>	Nitrogen Dioxide
PE	Primary Energy
PV	Photovoltaics
RED II	Renewable Energy Directive II
RED III	Renewable Energy Directive III
RES	Renewable Energy Sources
T0	Baseline reference year 2030
UN	United Nations
WILIAM	Within Limits Integrated Assessment Model
WP	Work Package

## Executive summary

This deliverable presents the outcomes of the holistic evaluation and simulation of policy measures selected from the RethinkAction Land-based Adaptation and Mitigation Solutions (LAMS) catalogue, in line with the objectives set in Work Package 4 (WP4). These measures, both single and integrated solutions, were assessed using the Within Limits Integrated Assessment Model (WILIAM) model at European Union (EU) and global scales, applying the Key Performance Indicator (KPIs) defined in the WP4 evaluation framework, already integrated in WILIAM in Task 5.4. The deliverable reports the key results from the simulation of these policy impacts across different sectors and scenarios, including the exploration of new scenarios that consider societal lifestyle recommendations and behavioural changes. Building on these evaluations, the deliverable provides specific recommendations to policy makers as summarised in Annex I.

The D5.6 Policy Recommendations Report at EU level, which builds upon the outcomes of the modelling exercises and analyses conducted in WP5, offers a comprehensive set of sector-specific policy recommendations derived from advanced simulation, based on the optimization approaches applied through the WILIAM model, at both EU and global levels. Looking ahead, the deliverable highlights the importance of fostering continued collaboration, further refinement of simulation methodologies, and a more in-depth analysis of combined uncertainties. These elements are essential to support policymakers in designing robust strategies that can drive sustainable and resilient socio-ecological transitions.

## 1 Introduction

The RethinkAction project, funded by the European Union under the Horizon 2020 programme aims to develop an integrated decision support platform to guide climate action for both adaptation and mitigation. Within Work Package 5, the Integrated Assessment Model WILIAM brings together seven sectoral modules (Economy & Finance; Renewable & Non Renewable Energy; Non Combustible Materials; Energy Infrastructure & Technologies; Land-use and Environment; Climate Change; Population & Society) to simulate, from 2005 through 2060 (extendable to 2100), the effects of implementing policies and interventions on greenhouse gas emissions, land use, natural resources and societal wellbeing at a global level, by capturing their biophysical and socio economic interactions and constraints. Deliverable "D5.6 Policy Recommendations Report at EU Level" reports results from the global scale simulations of policies aligned with the LAMS catalogue evaluated using performance indicators (KPIs) defined in WP4 (add name of the WP). Possible policy trajectories incorporating social transformations and behavioural changes have been modelled, which provides insights on the impacts of different policies on indicators including global temperature change, greenhouse gas emissions and land-use change.

## 1.1 Purpose of the document

The purpose of the document is to develop recommendations for international and EU policies, alongside measures to support behavioural change. Drawing on the analysis of WILIAM simulation results (D6.4), the report presents strategic guidelines to steer European and global policy efforts toward achieving climate neutrality by 2050. The policy recommendations will emphasize how alignment with the EU Green Deal and related regulatory frameworks—such as the Farm to Fork Strategy, the Land Use, Land Use Change and Forestry (LULUCF) regulation, the Nature Restoration Law, and the Carbon Removals Certification Framework (CRCF)—can enhance both climate change adaptation and mitigation on a global scale, advocating for coordinated action.

## 1.2 Structure of the document

The document is structured as follows:

**Section 1: Introduction** – Provides an overview of the document and gives background information on WILIAM model.

**Section 2: Storylines and scenarios definition** – Offers a detailed definition of the storyline developed and the associated scenarios.

**Section 3: Conclusion** – Provides a summary of the document’s key points and most relevant outcomes of the Task 5.5.

**Section 4: Annex I: Summary table of policy recommendations** – Lists all the policy recommendations at EU scale and describes them.

## 2 The WILIAM global model

**WILIAM (Within Limits Integrated Assessment Model)** is an integrated simulation model built using system dynamics to support policy evaluation and recommendation in response to specific sustainability related questions. Developed under the *LOCOMOTION* EU project, WILIAM contributes to climate change mitigation research by modelling the complex, non-linear interactions between human and natural systems, while accounting for biophysical constraints on energy and raw material availability through the end of the 21st century.

Rather than aiming to predict future outcomes, WILIAM excels in comparative analysis, assessing the effectiveness of different policy pathways under diverse plausible scenarios to achieve predefined goals. It supports the identification of trade-offs and synergies among policy options by evaluating a wide array of socio-environmental indicators through iterative “what-if” simulations.

The model architecture comprises eight interlinked modules that simulate feedback loops across key sectors. Notably, WILIAM offers several advanced features often lacking or underdeveloped in other integrated assessment models (IAMs), such as DICE<sup>1</sup>, or MESSAGE<sup>2</sup> models [Delannoy 2024]. These include a detailed dynamic representation of the economy, which facilitates a comprehensive analysis of the interconnections between economic activity, energy use, and material extraction. WILIAM also incorporates calculations of the system-wide Energy Return on Investment (EROI), including material requirements for renewable energy infrastructure, and includes the economic impacts of climate change. WILIAM is open-source and available via its [GitHub repository](#), where various versions are maintained. While the *RethinkAction* local model (D6.4) focuses on simulating the effect of local-scale land-use adaptation and mitigation solutions (LAMS) [Chiriaco et al 2025] across six case studies, WILIAM is applied at the global and EU levels to evaluate the broader systemic impacts of these solutions. The outcomes of this process will feed into Module 4 of the RethinkAction platform (Deliverables D5.5, D7.1, D7.5).

Policy implementation within WILIAM can be modeled in two main ways (see deliverable D5.5 for more details[D5.5]):

- **Step Function (Theta Function):** A policy is introduced instantaneously in a specific year, with the user defining both the start year and the target value.
- **Linear Ramp Function:** A policy is gradually introduced over a defined time interval, with the user specifying the initial year, final year, and target value, from which the implementation slope is derived.

Although these approaches are simplifications of real-world policy deployment, they offer a sufficiently robust framework for exploring system responses and conducting structured scenario analysis. For further technical details on WILIAM and the LOCOMOTION project, refer to project deliverables D5.4, D5.5[D5.4, D5.5] and Locmotion's deliverable [Locomotion D9.3] and the WILIAM Wiki [WILIAM wiki].

### 3 Storylines and scenarios definition

Starting from the 62 LAMS included in the LAMS Catalogue, the most relevant ones were selected based on their alignment with the objectives and priorities of the global and European climate political agenda. These were then combined and grouped according to main policies to define 7 **storylines**, each representing a possible pathway for climate change adaptation and mitigation to be simulated within the WILIAM model. Each storyline assumes the simultaneous adoption at the global level of multiple **policies** linked to the selected LAMS, explored under varying **scenarios of implementation intensity**. For each storyline, a set of key **output variables** was identified and analyzed at the EU and/or global level under the different intensity scenarios (Table 1). These outputs provide a foundation for formulating

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<sup>1</sup> <https://williamnordhaus.com/dicerice-models> ; [https://en.wikipedia.org/wiki/DICE\\_model](https://en.wikipedia.org/wiki/DICE_model)

<sup>2</sup> <https://www.pnas.org/doi/full/10.1073/pnas.2101899118>

concrete policy recommendations to be implemented on the ground to effectively support global climate change adaptation and mitigation efforts. To simplify data analysis and interpretation—and to limit the number of possible policy parameter combinations—all policies have been implemented uniformly from 2030 to 2050. However, the results can be extrapolated to other time periods. In all storylines, the selected scenarios are compared to the **baseline scenario**, which represents a *continuation of current trends* and is often referred to as the *Business-as-Usual* scenario.

Table 1: Storylines, including policies with different scenarios of implantation intensity, for WILLIAM simulations and output variables.

	Storylines	Policies included	Scenarios of implementation intensity	Outputs variables
A	Regenerative Agriculture and dietary transformation	Regenerative agriculture; Shift in diets.	4 scenarios	Global temperature change; Land-use change (EU & Global); Meat consumption (EU & Global); GHG emissions (EU & Global).
B	Coupling sustainable feed production with sustainable dietary transitions	Grassland management; Shift in diets.	3 scenarios	Global temperature change; Land-use change (EU & Global); Meat consumption (EU & Global); GHG emissions (EU & Global).
C	Harmonizing renewable energy expansion with ecosystem conservation	Sustainable management of solar installations; Afforestation; Grassland management.	3 scenarios	Global temperature change; Land-use change (EU & Global); Share Renewable Energy Sources (RES) in Primary Energy (PE) (Global); Global energy emissions; GHG emissions (EU & Global).
D	Balancing urban area development and increase of forests	Afforestation; Managing urban sprawl.	3 scenarios	Global temperature change; Land-use change (EU & Global); GHG emissions (EU & Global).
E	Integrated land and resource management	Forest protection; Grassland management; RES from forest biomass; Shift in diets.	3 scenarios	Global temperature change; Land-use change (EU & Global); Meat consumption (EU & Global); Share RES in PE (Global); GHG emissions (EU & Global).
F	Solar energy for a sustainable future	Increase in Photovoltaic (PV) energy production; Sustainable management of solar installations; Solar PV on rooftops.	3 scenarios	Global temperature change; Land-use change (EU & Global); Share RES in PE (Global); Global energy emissions; GHG emissions (EU & Global).

	Storylines	Policies included	Scenarios of implementation intensity	Outputs variables
G	Integrating marine and terrestrial renewables with sustainable land management	Sustainable management of solar installations; Afforestation; Grassland management; Offshore wind and ocean RES; Onshore wind RES; Increase in PV energy production; Hydroelectric power plants (dammed and run- of-river)	3 scenarios	Global temperature change; Land-use change (EU & Global); Share RES in PE (Global); Global energy emissions; GHG emissions (EU & Global).

### 3.1 Regenerative Agriculture and Dietary Transformation

#### 3.1.1 Definition of the storyline

This storyline includes the implementation of two policies related to “Regenerative agriculture” and “Shift in diets”. The integration of regenerative agriculture with a shift toward more sustainable diets offers a holistic pathway to simultaneously improve public health, bolster food system resilience, and address the intertwined challenges of climate change, biodiversity loss, and soil degradation in the European context. Regenerative agricultural practices, centered on soil health, crop diversification, reduced chemical inputs, and enhanced ecosystem services, are increasingly promoted within the European policy framework and specifically under the EU Common Agricultural Policy (CAP) and as key elements of the EU Green Deal, particularly through the Farm to Fork Strategy. These practices (e.g., cover cropping, crop rotation, reduced or no tillage, agroforestry) aim to restore soil fertility, improve water retention, foster biodiversity, and strengthen resilience to extreme weather events. However, their large-scale adoption could raise some concerns about potential reductions in yield capacity, especially when applied within food systems shaped by current consumption patterns, which are still heavily reliant on animal-based products and intensive monocultures.

Ensuring a safe potential increase in implementation of regenerative agriculture aligned with long-term food security, therefore requires not only a transformation in how food is produced, but also a shift in what is consumed. Transitioning to more sustainable and health-promoting dietary patterns, as encouraged by the Farm to Fork Strategy, plays a critical role in unlocking the potential of regenerative approaches.

Adopting more sustainable diets—such as flexitarian or fully plant-based models—can substantially reduce pressure on land, water, and other natural resources. When dietary shifts work synergistically with regenerative agricultural practices, land can be redirected toward agroecological uses, carbon farming, and biodiversity protection. In doing so, these policies, when implemented in combination, support a circular, resilient food system and contribute to key EU policy goals, including the Farm to

Fork Strategy, the LULUCF Regulation, and the Nature Restoration Law. They also enhance soil carbon sequestration, aligning with the EU Carbon Removals Certification Framework (CRCF).

### 3.1.2 Scenarios

For this storyline, four scenarios were explored based on different intensities of implementation of regenerative agriculture and dietary change (Table 2). The **Low scenario** assumes a transition to regenerative practices on 60% of global agricultural land, while maintaining baseline dietary trends (where baseline is intended as continuation of current trends). The **Medium-Low scenario** maintains the same level of regenerative agriculture but incorporates a dietary shift, with 50% of the global population adopting a flexitarian diet, as defined by the EAT- Lancet Commission [Willett et al. 2019]. The **Medium-High scenario** retains the dietary assumptions of the previous case but scales up regenerative agriculture to cover 100% of global agricultural land. The **High scenario** combines full adoption of regenerative agriculture with a significant dietary transformation, in which 50% of the global population adopts a fully plant-based diet.

Table 2: Specifications of the parameters of the two policies simulated in the 4 scenarios proposed (low, medium-low, medium-high, high) for the storyline A: Regenerative Agriculture and Dietary Transformation.

Storyline A	Policies	Scenarios of implementation intensity			
		A_Low	A_Medium-Low	A_Medium-High	A_High
Regenerative Agriculture and Dietary Transformation	Regenerative agriculture	60% of global agricultural land	60% of global agricultural land	100% of global agricultural land	100% of global agricultural land
	Shift in diets	Baseline	50% of global population is flexitarian	50% of global population is flexitarian	50% of global population shifts to 100% plant-based diet

### 3.1.3 Results of simulations

This section presents the results of the simulation of scenarios from Table 2, assessing their combined impacts compared to the baseline on the key output variables as identified in Table 1: Global temperature change, Global and EU Greenhouse Gas (GHG) emissions, Global and EU meat consumption, and Global and EU land use change.

#### 3.1.3.1 Global temperature change

##### Key Insights from Table 3 and Figure 1

- **Flexitarian diets can contribute significantly to limiting global temperature increase.** Even moderate shifts in eating habits can reduce temperature rise by up to 0.011 °C
- **Regenerative agriculture alone, without dietary change, delivers limited results**

- **A transformative change in food systems is essential.** The A\_HIGH scenario shows that deep changes in diets and agricultural practices offer the most effective path to reducing global warming, complementing decarbonization in the energy sector

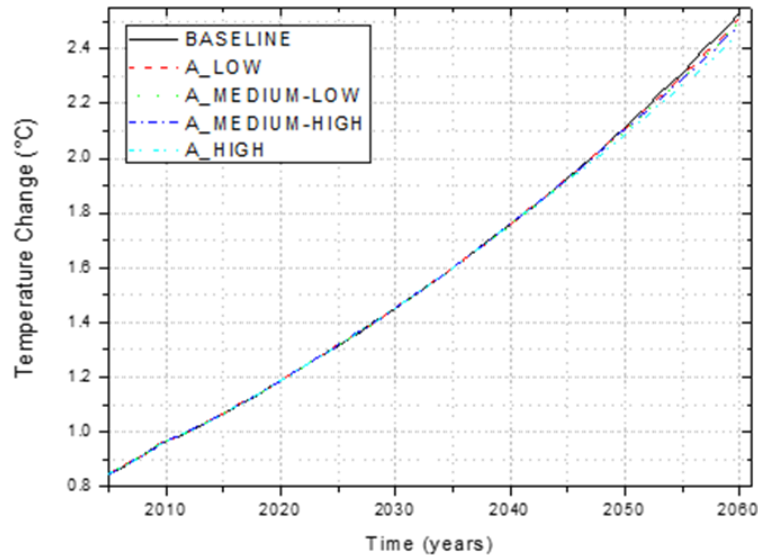


Figure 1: Impact on global temperature change based on simulations of policy scenarios under storyline A.

Table 3: Summary table of the global temperature change in 2060 for storyline A.

Scenario (2060)	Global Temperature increase (°C)	Δ vs Baseline
Baseline	2.531	-
A_Low	2.506	-0.025 °C
A_Medium-Low	2.495	-0.036 °C
A_Medium-High	2.488	-0.043 °C
A_High	2.459	-0.072 °C

### 3.1.3.2 Global land-use change

#### Key Insights from Table 4 and Figure 2

- **The combined implementation of regenerative agriculture and a shift in diets, allows for freeing up global cropland areas, mostly rain-fed.** Under all the scenarios of implementation intensity, croplands are relocated to other land uses, with total cropland falling by 0.7-2.6 M km<sup>2</sup> (-3 % to -13 % vs. baseline).
- **When regenerative agriculture and a shift in diets are jointly applied, global forests could increase.** Forest area expands across all scenarios and peaks at +1.34 M km<sup>2</sup> in the A\_High scenario, driven mainly by gains in managed and plantation forests, possibly increasing the LULUCF sequestration potential.

- **Global pasture systems are not heavily displaced.** Grassland changes are marginal (< 0.06 M km<sup>2</sup> across scenarios).
- **Other Land (wetland, ice, free barren land, etc.) and shrubland grow** by +0.3-1.1 M km<sup>2</sup>, possibly enhancing ecosystem integrity, biodiversity, and adaptation and resilience capacity.

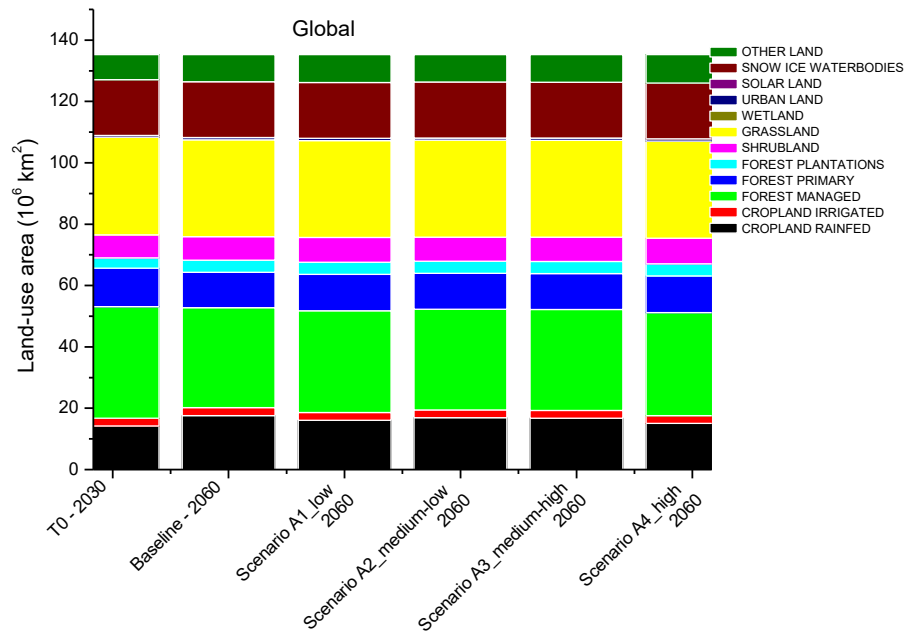


Figure 2: Impact on global land-use change under the policy simulation scenarios of storyline A by 2060, compared to the baseline year 2030 (T0) and the baseline scenario (business-as-usual).

Table 4: Global land-use change by 2060 under storyline A scenarios compared to baseline.

Land-use category	Baseline 2060 (M km <sup>2</sup> )	A_Low 2060 (M km <sup>2</sup> )	Δ vs baseline	A_Medium-Low 2060 (M km <sup>2</sup> )	Δ vs baseline	A_Medium-High 2060 (M km <sup>2</sup> )	Δ vs baseline	A_High 2060 (M km <sup>2</sup> )	Δ vs baseline
Cropland	20.17	18.62	-1.55	19.47	-0.70	19.28	-0.89	17.62	-2.55
Grassland	31.59	31.62	+0.03	31.60	+0.01	31.62	+0.03	31.65	+0.06
Forest	48.14	48.95	+0.82	48.49	+0.36	48.59	+0.45	49.48	+1.34
Other land + shrubland	16.43	17.13	+0.70	16.75	+0.32	16.84	+0.41	17.57	+1.14

### 3.1.3.3 EU27 land use change

#### Key insights from Table 5 and Figure 3

- When regenerative agriculture and dietary shifts are jointly implemented, a slight increase or **stabilization of European forest area** may occur. However, overall, forest area in Europe remains largely unchanged across all scenarios.
- **Grassland systems in Europe remains constant and cropland decrease.**

- Other Land (wetland, ice, free barren land, etc.) and shrubland in Europe grow by 0.07–0.24 M km<sup>2</sup>, possibly enhancing ecosystem integrity, biodiversity, and adaptation and resilience capacity.

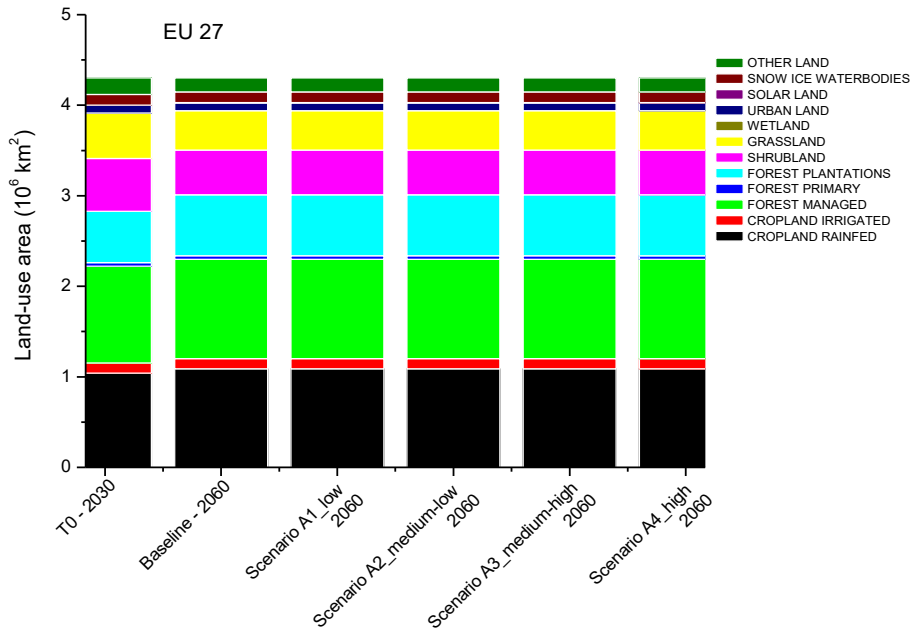


Figure 3: Impact on EU27 land-use change under the policy simulation scenarios of storyline A by 2060, compared to the baseline year 2030 (T0) and the baseline scenario (business-as-usual).

Table 5: EU27 land-use change by 2060 under storyline A scenarios compared to baseline.

Land-use category	Baseline 2060 (Mkm <sup>2</sup> )	A_Low 2060 (M km <sup>2</sup> )	Δ vs baseline	A_Medium-Low 2060 (M km <sup>2</sup> )	Δ vs baseline	A_Medium-High 2060 (M km <sup>2</sup> )	Δ vs baseline	A_High 2060 (M km <sup>2</sup> )	Δ vs baseline
Cropland	1.37	1.20	-0.17	1.29	-0.08	1.28	-0.09	1.11	-0.26
Grassland	0.41	0.43	+0.02	0.42	+0.01	0.42	+0.01	0.45	+0.04
Forest	1.80	1.81	+0.01	1.80	0	1.80	0	1.81	+0.01
Other land + shrubland	0.51	0.65	+0.14	0.58	+0.07	0.58	+0.07	0.75	+0.24

### 3.1.3.4 EU27 and global meat consumption

#### Key insights from and Figure 4 and Figure 5

- The High scenario nearly halves meat demand at EU and global scales. The integrated A\_High scenario cuts meat consumption by 47 %, aligning with the land-use analysis that showed the largest grassland contraction and forest expansion. Such a transformation is pivotal for meeting the EU Climate Law’s enhanced LULUCF-sink targets.
- In the baseline scenario, meat consumption by 2060 is projected to decline in the EU and to increase globally.

- Globally, regenerative agriculture could lead to a 17% decrease in meat availability for consumption compared to the baseline. This decline is driven by a decrease in feed supply, where the less intensive crop production system cannot meet the feed demand associated with the increase in meat consumption projected under the business-as-usual scenario.

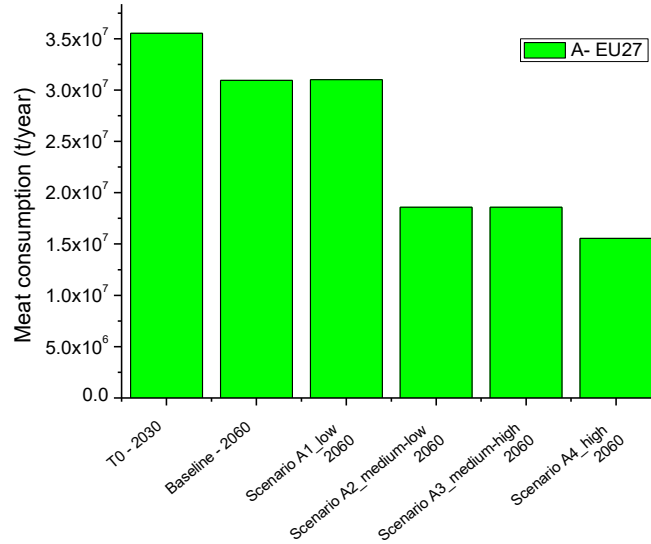


Figure 4: Impact on EU27 meat consumption based on the policies simulation scenarios by 2060, compared to T0 (2030) and the Baseline scenario (business-as-usual).

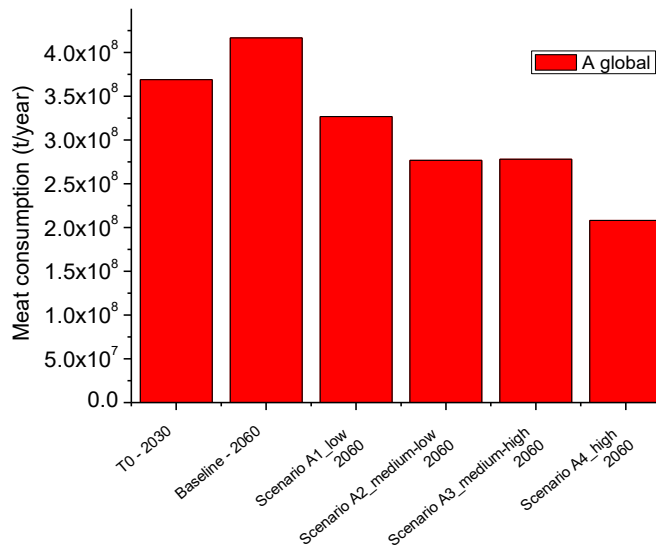


Figure 5: Impact on global meat consumption based on the policies simulation scenarios by 2060, compared to T0 (2030) and the Baseline scenario (business-as-usual).

### 3.1.3.5 EU27 GHG emissions

#### Key Insights from Table 6 and Figure 6

- **Dietary change is essential to reduce GHG emissions:** Even moderate shifts deliver clear emission reductions in Europe.

- **Supply-side action alone is not enough.** Partial adoption of regenerative agriculture yields minimal climate benefits in Europe if diets remain unchanged.
- **Integrated strategies are most effective.** Combining full regenerative agriculture with demand-side dietary shifts results in up to 0.60 GtCO<sub>2</sub>eq/year reduction.

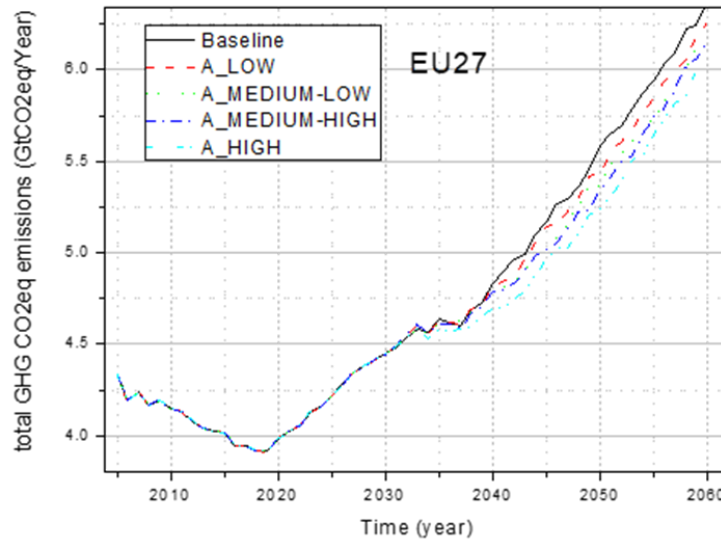


Figure 6: Impact on EU27 GHG CO<sub>2</sub>eq emissions based on simulations of policy scenarios under storyline A.

Table 6: Summary table of the U27 GHG Emissions in 2060 for storyline A.

Scenario (2060)	Emissions (GtCO <sub>2</sub> eq/year)	Δ vs Baseline
Baseline	6.15	–
A_Low	6.10	–0.05
A_Medium-Low	5.95	–0.20
A_Medium-High	5.75	–0.40
A_High	5.55	–0.60

### 3.1.3.6 Global GHG emissions

#### Key Insights from Table 7 and Figure 7

- **Global dietary change is a stronger lever than agriculture alone** – The difference between A\_Low and A\_Medium1 (–4 GtCO<sub>2</sub>eq/year) shows how impactful demand-side shifts can be when coupled with regenerative agriculture.

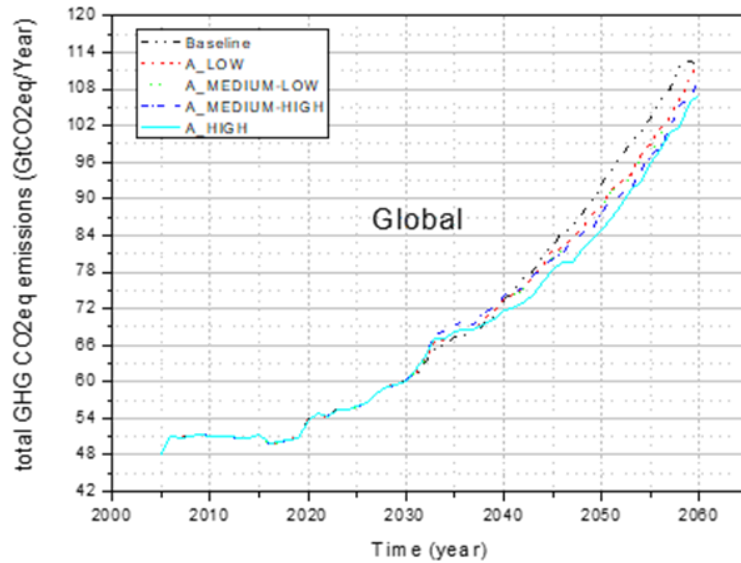


Figure 7: Impact on global GHG CO2eq emissions based on simulations of policy scenarios under storyline A.

Table 7: Summary table of the global GHG Emissions in 2060 for storyline A.

Scenario	GHG Emissions (GtCO <sub>2</sub> eq/year)	Δ vs Baseline
Baseline	~116	–
A1_Low	~114	–2
A2_Medium1	~110	–6
A3_Medium2	~106	–10
A4_High	~101	–15

### 3.1.4 Policy recommendations

**Recommendation 1: Encourage a shift toward flexitarian and/or plant-based diets together with promoting regenerative agriculture.** The results from model simulations indicate that shifting consumer behaviour and fostering regenerative agriculture could deliver substantial emission reductions, agricultural land use reduction and temperature reduction. Progress could be fostered by (i) making “sustainable and healthy” (flexitarian and/or plant-based) menus the default option in schools, hospitals and other publicly funded kitchens, (ii) rolling out an easy-to-read environmental label for food products, and (iii) running coordinated communication campaigns that present plant-based meals as tasty, modern and good for health.

**Recommendation 2: Relocate land to more efficient land uses.** In the high application scenario of regenerative agriculture and shift in diets, the EU could save up to 80 million hectares of grassland and cropland. This freed-up land could be relocated to forests and other carbon-rich ecosystems, increasing the carbon sink and fostering also a voluntary carbon market building on Regulation EU 2024/3012 on

the Carbon Removals Certification Framework (CRCF) which could provide tradable credits for verified carbon sequestration and increase biodiversity as co-benefit.

**Recommendation 3: Promote partnerships that spread regenerative standards beyond Europe.** Approximately half of the global benefits from the high scenario application of regenerative agriculture with shift in diets occurs outside the EU, underscoring the importance of global cooperation. International cooperation could improve environmental performance worldwide.

## 3.2 Coupling sustainable feed production with dietary transitions

### 3.2.1 Definition of the storyline

Grasslands cover a significant share of EU and global agricultural land and are essential for biodiversity, carbon sequestration, and soil health. At the same time, feed production drives a major share of land use and greenhouse gas emissions, while directly competing with food production for limited resources. To transform food systems in line with EU sustainability objectives (e.g., EU Green Deal, Nature Restoration Law, Farm to Fork Strategy and CAP eco-schemes), as well as staying within global planetary boundaries [Rockström et al., 2009], it is essential to address the interconnections between dietary patterns, feed production, and land use. The shift toward more sustainable diets will have profound implications for feed demand and grassland use. Therefore, developing integrated scenarios supports better foresight on land use dynamics, climate outcomes, and food system resilience, while ensuring that EU strategies are mutually reinforcing.

By preserving and restoring permanent grasslands and concurrently reducing reliance on intensive feed-crop monocultures through shifts toward flexitarian and plant-rich diets, a synergistic pathway is established that optimizes land-use efficiency and mitigates greenhouse gas emissions across the agri-food sector. The approach leverages the ecological resilience of species-rich meadows to enhance soil structure, water filtration, and habitat connectivity, thereby contributing to the objectives of the EU Nature Restoration Law and the Biodiversity Strategy for 2030. Simultaneously, attenuating feed demand alleviates pressure on arable land, reduces nutrient run-off, and diminishes enteric fermentation emissions, advancing the Farm to Fork Strategy's public-health and environmental targets. Further, by reducing the pressure to convert grasslands into high-input feed croplands, below-ground soil carbon stocks are preserved, while targeted restoration of degraded grasslands further boosts long-term carbon sequestration, furthering both LULUCF and CRCF objectives.

### 3.2.2 Scenarios

As part of this storyline, three scenarios were explored based on varying levels of adoption of “regenerative grassland management practices” and “dietary change” (Table 8). The **Low Scenario** assumes a transition to regenerative grazing practices on 60% of global grassland, while maintaining business as usual (baseline) global dietary trends. The **Medium Scenario** increases the level of regenerative practices in grasslands to cover 100% of global grasslands and incorporates a dietary shift,

with 50% of the global population adopting a flexitarian diet [Willett et al. 2019 ]. In the **High Scenario** 50% of the global population shifts to a 100% plant-based diet, while keeping the regenerative grazing practices to 100% of grasslands worldwide.

Table 8: Specifications of the parameters of the two policies simulated in the 3 scenarios proposed (low, medium, medium, high) for storyline B: Coupling feed production with sustainable dietary transitions.

Storyline B	Policies	Scenarios of implementation intensity		
		B_Low	B_Medium	B_High
Coupling feed production with sustainable dietary transitions	Grassland management	60% global grasslands under regenerative grazing	100% global grasslands under regenerative grazing	100% global grasslands under regenerative grazing
	Shift in diets	Baseline	50% of global population is flexitarian	50% of global population shifts to 100% plant-based diet

### 3.2.3 Results of simulation

This section presents the results of the simulation of scenarios from Table 8, assessing their combined impacts compared to the baseline on the key output variables as identified in Table 1: Global temperature change, Global and EU GHG emissions, Global and EU meat consumption, and Global and EU land use change.

#### 3.2.3.1 Global temperature change

Key insights from Table 9 and Figure 8

- A complete shift toward regenerative grazing globally combined with a flexitarian diet adopted by 50% of the global population could reduce global temperature increase by ~0.11 °C compared to the baseline, by 2060.
- A complete shift toward regenerative grazing globally combined with a full plant-based diet adopted by 50% of global population could reduce global temperature increase by ~0.14 °C compared to the baseline, by 2060.

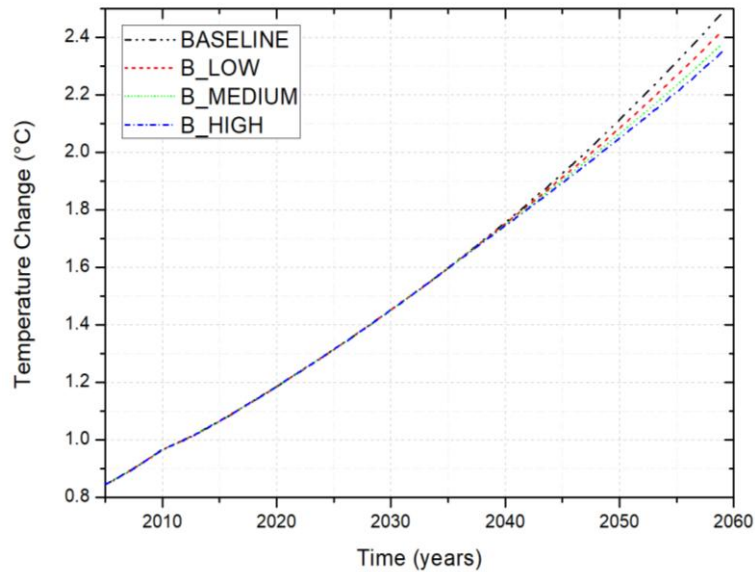


Figure 8: Impact on global temperature change based on simulations of policy scenarios under storyline B.

Table 9: Summary table of the global temperature change in 2060 for storyline B.

Scenario (2060)	Global Temperature increase (°C)	Δ vs Baseline
Baseline	2.531	
B_Low	2.465	-0.07
B_Medium	2.417	-0.11
B_High	2.388	-0.14

### 3.2.3.2 Global land use change

#### Key insights from Table 10 and Figure 9

- **Combining regenerative grazing with a moderate dietary shift shows a low synergistic potential.** A shift toward flexitarian diets for 50% of the global population does not provide substantial additional benefits compared to regenerative grazing alone.
- **Dietary transformation is a game-changer.** With half of the global population fully plant-based, cropland area is reduced by 17% compared to the baseline, freeing up land for forests and other ecosystems.
- **Grassland area stays stable irrespective of the scenario.** The reduced demand for animal-based products can be satisfied through regenerative grazing systems.
- **Integrating demand- and supply-side measures maximises climate and nature co-benefits.**

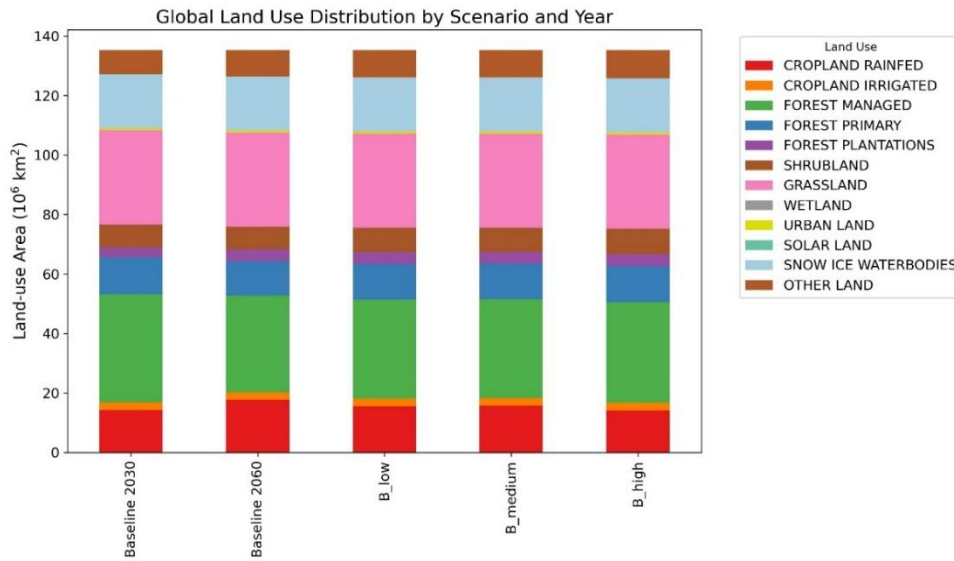


Figure 9: Impact on global land-use change under the policy simulation scenarios of storyline B by 2060, compared to the baseline year 2030 (T0) and the baseline scenario (business-as-usual).

Table 10: Global land-use change by 2060 under storyline B scenarios compared to baseline.

Land-use category	Baseline 2060 (M km <sup>2</sup> )	B_low (M km <sup>2</sup> )	Δ vs baseline	B_medium (M km <sup>2</sup> )	Δ vs baseline	B_high (M km <sup>2</sup> )	Δ vs baseline
Cropland	20,17	18,07	- 2,10	18,29	- 1,88	16,71	- 3,46
Forest	48,13	49,25	+ 1,12	49,13	+ 1,00	49,97	+ 1,84
Grassland	31,59	31,62	+ 0,03	31,62	+ 0,03	31,66	+ 0,07
Other land + shrubland	16,42	17,38	+ 0,96	17,28	+ 0,86	17,99	+ 1,57

### 3.2.3.3 EU27 land use change

#### Key insights from Table 11 and Figure 10

- **Reduced feed demand and increased sustainability in its production drive land sparing.** Combining regenerative grazing and a shift toward plant-based diets globally, would reduce EU pasture by 0.65 M km<sup>2</sup> (-45 %) and cropland falls by 0.15 M km<sup>2</sup> (-12 %).
- **Forest becomes the largest carbon sink opportunity.** Afforestation potential would rise up to **0.35 M km<sup>2</sup>** — a **21 %** expansion relative to the baseline— increasing the EU carbon sink and supporting carbon removal targets.
- Other Land (wetland, ice, free barren land, etc.) and shrubland adds **0.10–0.25 M km<sup>2</sup>**. In particular shrubland gains could be relevant for biodiversity protection, allowing for a possible expansion of ecological corridors and underpinning biodiversity and adaptation co-benefits.

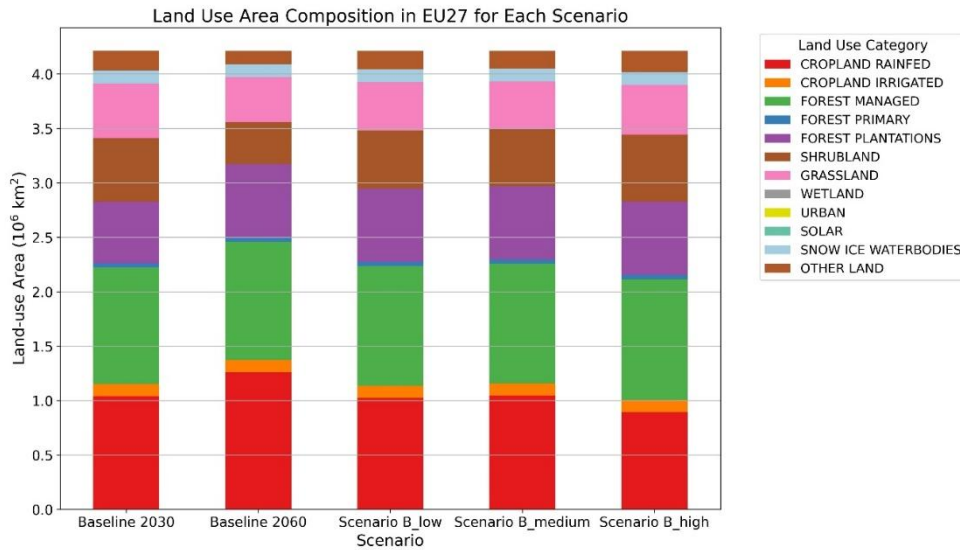


Figure 10: Impact on EU27 land-use change under the policy simulation scenarios of storyline B by 2060, compared to the baseline year 2030 (T0) and the baseline scenario (business-as-usual).

Table 11: EU27 land-use change by 2060 under storyline A scenarios compared to baseline.

Land-use category	Baseline 2060 (M km <sup>2</sup> )	B_low 2060 (M km <sup>2</sup> )	Δ vs baseline	B_medium 2060 (M km <sup>2</sup> )	Δ vs baseline	B_high 2060 (M km <sup>2</sup> )	Δ vs baseline
Cropland	1.37	1.14	-0.23	1.16	-0.21	1.01	-0.36
Forest	1.80	1.81	+0.01	1.81	+0.01	1.82	+0.02
Grassland	0.41	0.44	+0.03	0.44	+0.03	0.46	+0.05
Other land + shrubland	0.51	0.70	+0.19	0.68	+0.17	0.81	+0.31

### 3.2.3.4 EU27 and global meat consumption

#### Key Insights from Figure 11 and Figure 12

- As also shown in the figures, **meat consumption is projected to decline** in the EU and to increase globally in the baseline scenario by 2060.
- **Meat consumption in the EU is driven by demand.** No decline is associated with regenerative grazing, while a shift toward a flexitarian or plant-based diet leads to a 40-50% reduction in meat consumption.
- **Globally, regenerative grazing alone leads to a 22% decrease in meat consumption compared to the baseline.** This decline is driven by a reduction in feed supply, where the less intensive production system cannot sustain the increase in meat consumption projected under the business-as-usual scenario.

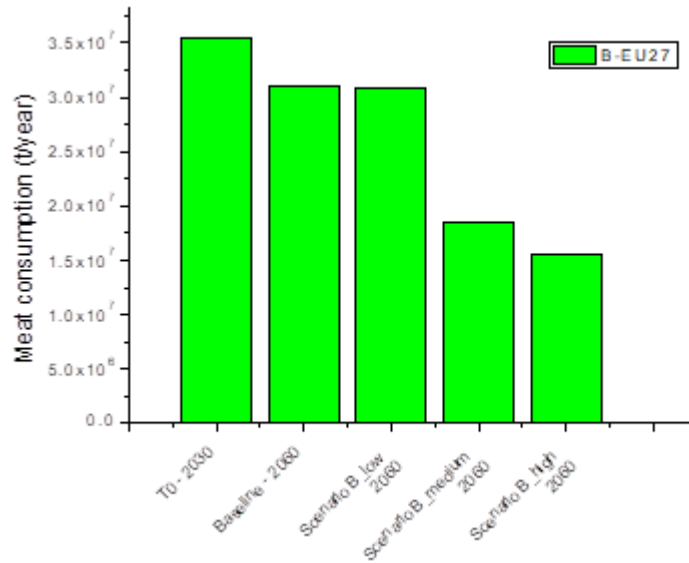


Figure 11: Impact on EU27 meat consumption based on the policies simulation scenarios by 2060, compared to T0 (2030) and the Baseline scenario (business-as-usual).

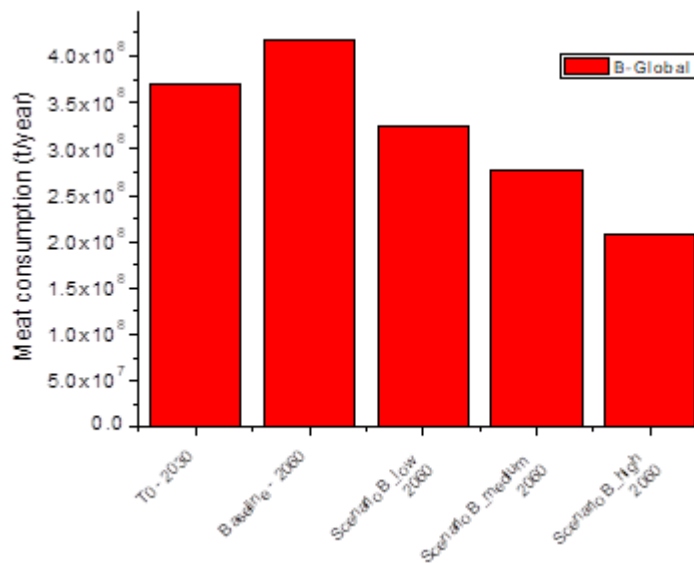


Figure 12: Impact on global meat consumption based on the policies simulation scenarios by 2060, compared to T0 (2030) and the Baseline scenario (business-as-usual).

### 3.2.3.5 EU27 GHG emissions

#### Key Insights from Table 12 and Figure 13

- Introducing regenerative grazing on 60% of grasslands can reduce GHG emissions by 5%. This underlines the high impact of intensive grazing on GHG emissions.
- Combining supply and demand measures doubles the GHG reduction potential. Full conversion to regenerative grazing paired with a shift to plant-based diets delivers a synergistic effect.

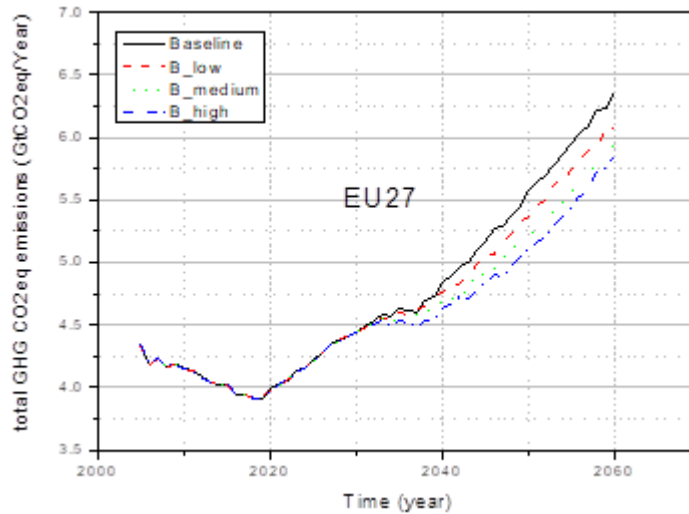


Figure 13: Impact on EU27 GHG CO2eq emissions based on simulations of policy scenarios under storyline B.

Table 12: Summary table of the U27 GHG Emissions in 2060 for storyline B.

Scenario	2060 emissions	Δ vs Baseline
Baseline	≈ 6.4 Gt CO <sub>2</sub> -eq yr <sup>-1</sup>	—
B_low	≈ 6.1 Gt CO <sub>2</sub> -eq yr <sup>-1</sup>	-0.3 Gt (≈ 5 %)
B_medium	≈ 6.0 Gt CO <sub>2</sub> -eq yr <sup>-1</sup>	-0.4 Gt (≈ 6 %)
B_high	≈ 5.8 Gt CO <sub>2</sub> -eq yr <sup>-1</sup>	-0.6 Gt (≈ 9 %)

### 3.2.3.6 Global GHG emissions

#### Key Insights from Table 13 and Figure 14

- **Business-as-usual keeps the sector on a steep upward trajectory.** At ≈ 112 Gt CO<sub>2</sub>-eq yr<sup>-1</sup>, the baseline pathway would almost certainly overshoot a 1.5 °C-compatible carbon budget, underscoring the urgency of targeted food-system mitigation.
- **Globally, introducing regenerative grazing on 60% of grasslands can reduce GHG emissions by 7%,** highlighting the high impact of intensive grazing on GHG emissions. This is also shown by the additional 6 Gt CO<sub>2</sub>-eq yr<sup>-1</sup> reduction obtained by converting 100% of global grasslands to regenerative management.
- **A shift towards plant-based diets would further increase the GHG reduction potential,** but with only a marginal effect, i.e. 1 Gt CO<sub>2</sub>-eq yr<sup>-1</sup> lower emissions compared to the 50% flexitarian diets scenario.

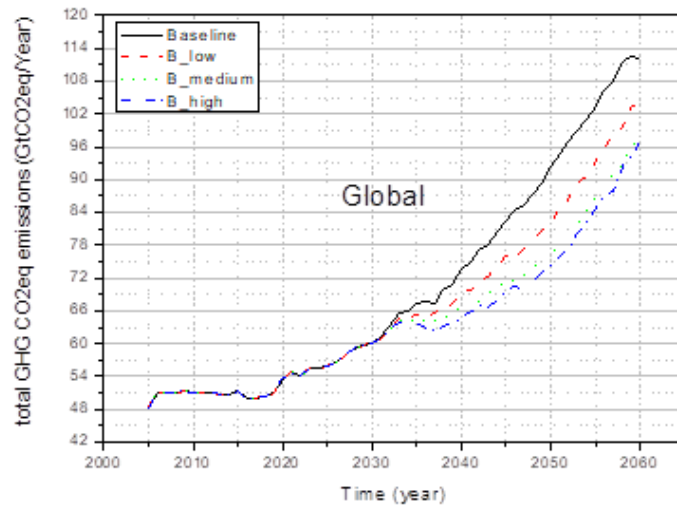


Figure 14: Impact on global GHG CO2eq emissions based on simulations of policy scenarios under storyline B.

Table 13: Summary table of the global GHG Emissions in 2060 for storyline B.

Scenario	Total GHG emissions (Gt CO <sub>2</sub> -eq yr <sup>-1</sup> )	Absolute change vs Baseline	Relative change vs Baseline
Baseline	≈ 112 Gt	—	—
B_low	≈ 104 Gt	– 8 Gt	– 7.1 %
B_medium	≈ 98 Gt	– 14 Gt	– 12.5 %
B_high	≈ 97 Gt	– 15 Gt	– 13.4 %

### 3.2.4 Policy recommendations

**Recommendation 4: Promote regenerative grazing systems to reduce greenhouse gas emissions from the agricultural sector.** Supply-side measures like improved grazing management can deliver important benefits in terms of greenhouse gas emissions reduction. Further, protecting and restoring permanent grasslands can preserve soil carbon and biodiversity. The Common Agricultural Policy (CAP) eco-schemes and the voluntary carbon market linked to the EU Carbon Removal and Carbon Farming Regulation should be leveraged to reward regenerative grazing and sustainable feed production systems, ensuring that intensive feed monocultures are minimized.

**Recommendation 5: Accelerate the shift toward sustainable diets to cut feed demand.** Synergistic effects can be obtained by combining supply and demand measures. Policymakers should expand campaigns and incentives (e.g. public procurement of plant-based meals, improved food labeling, education programs) to encourage lower meat consumption. This demand-side shift would maximize the mitigation benefits obtained by a conversion to regenerative grazing systems, while freeing up extensive cropland and pasture for other uses. A shift toward more plant-based diets also aligns with health guidelines, creating win-win outcomes for climate and public health.

**Recommendation 6: Align dietary shifts with land-use strategy to restore ecosystems and meet climate targets.** A scenario where 50% of global population shifts to plant-based diets could spare up to ~80 million hectares of EU grassland and cropland by 2060. Governments should anticipate this by developing plans to restore a portion of retired pasture and feed-crop land into carbon-rich ecosystems or alternative crops. For example, reforestation or rewilding areas formerly used for intensive feed can sequester carbon and boost biodiversity. The EU Nature Restoration Law and LULUCF targets should incorporate these opportunities, backed by voluntary carbon credit markets to reward farmers for turning excess farmland into forests or wetlands.

**Recommendation 7: Support farmers through the transition.** A decline in livestock product demand will impact farmers who rely on feed and meat markets. To ensure a just transition, the EU and Member States could extend the Just Transition support envisioned by the European Green Deal to rural areas. This would include advisory services and training to help livestock and feed-crop farmers shift to new income streams – for instance, growing plant proteins (pulses, legumes) for human consumption, agroforestry, or eco-tourism. Diversifying farm production with guidance and low-interest loans will reduce socioeconomic disruptions as feed production scales down, while also improving EU protein self-sufficiency.

### 3.3 Harmonizing renewable energy expansion with ecosystem conservation

#### 3.3.1 Definition of the storyline

This storyline envisages a synergistic integration of renewable energy management, specifically ground-mounted solar photovoltaics, with the conservation and restoration of forests and permanent grasslands, enhancing natural carbon sinks, supporting the carbon neutrality goal of the EU Green Deal. Further, it reflects the objectives of the EU Biodiversity Strategy for 2030, which emphasizes the protection and restoration of ecosystems, including forests and grasslands, and the EU Forest Strategy, which promotes sustainable forest management and afforestation. This integrated approach represents a strategic, cross-sectoral response to the climate crisis, aligning decarbonization, ecosystem restoration, and land management, key pillars also emphasized in the EU Climate Adaptation Strategy and the Common Agricultural Policy (CAP).

Following current expansion trends of solar capacity while excluding it from protected areas would increase energy security and displace fossil fuel use, significantly reducing emissions from the energy sector, the largest contributor to EU greenhouse gas emissions. Integrating nature-based solutions with renewable energy would ensure that climate action does not compromise but rather reinforces landscape resilience. In addition to increasing and preserving carbon stocks in the soil and plant biomass, afforestation and regenerative grazing systems would promote soil health, improved water quality, drought resilience, and flood mitigation.

### 3.3.2 Scenarios

As part of this storyline, three scenarios were explored based on varying levels of sustainable deployment of solar installations, assuming a PV expansion that follows current trends, the adoption of regenerative grassland management practices, and afforestation efforts (Table 14). The **Low scenario** assumes a transition to regenerative grazing on 60% of global grassland, afforestation on 20% of globally suitable land, and the protection of 50% of forest areas from solar infrastructure. The **Medium scenario** increases ambition by assuming the protection of 50% of forests and full protection of grasslands and croplands from solar installations, and scaling up regenerative grazing and afforestation to 100% and 60% of suitable areas, respectively. The **High scenario** represents the most ambitious level of policy implementation, with regenerative grazing and afforestation extended to all suitable areas, and solar installations fully excluded from all land classified as forest, grassland, or cropland.

Table 14: Specifications of the parameters of the three policies simulated in the 3 scenarios proposed (low, medium, high) for storyline C: Harmonizing renewable energy expansion with ecosystem conservation.

Storyline C	Policies	Scenarios of implementation intensity		
		C_Low	C_Medium	C_High
Harmonizing renewable energy expansion with ecosystem conservation	Sustainable management of solar installations	Protection of 50% of global forests	Protection of 50% of global forests and 100% of cropland and grassland	Protection of 100% of global forests and 100% of cropland and grassland
	Grassland management	60% global grasslands under regenerative grazing	100% global grasslands under regenerative grazing	100% global grasslands under regenerative grazing
	Afforestation	20% of suitable land	60% of suitable land	100% of suitable land

### 3.3.3 Results of simulation

This section presents the results of the simulation of scenarios from Table 14, assessing their combined impacts compared to the baseline on the key output variables as identified in Table 1: Global temperature change, Global and EU land use change, Global share RES in PE, Global energy emission in PE and Global and EU GHG emissions.

#### 3.3.3.1 Global temperature change

Key insights from Table 15 and Figure 15

- **Management of ground mounted solar photovoltaics while preserving and expanding land carbon sinks can lower global temperature increase** by 0.11 to 0.40°C by 2060, compared to business as usual.

- **Forests are key to reduce temperature change, but synergy matters.** Full forest protection and implementation of the afforestation policy under the High scenario can lower temperature increase by an additional 0.13°C compared to the C\_Medium scenario. Deploying all three policies together maximises benefits and minimises trade-offs.

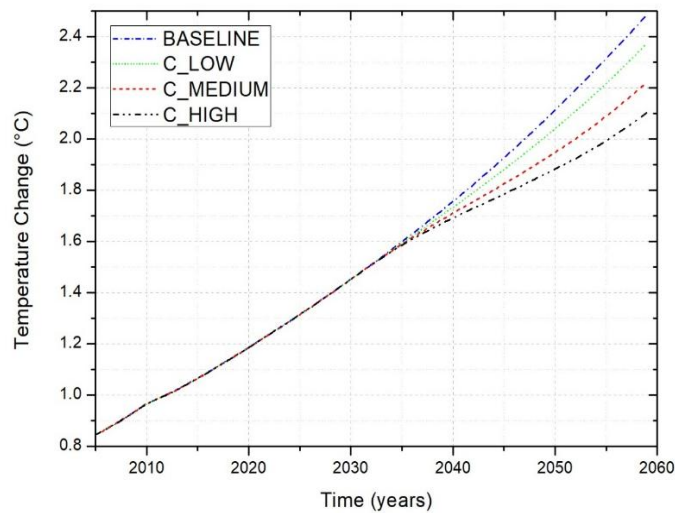


Figure 15: Impact on global temperature change based on simulations of policy scenarios under storyline C.

Table 15: Summary table of the global temperature change in 2060 for storyline C.

Scenario (2060)	Global temperature increase at 2060 (°C)	Δ vs Baseline (°C)
Baseline	≈ 2.53	—
C_low	≈ 2.42	- 0.11
C_medium	≈ 2.26	- 0.27
C_high	≈ 2.13	- 0.40

### 3.3.3.2 Global land use change

#### Key insights from Table 16 and Figure 16

- **Afforestation is the primary driver of land-use change.** Globally, implementing afforestation on 100% of suitable land leads to an increase in forest area of 20 M km<sup>2</sup> compared to the baseline. Land converted to forest would come mainly from grasslands other land and shrubland, and to a minor extent from cropland.

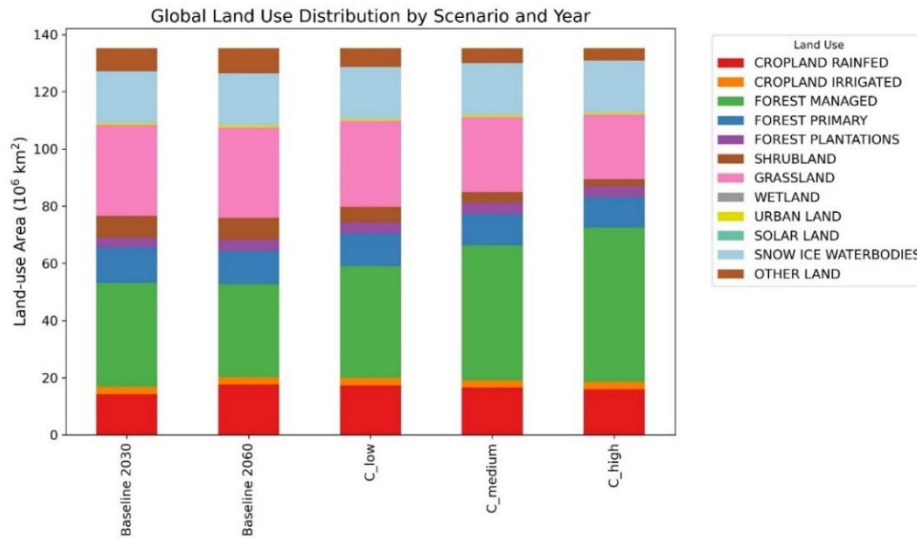


Figure 16: Impact on global land-use change under the policy simulation scenarios of storyline C by 2060, compared to the baseline year 2030 (T0) and the baseline scenario (business-as-usual).

Table 16: Global land-use change by 2060 under storyline C scenarios compared to baseline.

Land-use category	Baseline 2060 (Mkm <sup>2</sup> )	C_low (M km <sup>2</sup> )	Δ vs baseline	C_medium (M km <sup>2</sup> )	Δ vs baseline	C_high (M km <sup>2</sup> )	Δ vs baseline
Cropland	20.17	19.89	-0.28	19.13	-1.04	18.51	-1.66
Forest	48.14	54.46	+6.32	62.06	+13.92	68.47	+20.33
Grassland	31.59	30.05	-1.54	26.27	-5.32	22.55	-9.04
Other land + shrubland	16.42	11.91	-4.50	8.87	-7.55	6.81	-9.61

### 3.3.3.3 EU27 land use change

#### Key Insights from Table 17 and Figure 17

- Increasing afforestation intensity is reflected in a decline in grassland and natural land. When afforestation is implemented on 100% of suitable land, forest areas increase by 55% in 2060 compared to the baseline. This corresponds to a complete conversion of grasslands to forest.

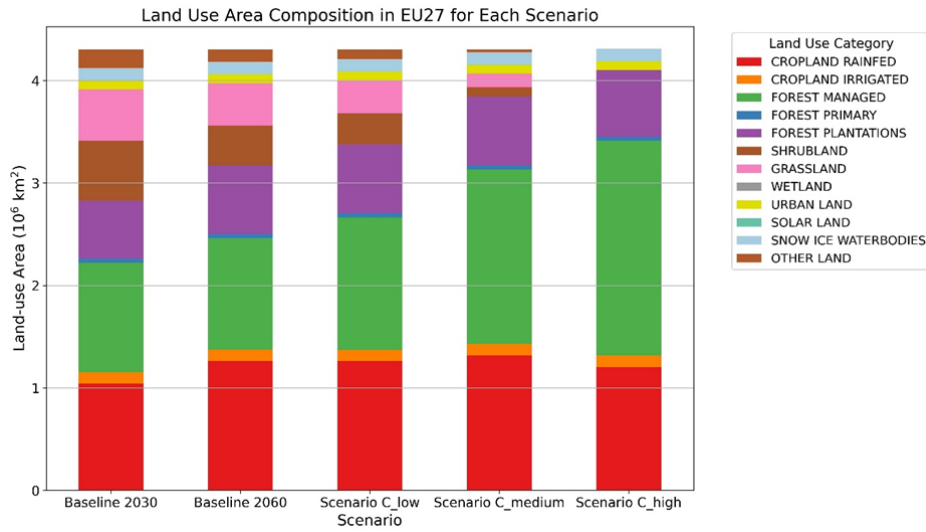


Figure 17: Impact on EU land-use change under the policy simulation scenarios of storyline C by 2060, compared to the baseline year 2030 (T0) and the baseline scenario (business-as-usual).

Table 17: EU27 land-use change by 2060 under storyline C scenarios compared to baseline.

Land-use category	Baseline 2060 (M km <sup>2</sup> )	C_low 2060 (M km <sup>2</sup> )	Δ vs baseline	C_medium 2060 (M km <sup>2</sup> )	Δ vs baseline	C_high 2060 (M km <sup>2</sup> )	Δ vs baseline
Cropland	1.37	1.37	0.00	1.43	+0.06	1.31	-0.06
Forest	1.80	2.00	+0.21	2.41	+0.62	2.79	+0.99
Grassland	0.41	0.32	-0.09	0.13	-0.28	0.00	-0.41
Other land + shrubland	0.51	0.39	-0.12	0.12	-0.39	0.00	-0.51

### 3.3.3.4 Global share RES in PE

#### Key insights from Table 18, Table 19 and Figure 18

- Protecting forest land from expansion of solar photovoltaics is the main factor limiting the potential increase in the share solar energy in total energy production. With business as usual, by 2060 renewables would deliver about 139 Exajoule (EJ) yr<sup>-1</sup>, equivalent to 12.1 % of global primary energy production. In the Low and Medium scenario this share grows to 12.4%, while it decreases to 12.2 in the High scenario.

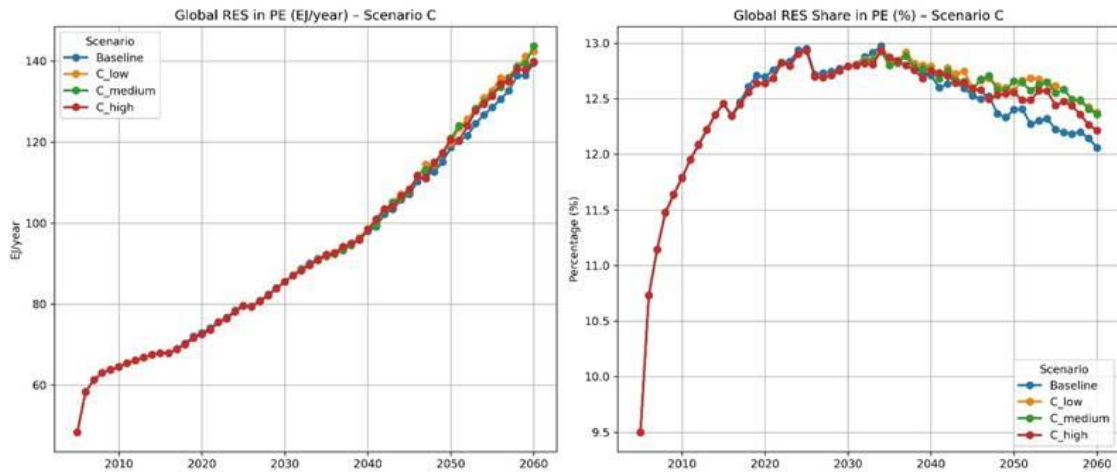


Figure 18: Impact on global RES in PE (EJ yr<sup>-1</sup> and %) based on simulations of policy scenarios under storyline C.

Table 18: Summary table of the global RES in PE (EJ yr<sup>-1</sup>) in 2060 for storyline C.

Scenario	RES in PE 2060 (EJ yr <sup>-1</sup> )	Δ vs Baseline 2060 (EJ yr <sup>-1</sup> )
Baseline 2060	139.50	—
C_low	142.36	+ 2.86
C_medium	143.73	+ 4.22
C_high	139.85	+ 0.35

Table 19: Summary table of the global RES share in PE (%) in 2060 for storyline C.

Scenario	RES share in PE 2060 (%)	Δ vs Baseline 2060 (pp)
Baseline 2060	12.06	—
C_low	12.38	+ 0.32
C_medium	12.36	+ 0.30
C_high	12.21	+ 0.15

### 3.3.3.5 Global energy emissions

#### Key insights from Table 20 and Figure 19

- For all three scenarios, the small decrease in the share of solar energy in global primary energy production corresponds to insignificant changes in GHG emissions from the energy sector.

Global GHG Energy Emissions – Scenario C

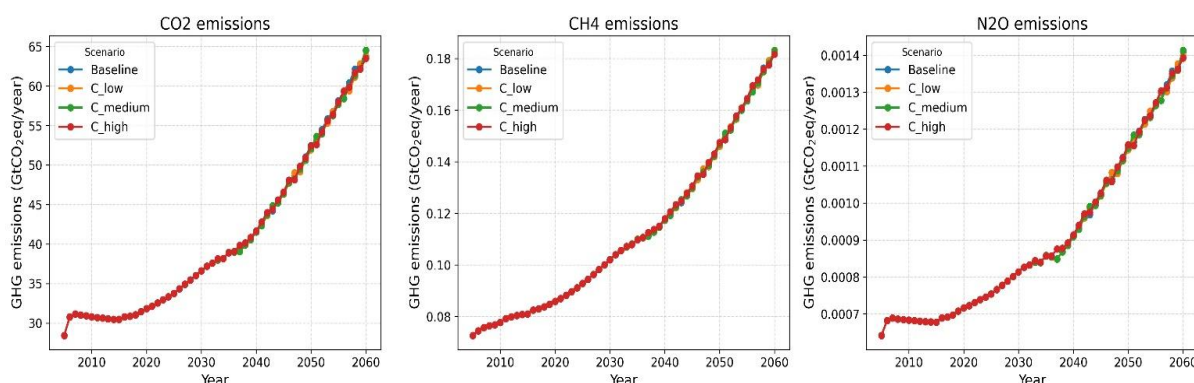


Figure 19: Impact on global GHG energy emissions (CO<sub>2</sub>, CH<sub>4</sub>, NO<sub>2</sub>) based on simulations of policy scenarios under storyline C.

Table 20: Summary table of the global GHG energy emissions in 2060 for storyline C.

Scenario (2060)	CO <sub>2</sub> (Gt yr <sup>-1</sup> )	Δ vs Baseline (Gt yr <sup>-1</sup> )	CH <sub>4</sub> (Gt yr <sup>-1</sup> )	Δ vs Baseline (Gt yr <sup>-1</sup> )	N <sub>2</sub> O (Gt yr <sup>-1</sup> )	Δ vs Baseline (Gt yr <sup>-1</sup> )
Baseline	64.51	—	0.18	—	0.0014	—
C_low	63.80	-0.70	0.18	0.00	0.0013	-0.0001
C_medium	64.53	+0.03	0.18	0.00	0.0014	0.00
C_high	63.51	-0.99	0.18	0.00	0.0014	0.00

### 3.3.3.6 Global GHG emissions

#### Key insights from Table 21 and Figure 20

- **Partial implementation of regenerative grazing and forest protection and expansion policies offers only incremental benefits.** The Low scenario leads to a similar reduction in global GHG emissions as compared to the B\_Low scenario (60% of global grassland under regenerative grazing), without additional benefits from a low-ambition afforestation policy.
- **Increasing the ambition triples the benefit.** The medium scenario delivers a  $\approx 19$  Gt CO<sub>2</sub>-eq yr<sup>-1</sup> drop (-17 %) below the baseline by 2060.
- **Full deployment of afforestation yields a system-scale mitigation wedge.** The High scenario removes  $\approx 34$  Gt CO<sub>2</sub>-eq yr<sup>-1</sup>, cutting total 2060 emissions by one-third. This single land-sector measure set closes roughly half of the global mitigation gap to a 1.5 °C pathway. Protection of cropland and forest land from solar photovoltaics prevents indirect land-use change that would otherwise offset forestry gains.

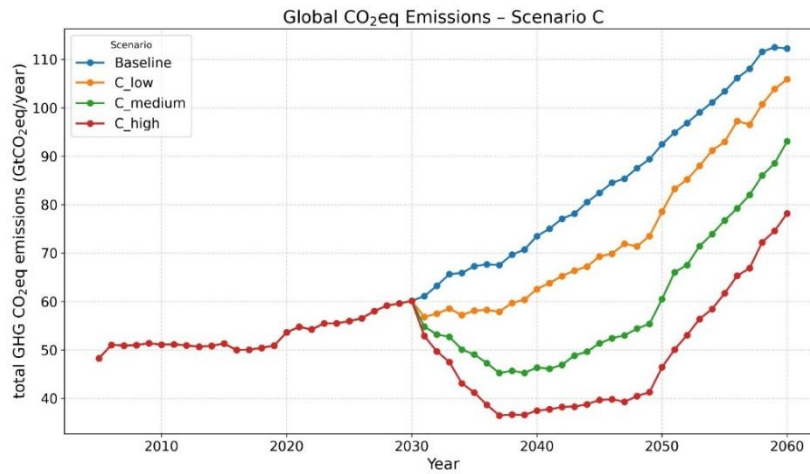


Figure 20: Impact on global GHG CO<sub>2</sub>eq emissions based on simulations of policy scenarios under storyline C.

Table 21: Summary table of the global GHG Emissions in 2060 for storyline C.

Scenario	Total GHG emissions (Gt CO <sub>2</sub> -eq yr <sup>-1</sup> )	Absolute change vs Baseline (Gt)	Relative change vs Baseline
Baseline	112.22	—	—
C_low	105.88	- 6.34	- 5.6 %
C_medium	93.06	- 19.16	- 17.1 %
C_high	78.18	- 34.04	- 30.3 %

### 3.3.3.7 EU27 GHG emissions

#### Key Insights from Table 22 and Figure 21

- **Partial implementation of regenerative grazing and forest protection and expansion policies offers only incremental benefits.** EU GHG emissions would decrease by 7% in the Low scenario compared to the baseline. Small additional benefits from a low-ambition afforestation policy are visible compared to the B-Low scenario, with the same intensity of regenerative grazing but no afforestation policy.
- **Increasing the ambition triples the benefit.** The medium scenario delivers a  $\approx 1.25$  Gt CO<sub>2</sub>-eq yr<sup>-1</sup> drop (-20 %) below the baseline by 2060.
- **Full deployment of afforestation yields a system-scale mitigation wedge.** The High scenario would cut total 2060 EU GHG emissions by one-third. Protection of cropland and forest land from solar photovoltaics prevents indirect land-use change that would otherwise offset forestry gains.

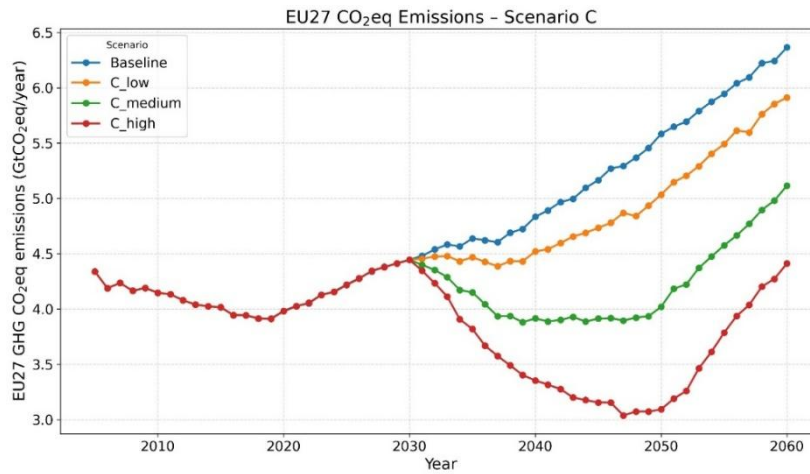


Figure 21: Impact on EU27 GHG CO<sub>2</sub>eq emissions based on simulations of policy scenarios under storyline C.

Table 22: Summary table of the U27 GHG Emissions in 2060 for storyline C.

Scenario	Total GHG emissions (Gt CO <sub>2</sub> -eq yr <sup>-1</sup> )	Absolute change vs Baseline (Gt)	Relative change vs Baseline
Baseline	6.37	—	—
C_low	5.91	-0.45	-7.1 %
C_medium	5.12	-1.25	-19.6 %
C_high	4.41	-1.95	-30.7 %

### 3.3.4 Policy recommendations

**Recommendation 8: Scale up afforestation and grassland restoration efforts as a core climate strategy.**

Large-scale ecosystem restoration is indispensable for transformative climate change mitigation: in the ambitious scenario over half of the GHG reduction came from afforestation and regeneration of grasslands. EU and national policies should significantly expand tree-planting programs (e.g. contribute to the “3 billion trees by 2030” pledge) and incentivize restoring degraded grasslands. Full afforestation (+55% forest area) contributes to a net GHG emissions reduction in the EU and globally by one third compared to the baseline, by 2060. To maximize returns, restoration initiatives must be well-funded and coupled with sustainable forest management so that new forests persist as long-term carbon sinks.

**Recommendation 9: Implement integrated land-energy planning to avoid trade-offs.**

Policies that jointly consider renewable energy expansion and protection and restoration of ecosystems can prevent trade-offs in terms of land-use change. For instance, national energy and climate plans (NECPs) and spatial plans should be coordinated to ensure that when land is set aside for nature (afforestation zones, protected habitats), energy strategies compensate by using other resources (offshore wind, urban solar, efficiency improvements). An integrated approach will minimize the risk of an “emissions rebound” at intermediate ambition and instead allow land-focused policies to fully contribute to climate goals.

**Recommendation 10: Leverage synergies between renewables and ecosystem restoration for co-benefits.**

When designed together, land and energy measures can reinforce each other: strict solar siting rules free up land for reforestation without significantly hurting clean energy output, and healthy forests and grasslands can in turn support the renewable transition (for example, by providing sustainable biomass or improving grid resilience against heatwaves and floods). The EU should promote projects that combine these aims – for instance, solar farms on low-quality land coupled with adjacent habitat restoration, or wind parks that fund local reforestation. By deploying renewables in a nature-sensitive way, the EU can achieve climate neutrality while also enhancing food security and biodiversity. The high-ambition model pathway demonstrated this complementarity, aligning EU climate, biodiversity, and food-system objectives without large cropland loss

### 3.4 Balancing urban area development and increase of forests

#### 3.4.1 Definition of the storyline

Urbanization represents the major hub of economic activity, yet it also contributes significantly to greenhouse gas emissions, resource consumption, and land use. On the other hand, forests offer critical ecosystem services, acting as natural carbon sinks, biodiversity reserves, and regulators of local climates. Expanding forest areas contributes to carbon sequestration, enhances air quality, and protects water resources. As climate challenges intensify and urban areas continue to expand, adopting integrated approaches that bridge the gap between urban planning and environmental conservation could be beneficial. This vision aligns with the European Green Deal, which aims to climate-neutrality by 2050, and is further supported by the EU Biodiversity Strategy for 2030, which calls for the protection and restoration of nature.

Combining urban sustainability with strategic forest expansion can optimize land use. Carefully planned urban growth can coexist with forested landscapes by incorporating green buffers, urban forests, and peri-urban conservation zones, thereby mitigating environmental impacts and promoting ecological connectivity. These approaches also support the EU Strategy on Adaptation to Climate Change, which emphasizes nature, based solutions and resilient urban development.

By unlocking this cross-sectoral synergy, the storyline can contribute not only to meeting the objectives of the European Climate Law and other climate commitments but also to ensuring that future growth is balanced, resilient, and sustainable. This integrated perspective is essential for building adaptive, climate, positive communities that benefit from both urban innovation and natural ecosystems.

This storyline focuses on potential conflicts and interactions between urban sprawl and increased afforestation, exploring how these two policies influence each other and assessing their combined impacts on GHG emissions, land use, and land-type distribution.

#### 3.4.2 Scenarios

In this analysis, three illustrative scenarios are constructed to investigate the outcomes of land-use competition arising from the interaction between two key policies: afforestation and urban land expansion. The *Low* scenario assumes limited afforestation, targeting 20% of suitable global land,

alongside compact urban development with a low urban land per capita of 80 m<sup>2</sup>/person, resulting in minimal pressure on land availability. The *Medium* scenario reflects a moderate policy implementation, with afforestation expanding to 60% of suitable areas and urban land per capita increasing to 150 m<sup>2</sup>/person, thereby introducing a balanced yet growing demand for land from both nature-based and infrastructural needs. The *High* scenario presents the most intense level of land-use competition, combining full afforestation deployment on 100% of suitable land with an urban sprawl pattern reaching 220 m<sup>2</sup>/person. Through these scenarios, the model evaluates how competing claims on land from ecological restoration and urban growth policies can shape future land-use dynamics and availability. The population projections used across all three scenarios are the same as in the baseline to ensure comparability of the resulting land-use outcomes.

Table 23: Specifications of the parameters of the two policies simulated in the 3 scenarios proposed (low, medium, medium, high) for storyline D: Balancing urban area development and increase of forests.

Storyline D	Policies	Scenarios of implementation intensity		
		D_Low	D_Medium	D_High
Balancing urban area development and increase of forests	Afforestation	20% of suitable land	60% of suitable land	100% of suitable land
	Managing urban sprawl	Urban land per capita 80 m <sup>2</sup> /person	Urban land per capita 150 m <sup>2</sup> /person	Urban land per capita 220 m <sup>2</sup> /person

### 3.4.3 Results of simulation

This section presents the results of the simulation of scenarios from Table 23, assessing their combined impacts compared to the baseline on the key output variables as identified in Table 1: Global temperature change, Global and EU land use change and Global and EU GHG emissions.

#### 3.4.3.1 Global temperature change

##### Key Insights from Table 24 and Figure 22

- **Afforestation is the main cooling driver:** Scaling tree planting from 20% to 60% significantly boosts avoided warming (up to 0.32 °C by 2060), with early action maximizing benefits.
- **Urban density has minor impact:** urban policy changes yield small gains and cause negligible land-use ripple effects.

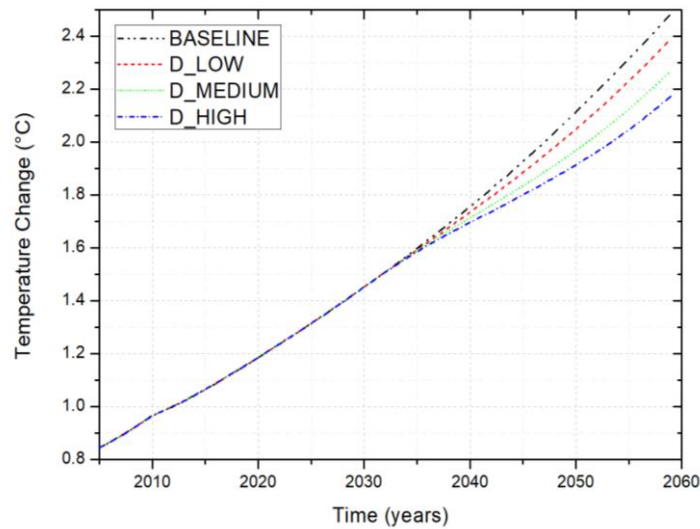


Figure 22: Impact on global temperature change based on simulations of policy scenarios under storyline D.

Table 24: Summary table of the global temperature change in 2060 for storyline D.

Scenario (2060)	Temperature increase at 2060 (°C)	Δ vs Baseline (°C)
Baseline	≈ 2.53	—
D_low	≈ 2.43	- 0.10
D_medium	≈ 2.31	- 0.22
D_high	≈ 2.21	- 0.32

### 3.4.3.2 Global land use change

#### Key insights from Table 25 and Figure 23

- **Even partial afforestation yields substantial forest gains.** Under D\_low (20 % afforestation, high urban densification), forest area rises by +6.24 M km<sup>2</sup> (+13 %) by 2060, showing that even limited planting programmes can meaningfully expand carbon-dense ecosystems.
- **High-ambition planting nearly doubles that increase.** At full (100 %) afforestation and highest urban land per capita (220 m<sup>2</sup>/person), forests swell by +19.83 M km<sup>2</sup> (+41 %), underscoring the outsized leverage of large-scale tree-planting.
- **Most gains come at the expense of Grassland, Other land and shrubland.** In the D\_high pathway, Grassland shrinks by -9.05 M km<sup>2</sup> (-29 %) and other land (wetland, ice, free barren land, etc.) and shrubland by -9.74 M km<sup>2</sup> (-28 %), indicating that new woodlands largely replace non-forest natural covers rather than cropland.
- **Cropland is minimally affected.** Even under D\_high, Cropland contracts by only -1.03 M km<sup>2</sup> (-5 %), suggesting that afforestation pressures fall mostly on lower-value natural lands.
- **Net natural-land increase is modest.** Forest gains (19.83 M km<sup>2</sup>) exceed combined losses of Grassland and other land (wetland, ice, free barren land, etc.) and shrubland (18.79 M km<sup>2</sup>) by just

≈1.0 M km<sup>2</sup>, highlighting the need to pair afforestation with policies that protect existing natural habitats to achieve larger biodiversity and carbon-sequestration co-benefits.

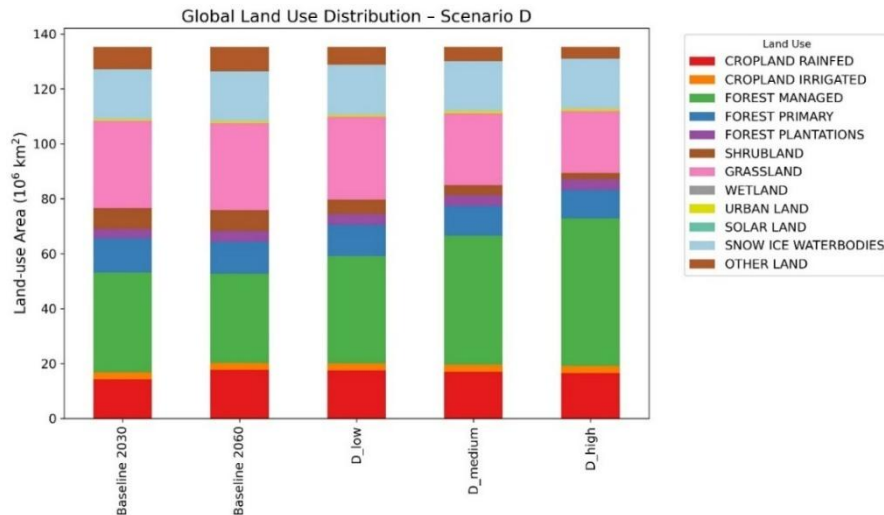


Figure 23: Impact on global land-use change under the policy simulation scenarios of storyline D by 2060, compared to the baseline year 2030 (T0) and the baseline scenario (business-as-usual).

Table 25: Global land-use change by 2060 under storyline D scenarios compared to baseline.

Land-use category	Baseline 2060 (M km <sup>2</sup> )	D_low (M km <sup>2</sup> )	Δ vs baseline	D_medium (M km <sup>2</sup> )	Δ vs baseline	D_high (M km <sup>2</sup> )	Δ vs baseline
Cropland	20.17	20.06	-0.11	19.60	-0.57	19.14	-1.03
Forest	48.14	54.37	+6.24	61.71	+13.58	67.97	+19.83
Grassland	31.59	30.05	-1.54	26.26	-5.33	22.54	-9.05
Other land + shrubland	16.43	11.82	-4.61	8.69	-7.74	6.57	-9.86

### 3.4.3.3 EU27 land use change

#### Key insights from Table 26 and Figure 24

Raising the urban-density cap and the afforestation rate triggers a pronounced land re-allocation across Europe. At the **low ambition** level, cropland expands slightly as compact-city rules curb peri-urban sprawl, releasing marginal soils that are swiftly converted to crops, while a modest 11 % rise in forest cover is achieved mainly on surplus grassland (-20 %). When the package is scaled to the **medium variant**—150 m<sup>2</sup>/person urban land per capita, 60 % afforestation—forest gains accelerate to more than one-third above today, yet this comes at the expense of an additional quarter of all pasture and two-fifths of wetlands and shrubland.

The **high-ambition** pathway, with very sprawl urban form (220 m<sup>2</sup>/person) and a 100 % tree-planting target, essentially eradicates grassland, converts the best remaining sites to woodland and pushes cropland down by 3 %. Forests end up occupying **2.77 M km<sup>2</sup>**, a rise of almost one million square

kilometres relative to baseline—enough, on paper, to double the EU-27 sink required under the Climate Law. Yet the contraction of “other natural land” (−0.51 M km<sup>2</sup>) flags a biodiversity trade-off: habitat mosaics give way to plantations and forests.

Overall, the results show that curbing urban sprawl makes land available for food production and carbon sinks without significant ecological side effects. In contrast, full afforestation provides the greatest climate benefit, but it eliminates Europe’s remaining open grasslands and large areas of wetlands, even in areas with high levels of urban sprawl.

Crafting a balanced mix may therefore be critical to align climate, food-security and biodiversity goals.

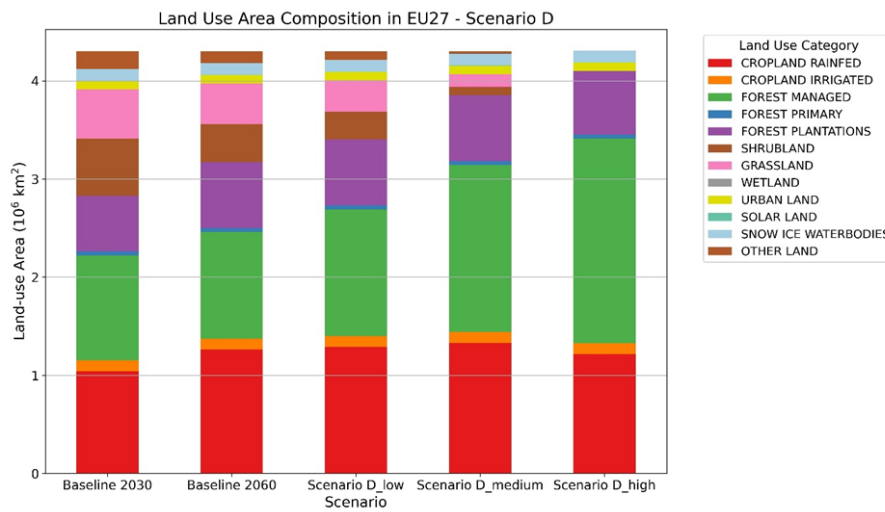


Figure 24: Impact on EU27 land-use change under the policy simulation scenarios of storyline D by 2060, compared to the baseline year 2030 (T0) and the baseline scenario (business-as-usual).

Table 26: EU27 land-use change by 2060 under storyline D scenarios compared to baseline.

Land-use category	Baseline 2060 (M km <sup>2</sup> )	D_low 2060 (M km <sup>2</sup> )	Δ vs baseline	D_medium 2060 (M km <sup>2</sup> )	Δ vs baseline	D_high 2060 (M km <sup>2</sup> )	Δ vs baseline
Cropland	1.37	1.40	+0.03	1.44	+0.07	1.33	−0.05
Forest	1.80	2.00	+0.20	2.41	+0.61	2.77	+0.97
Grassland	0.41	0.32	−0.09	0.13	−0.28	0.00	−0.41
Other land + shrubland	0.51	0.37	−0.14	0.11	−0.40	0.00	−0.51

### 3.4.3.4 Global GHG emissions

#### Key Insights from Table 27 and Figure 25

- **Scaling up afforestation substantially amplifies climate benefits:** Moving from partial (20%) to full (100%) forest restoration boosts avoided land-sector emissions from 7.4% to nearly 20% by 2060—

even when paired with relatively high urban sprawl (up to 220 m<sup>2</sup>/person)—showing that afforestation can remain effective alongside expansion.

- **Early action is key to maximizing impact:** Because Forest carbon sinks take decades to mature, front-loading afforestation is essential for capturing the full climate benefit by mid-century, especially when urban land pressures may increase.

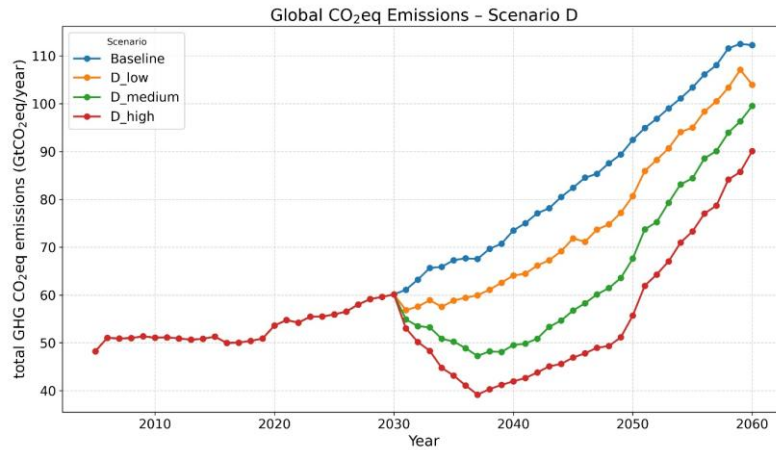


Figure 25: Impact on global GHG CO<sub>2</sub>eq emissions based on simulations of policy scenarios under storyline D.

Table 27: Summary table of the global GHG Emissions in 2060 for storyline D.

Scenario	Total GHG emissions (Gt CO <sub>2</sub> -eq yr <sup>-1</sup> )	Absolute change vs Baseline (Gt)	Relative change vs Baseline
Baseline	112.22	—	—
D_low	103.96	- 8.27	- 7.4 %
D_medium	99.53	- 12.69	- 11.3 %
D_high	90.09	- 22.13	- 19.7 %

### 3.4.3.5 EU27 GHG emissions

#### Key Insights from Table 28 and Figure 26

- **Ambitious afforestation delivers major emissions cuts even with urban expansion:** Scaling Forest restoration from 20% to 100% reduces EU27 land-sector emissions by up to 29.5% (-1.88 Gt) by 2060—comparable to today’s agricultural footprint—despite increasing urban sprawl to 220 m<sup>2</sup>/person.
- **Afforestation outpaces other land** (wetland, ice, free barren land, etc.) and shrubland levers: Tree-planting remains the most impactful driver of mitigation, accounting for more than half of the reductions in the high-ambition pathway.

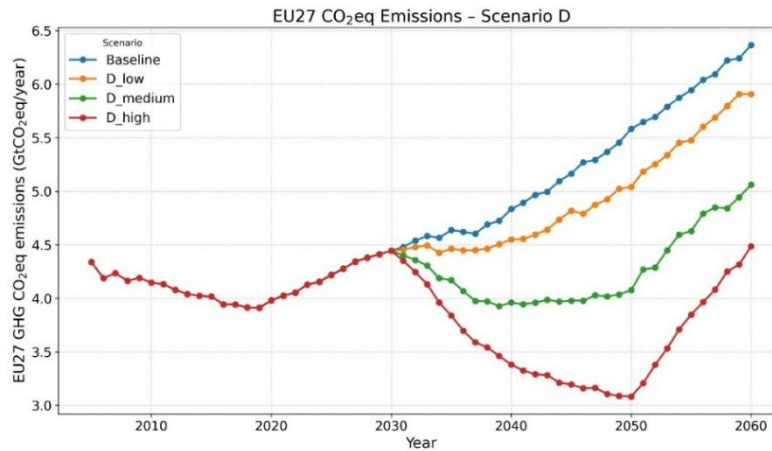


Figure 26: Impact on EU27 GHG CO<sub>2</sub>eq emissions based on simulations of policy scenarios under storyline D.

Table 28: Summary table of the U27 GHG Emissions in 2060 for storyline D.

Scenario	Total GHG emissions (Gt CO <sub>2</sub> -eq yr <sup>-1</sup> )	Change vs Baseline (Gt)	Relative change vs Baseline
Baseline	6.37	—	—
D_low	5.91	- 0.46	- 7.2 %
D_medium	5.06	- 1.31	- 20.5 %
D_high	4.49	- 1.88	- 29.5 %

### 3.4.4 Policy recommendations

**Recommendation 11: Encourage efficient use of land to manage urban sprawl.** The competition between land use and urban expansion policies is generally thought to be crucial to preventing urban expansion from consuming forests or fertile land. However, even at high levels of urban sprawl, the scenarios indicate that it is possible to keep cropland loss to only ~5% by 2060, despite high population and economic growth. Member States should establish urban growth boundaries or incentivize the redevelopment of brownfield sites, ensuring that new housing and infrastructure are accommodated within existing urban footprints. EU cohesion and recovery funds can support cities in upgrading infrastructure and increasing housing density (e.g. through public transport projects and vertical development), enabling them to absorb growth without outward sprawl. By intensifying land use in urban areas, Europe can protect rural land and help preserve productive soils and natural areas.

**Recommendation 12: Combine ambitious afforestation with strong land protection to maximize land-sector mitigation.** Large-scale tree planting is the single largest contributor to land-based emissions cuts—accounting for around half of total mitigation in the high scenario—while preserving existing natural land is essential to avoid backsliding. Policymakers should adopt a dual strategy: set bold afforestation and reforestation targets aligned with the EU Forest Strategy, while simultaneously strengthening land-use policies that curb urban encroachment on high-carbon and high-biodiversity landscapes. This includes restoring degraded areas, incentivizing forest expansion on marginal farmland

or pasture, and using zoning laws and conservation easements to protect peri-urban forests and agricultural belts. The model's most ambitious tree-cover expansion increased global forest area by +13% without major cropland losses and delivered deep carbon reductions. Such a "maximalist" approach could cut EU land-use emissions by 20–30% by 2050. Co-benefits include enhanced biodiversity, soil health, and natural flood defenses, reinforcing the need for integrated instruments like the EU Nature Restoration Law and national conservation frameworks.

**Recommendation 13: Integrate urban growth with forest conservation through spatial planning and targeted investment.** To unlock the full mitigation and biodiversity benefits of afforestation, cities and surrounding regions must be planned in tandem. Urban expansion should be matched by parallel commitments to conserve or restore green spaces—through national rules requiring reforestation offsets for land take, or municipal urban greening plans aligned with housing development. At the same time, the EU and Member States should provide financial and technical support to make this integration feasible. Instruments like the Just Transition Fund and Regional Development Fund can help cities invest in brownfield regeneration, green transport, and livable density, while CAP rural development programs and carbon credit schemes can reward landowners who establish peri-urban forests or green belts. This coordinated urban–rural approach ensures that afforestation and densification reinforce one another, allowing cities to grow sustainably while nearby landscapes deliver carbon, biodiversity, and social co-benefits. It represents a balanced strategy to align climate mitigation with broader sustainability goals.

## 3.5 Integrated Land and Resource Management

### 3.5.1 Definition of the storyline

This storyline envisions a comprehensive transition towards sustainable land use and energy systems, combining enhanced forest protection, improved grassland management, responsible use of forest biomass for renewable energy, and a societal shift towards more sustainable diets, with the final aim to ensure an integrated approach which seeks to balance biodiversity conservation, climate mitigation, and food security. Such an integrated implementation of policies aligns closely with the objectives of the European Green Deal, the EU Biodiversity Strategy for 2030, the EU Forest Strategy, and the Farm to Fork Strategy, which all promote sustainable resource use, nature restoration, climate neutrality, and healthier, more sustainable food systems.

Forests and grasslands play a crucial role as carbon sinks and biodiversity reservoirs. Their coordinated protection and management, in synergy with bioenergy production and dietary shifts, help mitigate climate change while avoiding trade-offs, such as converting natural habitats into bioenergy plantations or agricultural areas. When sourced sustainably, forest biomass can contribute to replacing fossil fuels and reducing emissions, provided it follows the criteria outlined in the EU Renewable Energy Directives (RED II and RED III<sup>3</sup>). At the same time, shifting diets towards plant-based options reduces the demand

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<sup>3</sup> [https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive\\_en](https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive_en)

for livestock and feed, freeing land for reforestation and improving carbon sequestration. These measures align also with the Farm to Fork Strategy and the Common Agricultural Policy (CAP), which promote eco-schemes and sustainable land management, as well as more in general with the Paris Agreement and the United Nations (UN) Sustainable Development Goals, particularly those focused on climate action, life on land, and responsible consumption.

### 3.5.2 Scenarios

The scenarios are differentiated by increasing levels of policy ambition across four domains: forest protection, grassland management, use of forest biomass for renewable energy (RES), and dietary shifts. In the **Low Scenario** 20% of both primary and managed forests are protected, and regenerative grassland management is implemented on 20% of grasslands. The use of forest biomass for energy is associated with minimal capacity expansion and low allocation priority. Dietary patterns remain at baseline levels. In the **Medium Scenario**, protection of forests increased to 60%, and regenerative grassland management is scaled up to 60% of grassland areas. This scenario assumes moderate capacity expansion and allocation priority for forest biomass as a renewable energy source. Additionally, it reflects a dietary shift with 50% of the global population following a flexitarian diet. The **High Scenario** represents the most ambitious policy setting: full protection of both primary and managed forests, widespread adoption of regenerative grazing practices across all grasslands, and maximum expansion and prioritization of forest biomass in the renewable energy mix. In parallel, it assumes a plant-based diet for 50% of the global population.

Table 29: Specifications of the parameters of the four policies simulated in the 3 scenarios proposed (low, medium, high) for storyline E: Integrated land and resource management.

Storyline E	Policies	Scenarios of implementation intensity		
		E_Low	E_Medium	E_High
Integrated land and resource management	Forest protection	20% of primary and managed forests are protected	60% of primary and managed forests are protected	100% of primary and managed forests are protected
	Grassland management	Regenerative grassland management is implemented on 20% of grasslands	Regenerative grassland management is implemented on 60% of grasslands	Regenerative grassland management is implemented on 100% of grasslands
	RES from forest biomass	Low capacity expansion and allocation priority for forest biomass as a renewable energy source (0.2)	Moderate capacity expansion and allocation priority for forest biomass as a renewable energy source (0.7)	Maximum capacity expansion and allocation priority for forest biomass as a renewable energy source (1.2)
	Shift in diets	Baseline	50% global population shifting to a flexitarian diet	50% global population shifting to a plant-based diet

### 3.5.3 Results of simulation

This section presents the results of the simulation of scenarios from Table 29, assessing their combined impacts compared to the baseline on the key output variables as identified in Table 1: Global temperature change, Global and EU land use change, Global and EU meat consumption, Global share RES in PE, and Global and EU GHG emissions.

#### 3.5.3.1 Global temperature change

Key insights from Table 30 and Figure 27

- **A partial adoption of integrated land and resource management yields only a tenth-degree benefit.** Protecting and sustainably managing just one-fifth of global forests and grasslands, respectively, a modest energy use of forest biomass, and no dietary change trims projected 2060 warming by about 0.10 °C, confirming that the limited implementation of land measures alone cannot align with the Paris Agreement expected temperature range.
- **Full deployment of integrated land and resource management delivers just under two-tenths of a degree.** The high-ambition mix—complete forest safeguarding, full regenerative grazing, high exploitation of biomass for energy use and half of global population going fully plant-based—cuts 2060 warming by  $\approx 0.18$  °C. While still limited, this is a meaningful land-sector wedge that must complement decarbonisation of fossil fuels.

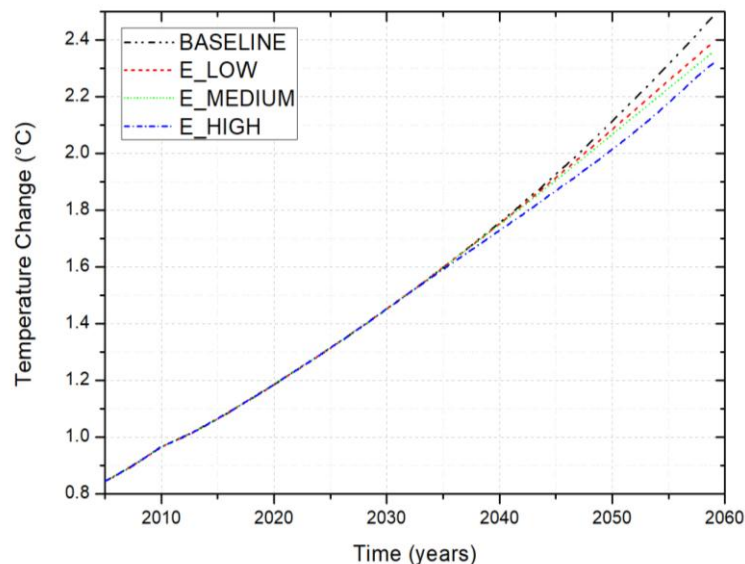


Figure 27: Impact on global temperature change based on simulations of policy scenarios under storyline E.

Table 30: Summary table of the global temperature change in 2060 for storyline E.

Scenario (2060)	Global temperature increase (°C)	Δ vs Baseline (°C)
Baseline	≈ 2.53	—
E_low	≈ 2.43	0.10
E_medium	≈ 2.39	0.14
E_high	≈ 2.35	0.18

### 3.5.3.2 Global land use change

#### Key insights from Table 31 and Figure 28

- **A partial adoption of integrated land and resource management could free almost 2 M km<sup>2</sup> which could be then devoted to nature.** Even with just 20% global forest protection, modest grazing measures, low exploitation of forest biomass for energy and no diet shift, the global cropland area shrinks by approximately 2 million km<sup>2</sup>. This is mainly due to the more efficient use of grazing lands, which reduces the need to produce feed on cropland. The freed-up land allows for an expansion of forests and other natural ecosystems, demonstrating that even limited interventions in the land sector can increase space for carbon-rich ecosystems.
- **High ambition is transformative, with croplands that contract by 27 %.** With full forest protection and regenerative grazing, high exploitation of forest biomass for energy, and half of the global population eating fully plant-based diet, cropland shrinks by -5.4 M km<sup>2</sup> with respect to the projected baseline scenario in 2060, allowing for a potential forest growth by +4.6 M km<sup>2</sup>.

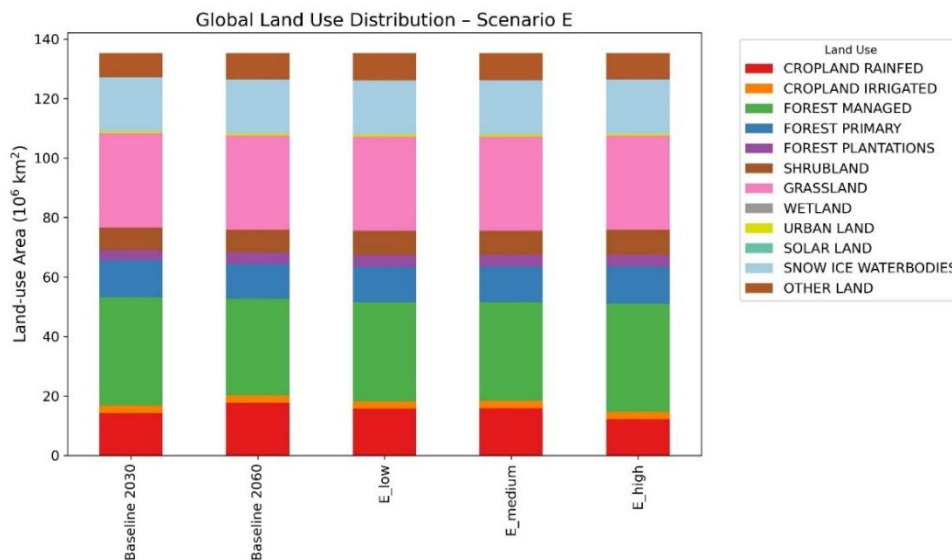


Figure 28: Impact on global land-use change under the policy simulation scenarios of storyline E by 2060, compared to the baseline year 2030 (T0) and the baseline scenario (business-as-usual).

Table 31: Global land-use change by 2060 under storyline E scenarios compared to baseline.

Land-use category	Baseline 2060 (M km <sup>2</sup> )	E_low (M km <sup>2</sup> )	Δ vs baseline	E_medium (M km <sup>2</sup> )	Δ vs baseline	E_high (M km <sup>2</sup> )	Δ vs baseline
Cropland	20.17	18.23	-1.94	18.40	-1.77	14.73	-5.44
Forest	48.14	49.15	+1.02	49.06	+0.93	52.73	+4.59
Grassland	31.59	31.61	+0.02	31.61	+0.02	31.64	+0.05
Other land + shrubland	16.42	17.30	+0.88	17.22	+0.80	17.19	+0.77

### 3.5.3.3 EU27 land use change

#### Key insights from Table 32 and Figure 29

**Even modest efforts in pursuing integrated land and resource management** – with just 20% global forest protection, modest grazing measures, low exploitation of forest biomass for energy and no diet shift – **frees 0.22 M km<sup>2</sup> of European cropland**, allowing expansion of Other Land (wetland, ice, free barren land, etc.) and shrubland. **It is only with high ambition** —complete global forest protection and regenerative grazing, maximised exploitation of forest biomass for energy use, and half of the global population switching to 100 % plant-based diets—**that cropland gives way on a transformative scale in Europe**: more than half a million square kilometres could revert to nature. Most of that area could become species-rich grasslands, forests, other land (wetland, ice, free barren land, etc.) and shrubland.

**Forest protection alone results in only modest land area gains unless it is accompanied by strong demand-side measures that reduce cropland expansion.** It is also essential to ensure the optimized use of forest biomass for energy, in order to adequately preserve carbon-rich ecosystems and achieve a balanced coexistence of climate mitigation, food security, and biodiversity goals in Europe.

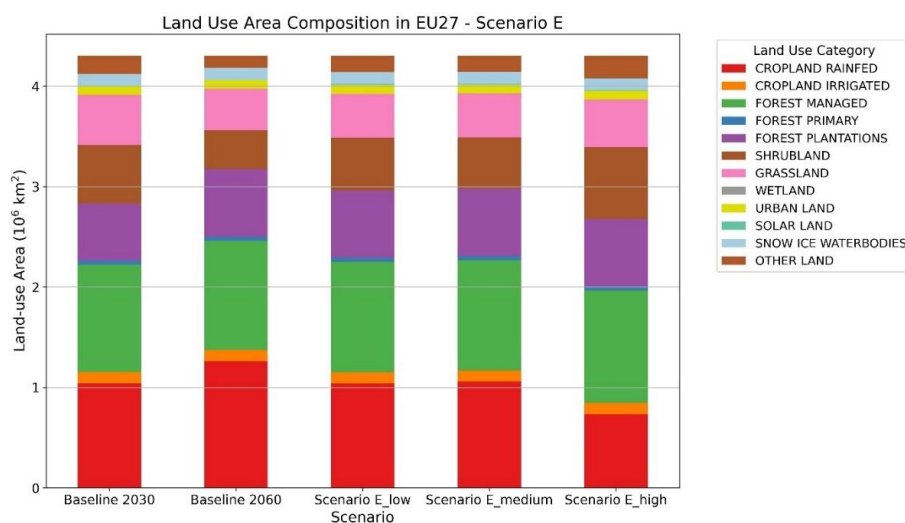


Figure 29: Impact on EU27 land-use change under the policy simulation scenarios of storyline E by 2060, compared to the baseline year 2030 (T0) and the baseline scenario (business-as-usual).

Table 32: EU27 land-use change by 2060 under storyline E scenarios compared to baseline.

Land-use category	Baseline 2060 (M km <sup>2</sup> )	E_low 2060 (M km <sup>2</sup> )	Δ vs baseline (E_low)	E_medium 2060 (M km <sup>2</sup> )	Δ vs baseline (E_medium)	E_high 2060 (M km <sup>2</sup> )	Δ vs baseline (E_high)
Cropland	1.37	1.15	-0.22	1.17	-0.20	0.85	-0.52
Forest	1.80	1.81	+0.01	1.81	+0.01	1.83	+0.03
Grassland	0.41	0.44	+0.03	0.44	+0.03	0.48	+0.07
Other land + shrubland	0.51	0.69	+0.18	0.67	+0.16	0.94	+0.43

### 3.5.3.4 EU and global meat consumption

Results of simulations for EU and global meat consumption are completely aligned with those coming from the Storyline A “Regenerative Agriculture and Dietary Transformation” (see par 3.1.3.4 and Figure 4 and Figure 5).

#### Key insights

- In the baseline scenario, meat consumption by 2060 is projected to decline in the EU and to increase globally.
- The High scenario nearly halves meat demand at EU and global scales. The integrated A\_High scenario cuts meat consumption by -47 %, aligning with the land-use analysis that showed the largest grassland contraction and forest expansion. Such a transformation is pivotal for meeting the EU Climate Law’s enhanced LULUCF-sink targets.
- Globally, regenerative agriculture leads to a 17% decrease in meat consumption compared to the baseline. This decline is driven by a decrease in feed supply, where the less intensive crop production system cannot meet the feed demand associated with the increase in meat consumption projected under baseline scenario.

### 3.5.3.5 Global share RES in PE

#### Key Insights from Table 33, Table 34 and Figure 30

- Modest effort delivers only small incremental gains. Low forest biomass exploitation raises renewable supply by just 12 EJ—a 4.9-percentage-point bump in the global primary energy mix. This narrows but does not close the gap with a Paris-aligned trajectory.
- High ambition is transformational. Maximised forest biomass exploitation sustainably – allowing also for full forest protection and regenerative grazing on all grasslands, and half of global population going fully plant-based – soars the RES share of primary energy to 37 %, a 25-point jump that would slash fossil demand and associated CO<sub>2</sub> emissions in the power and heat sectors.
- Excessive reliance on biomass as a renewable energy source for electricity, solid fuels, and heat leads to a sharp and potentially unsustainable rise in biomass consumption, as noted by [Capellán-Pérez et al. (2019)]. The system intensifies biomass-based energy production, which has generally

a very low EROI, in an effort to boost net energy, but this also results in increased GHG emissions (see next image). When the policy is withdrawn, the system stabilizes—highlighting that biomass use should be carefully limited. Such constraints are essential to prevent forest overexploitation and to avoid a significant decline in the global system's overall EROI

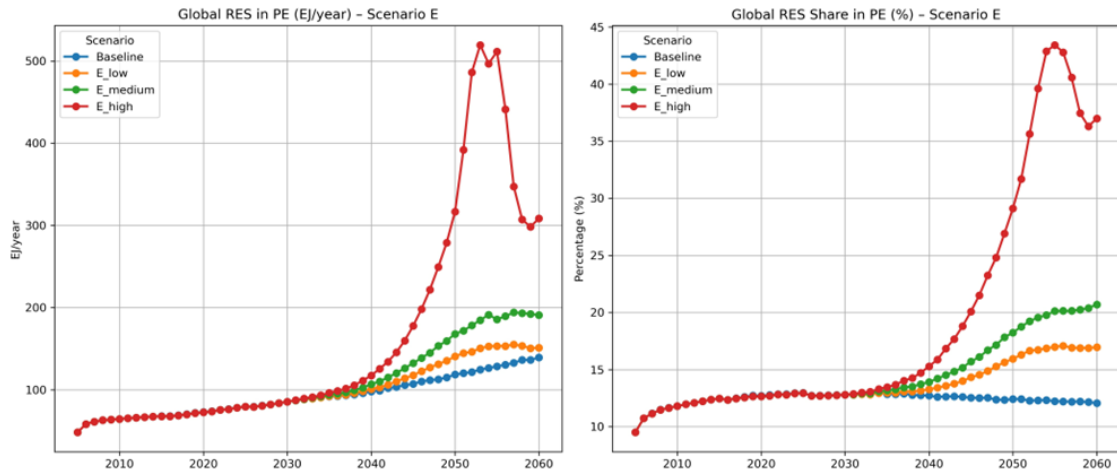


Figure 30: Impact on global RES in PE (EJ yr<sup>-1</sup> and %) based on simulations of policy scenarios under storyline E.

Table 33: Summary table of the global RES in PE (EJ yr<sup>-1</sup>) in 2060 for storyline E.

Scenario	RES in PE 2060 (EJ yr <sup>-1</sup> )	Δ vs Baseline 2060 (EJ yr <sup>-1</sup> )
Baseline 2060	139.50	—
E_low	151.19	+ 11.69
E_medium	190.89	+ 51.39
E_high	308.49	+ 168.99

Table 34: Summary table of the global RES in PE (%) in 2060 for storyline E.

Scenario	RES share in PE 2060 (%)	Δ vs Baseline 2060 (pp)
Baseline 2060	12.06	—
E_low	16.95	+ 4.89
E_medium	20.69	+ 8.63
E_high	37.00	+ 24.94

### 3.5.3.6 Global GHG emissions

#### Key Insights from Table 35 and Figure 31

- **Partial measures shave off 30 % of global emissions.** With only one-fifth of forest protected and regenerative grazing and a low exploitation of biomass for energy, global 2060 GHG emissions are dimmed by ≈ 81 Gt (–31%), useful for a Paris-aligned pathway.

- **Adding a flexitarian diet unlocks the first big step-change.** The shift of the 50 % global population towards a flexitarian diet with reduction in animal-protein demand plus moderate biomass exploitation removes an extra 4.5 Gt, pushing the cut to –31 %.
- **Full ambition almost reaches a one-fifth reduction.** When forest protection and regenerative grazing go to 100 %, biomass are extensively exploited and half global population move fully plant-based, emissions fall by ≈ 55 Gt (–49 %). Again, this should be carefully considered, as the forced overuse of biomass, which has a low EROI, could lead to a rapid increase in both biomass consumption and GHG emissions in an attempt to stabilize the system at a higher Net energy.

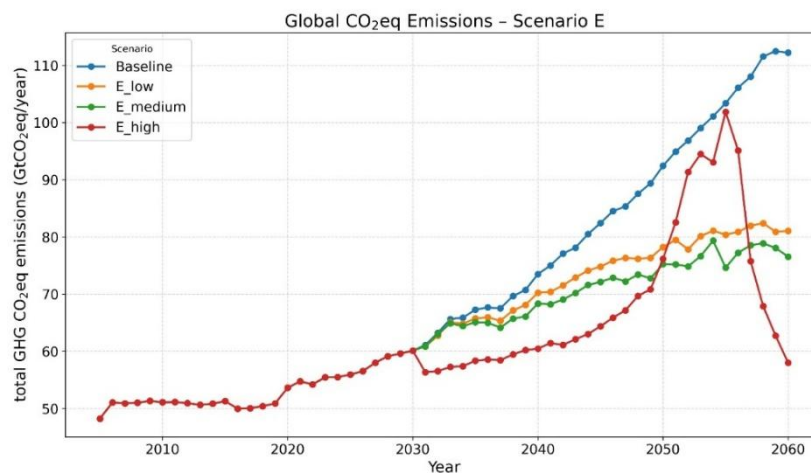


Figure 31: Impact on global GHG CO<sub>2</sub>eq emissions based on simulations of policy scenarios under storyline E.

Table 35: Summary table of the global GHG Emissions in 2060 for storyline E.

Scenario (2060)	Total GHG emissions (Gt CO <sub>2</sub> -eq yr <sup>-1</sup> )	Absolute change vs Baseline (Gt)	Relative change vs Baseline
Baseline	112.22	0.00	0.00%
E_low	81.04	–31.18	–27.78%
E_medium	76.54	–35.68	–31.79%
E_high	57.09	–55.13	–49.13%

### 3.5.3.7 EU27 GHG emissions

#### Key insights from Table 36 and Figure 32

**Full deployment of integrated land and resource management** – complete global forest protection and regenerative grazing, sustainably bioenergy expansion and half the global population going fully plant-based—cuts projected 2060 EU GHG emissions by ≈ 1.31 Gt CO<sub>2</sub>eq per year.

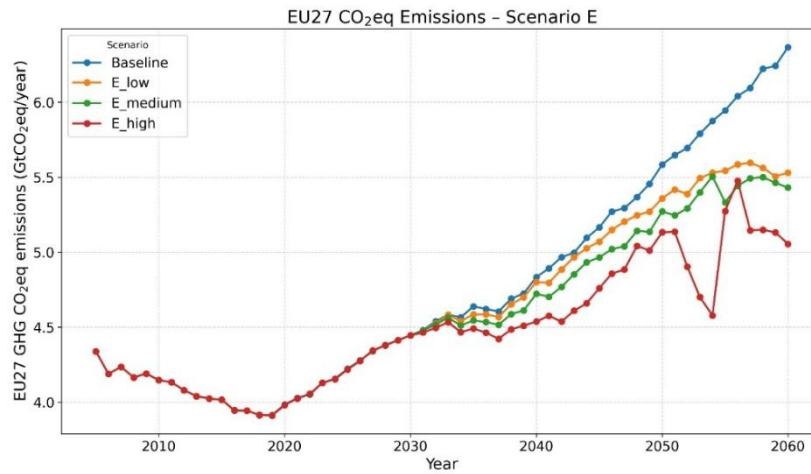


Figure 32: Impact on EU27 GHG CO<sub>2</sub>eq emissions based on simulations of policy scenarios under storyline A.

Table 36: Summary table of the U27 GHG Emissions in 2060 for storyline E.

Scenario (2060)	Total GHG emissions (Gt CO <sub>2</sub> -eq yr <sup>-1</sup> )	Absolute change vs Baseline (Gt)	Relative change vs Baseline
Baseline	6.37	—	—
E_low	5.53	-0.84	-13.1 %
E_medium	5.43	-0.94	-14.7 %
E_high	5.05	-1.31	-20.6 %

### 3.5.4 Policy recommendations

**Recommendation 14: Adopt holistic policy packages that integrate climate, energy, and land objectives to be pursued simultaneously to mutual benefit**, so to maximize co-benefits and create a more robust path to climate neutrality. When forest protection, forest bioenergy, regenerative grazing, and dietary change are implemented together, the outcomes include a significantly ~20% cut in EU GHG emissions by mid-century – while supporting biodiversity and healthier diets.

**Recommendation 15: Design and implement policy packages that mirror synergies in forest sector, grazing practices, bioenergy from biomass and sustainable diets**, including for example sustainable forest management and reforestation programmes, thus increasing carbon sequestration and boosting biomass fuel supply, coupled with spread of guidelines and campaigns fostering a shift towards more sustainable and healthy diets, and support to farmers to encourage a shift to sustainable practices especially for grazing lands. **Biomass use should be carefully managed** to prevent its rapid exploitation in pursuit of higher net energy availability as final energy.

## 3.6 Solar Energy for a Sustainable Future

### 3.6.1 Definition of the storyline

This storyline emphasizes the sustainable use of land and the accelerated deployment of photovoltaic energy through both land-based systems and rooftop solar panel installations. It envisions a transformative shift toward a solar-powered future that maximizes renewable energy output, minimizes environmental impacts, and promotes energy decentralization. Through integrated solar land management strategies—such as careful site planning—the storyline ensures optimized land use while preserving biodiversity and ecological integrity, fully aligning with the EU Biodiversity Strategy for 2030. The combined rollout of utility-scale solar projects and distributed rooftop systems strengthens the resilience and inclusivity of the energy system, reaching both urban and rural areas. This holistic approach supports the goals of the European Green Deal, the Renewable Energy Directive (RED II and RED III), and the Clean Energy Package by enabling a climate-neutral, resource-efficient economy. This strategy addresses key environmental and energy challenges by reinforcing innovation, sustainability, and resilience.

The scenarios are expected to lead to an overall increase in photovoltaic energy production share and a reduction in fossil fuel dependency. Rooftop solar installations empower communities, lower household energy costs, and drive job creation, especially in rural areas. The scenarios ultimately contribute to EU and global climate targets, including the Paris Agreement, while supporting equitable regional development under the EU Cohesion Policy.

### 3.6.2 Scenarios

In the analysis, three illustrative scenarios are examined, each reflecting different levels of policy implementation related to land-use competition between solar photovoltaic (PV) deployment and alternative land uses. The scenarios consider both ground-mounted solar PV and rooftop solar PV installations. Policy implementation for both types of solar PV is represented through varying levels of capacity expansion, according to the availability of space calculated by the model (rooftop and/or ground-mounted PV), while allocation priority for most renewable electricity sources remains fixed at the maximum level by default, as supported by historical data.

The *Low* scenario assumes minimal land-use competition from solar PV, with 50% of forest areas protected from ground-mounted solar infrastructure. Rooftop solar PV is assumed to expand to the maximum capacity feasible based on the available global rooftop area under current urban organization, while ground-mounted solar PV follows current expansion trends. The *Medium* scenario reflects a higher level of ambition, assuming full protection of grasslands and croplands, while maintaining 50% forest protection. At the same time, ground-mounted solar PV is scaled to maximum capacity expansion, alongside continued maximum expansion of rooftop solar. The *High* scenario represents the most ambitious policy pathway, characterized by maximum capacity expansion for both rooftop and ground-mounted solar PV, while simultaneously ensuring full protection (100%) of forests, grasslands, and croplands from solar infrastructure development.

Table 37: Specifications of the parameters of the three policies simulated in the 3 scenarios proposed (low, medium, medium, high) for storyline F: Solar energy for a sustainable future.

Storyline F	Policies	Scenarios of implementation intensity		
		F_Low	F_Medium	F_High
Solar energy for a sustainable future	Sustainable management of solar installations	Protection of 50% of forests from conversion to Solar energy infrastructure.	Protection of 50% of forests, 100% of grasslands and cropland from conversion to Solar energy infrastructure	Protection of 100% of forests, grasslands and cropland from conversion to Solar energy infrastructure
	Increase in PV energy production	Continuation of current trends	Maximum capacity expansion of solar ground-mounted arrays	Maximum capacity expansion of solar ground-mounted arrays
	Solar panels on rooftop/buildings	Maximum capacity expansion of solar PV on rooftops	Maximum capacity expansion of solar PV on rooftops)	Maximum capacity expansion of solar PV on rooftops

### 3.6.3 Results of simulation

This section presents the results of the simulation of scenarios from Table 37, assessing their combined impacts compared to the baseline on the key output variables as identified in Table 1: Global temperature change, Global and EU land use change, Global share of RES in PE, Global energy emissions and Global and EU GHG emissions.

#### 3.6.3.1 Global temperature change

##### Key insights from Table 38 and Figure 33

**Rooftop-first solar strategies offer modest climate benefits:** Prioritizing rooftop PV and protecting forests reduces 2060 warming by ~0.04 °C—useful but not transformative—highlighting limited temperature impact from siting changes alone.

**Stricter land protections yield diminishing climate returns:** Adding safeguards for farmland and expanding exclusion zones brings minimal additional cooling (<0.005 °C), showing that emissions reductions depend more on total PV capacity than location.

**Siting policies deliver key co-benefits beyond cooling:** While climate impacts are minor, rooftop-first approaches support biodiversity, avoid land-use conflicts, ease permitting, and reduce transmission losses—boosting the social and ecological viability of solar expansion.

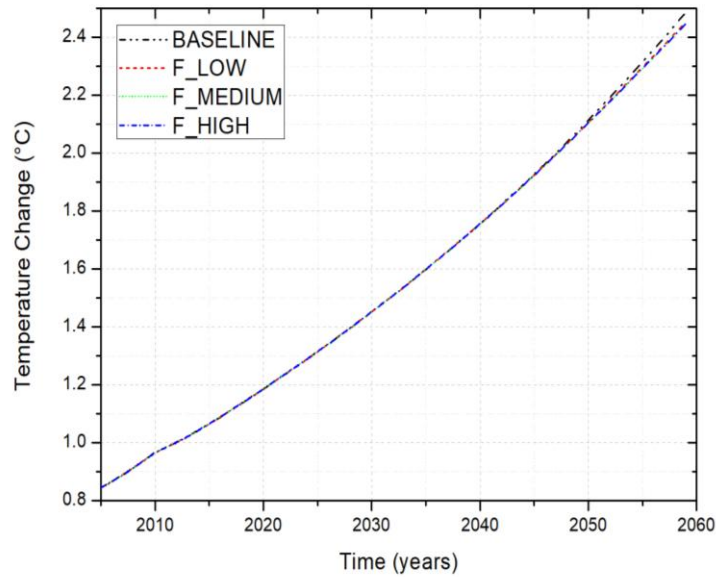


Figure 33: Impact on global temperature change based on simulations of policy scenarios under storyline F.

Table 38: Summary table of the global temperature change in 2060 for storyline F.

Scenario	Global temperature increase (°C)	Δ vs Baseline (°C)
Baseline	2.531	—
F_low	2.492	-0.039
F_medium	2.488	-0.043
F_high	2.488	-0.044

### 3.6.3.2 Global land use change

#### Key insights from Table 39 and Figure 34

- **Global land impacts of solar siting policies are modest:** Shifting PV to rooftops and converted land slightly reduces cropland ( $\leq 0.3$  M km<sup>2</sup>) and forests ( $\leq 0.1$  M km<sup>2</sup>), with limited influence on global land metrics—though these changes may carry local significance.
- **Exclusion zones protect food-producing land and forests:** Extending siting rules to cropland and grassland (F\_medium & F\_high) reduces cropland loss by approximately 40%, and forest areas increase slightly (+0.04–0.09 M km<sup>2</sup>), showing that stronger safeguards redirect solar away from sensitive ecosystems.
- **Greater land-use benefits depend on scaling up solar, not just better placement:** To unlock larger gains, stricter siting must be paired with a more ambitious renewable energy build-out, enabling rooftop-first strategies to deliver meaningful climate and land-sparing outcomes.

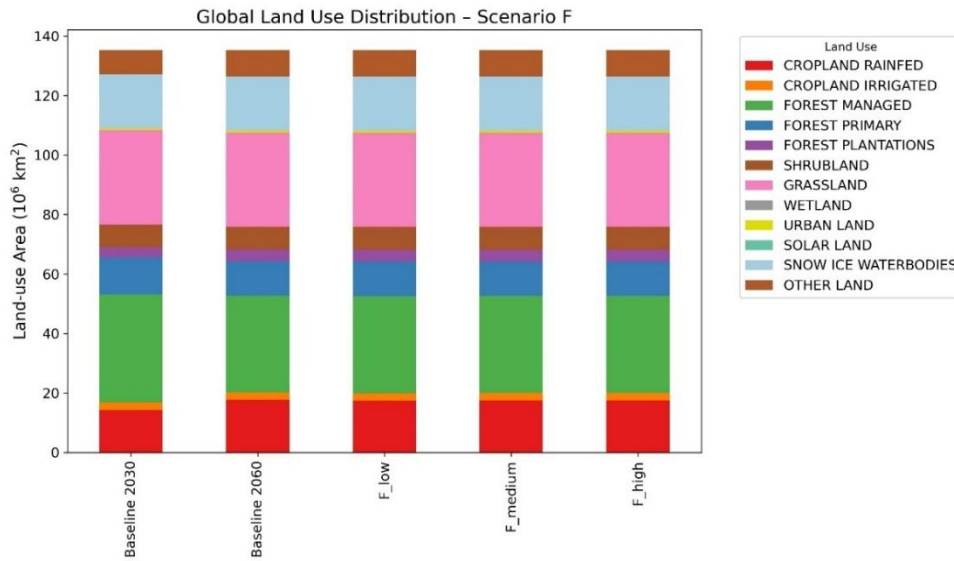


Figure 34: Impact on global land-use change under the policy simulation scenarios of storyline F by 2060, compared to the baseline year 2030 (T0) and the baseline scenario (business-as-usual).

Table 39: Global land-use change by 2060 under storyline F scenarios compared to baseline.

Land-use category	Baseline 2060 (M km <sup>2</sup> )	F_low (M km <sup>2</sup> )	Δ vs baseline	F_medium (M km <sup>2</sup> )	Δ vs baseline	F_high (M km <sup>2</sup> )	Δ vs baseline
Cropland	20.17	19.95	-0.22	20.03	-0.14	20.03	-0.14
Forest	48.14	48.23	+0.09	48.18	+0.04	48.17	+0.04
Grassland	31.59	31.59	0.00	31.58	-0.01	31.58	-0.01
Other land + shrubland	16.43	16.52	+0.09	16.47	+0.04	16.47	+0.04

### 3.6.3.3 EU27 land use change

#### Key insights from Table 40 and Figure 35

- **Rooftop-first strategies modestly spare cropland and marginal lands:** Prioritizing rooftop solar (F\_low) reduces cropland use by ~2.5% and limits expansion into other land (wetland, ice, free barren land, etc.) and shrubland, while forest and grassland areas remain largely unaffected across all scenarios.
- **Broader siting restrictions yield little added benefit without faster solar expansion:** Once cropland and grassland are protected (F\_medium), further land savings plateau (F\_high), highlighting that meaningful land-sparing gains depend more on accelerating PV deployment than tightening exclusion zones.

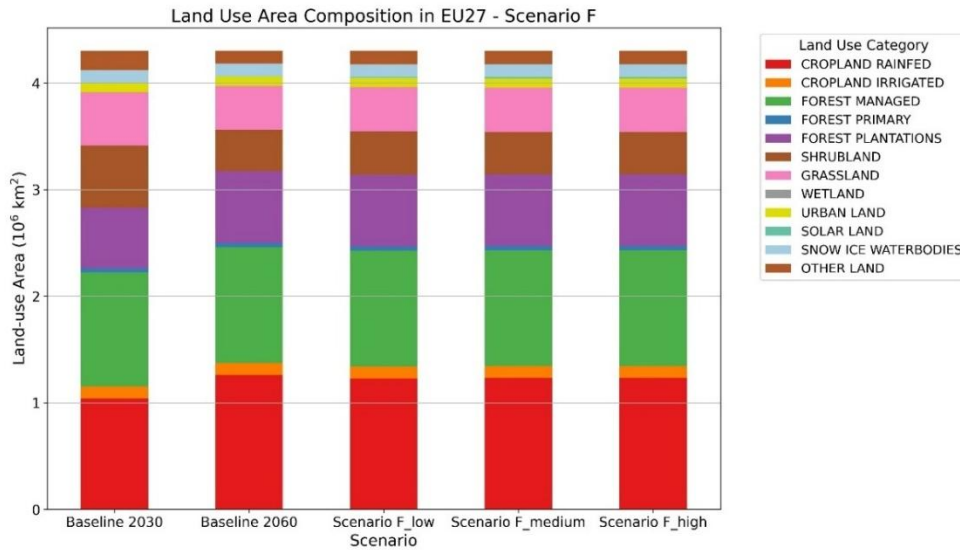


Figure 35: Impact on EU 27 land-use change under the policy simulation scenarios of storyline F by 2060, compared to the baseline year 2030 (T0) and the baseline scenario (business-as-usual).

Table 40: EU27 land-use change by 2060 under storyline F scenarios compared to baseline.

Land-use category	Baseline 2060 (M km <sup>2</sup> )	F_low 2060 (M km <sup>2</sup> )	Δ vs baseline	F_medium 2060 (M km <sup>2</sup> )	Δ vs baseline	F_high 2060 (M km <sup>2</sup> )	Δ vs baseline
Cropland	1.37	1.34	-0.03	1.34	-0.03	1.34	-0.03
Forest	1.80	1.80	-0.00	1.80	-0.00	1.80	-0.00
Grassland	0.53	0.54	+0.01	0.54	+0.01	0.54	+0.01
Other land + shrubland	0.51	0.53	+0.02	0.52	+0.01	0.52	+0.01

### 3.6.3.4 Global share of RES in PE

#### Key insights from Table 41 and Figure 36

- **Rooftop-first delivers the largest efficiency gain:** Prioritizing building-mounted PV (F\_low) raises the RES share by roughly 10 percentage points—a 80% boost over baseline—without accelerating total solar build-out, making it the most impactful standalone measure.
- **Additional ground-mounted PV offers diminishing returns:** Expanding open-space solar (F\_medium) increases the RES share slightly (+1.45 pp), while full land protection (F\_high) has negligible impact (-0.3 pp), as these rules affect location, not capacity.
- **Early siting policies amplify long-term gains and co-benefits:** Though differences narrow before 2040, siting priorities compound over time, widening the gap by 2060. F\_high secures added biodiversity and social acceptance with nearly identical RES outcomes to F\_medium.

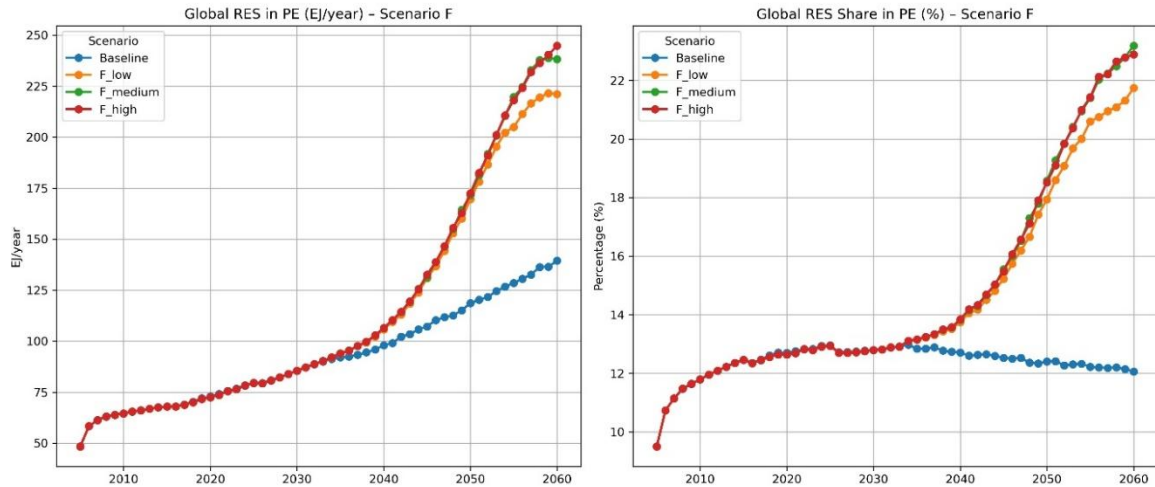


Figure 36: Impact on global RES in PE (EJ yr<sup>-1</sup> and %) based on simulations of policy scenarios under storyline F.

Table 41: Summary table of the global RES in PE (%) in 2060 for storyline F.

Scenario	RES share in PE 2060	Δ vs Baseline (pp)
Baseline	12.06 %	—
F_low	21.74 %	+ 9.68 pp
F_medium	23.19 %	+ 11.13pp
F_high	22.89 %	+ 10.83 pp

### 3.6.3.5 Global energy emissions

#### Key insights from Table 42 and Figure 37

- Rooftop-first offers the largest emissions cuts, but overall climate impact remains modest:** The F\_low scenario already reduces energy-sector CO<sub>2</sub> emission by roughly 30% and CH<sub>4</sub>/N<sub>2</sub>O by ~1% by 2060, while adding an increase deployment of solar PV with protection does not increase substantially the energy-sector CO<sub>2</sub> emission—highlighting that siting choices have limited influence on global emissions unless paired with larger fossil fuel displacement.
- Main value lies in co-benefits, not direct GHG savings:** While the °C impact is minimal, rooftop-first strategies minimize land-clearing, soil sealing, and permitting delays, while protecting biodiversity and easing grid integration—critical advantages for accelerating a socially and ecologically responsible energy transition.

Global GHG Energy Emissions – Scenario F

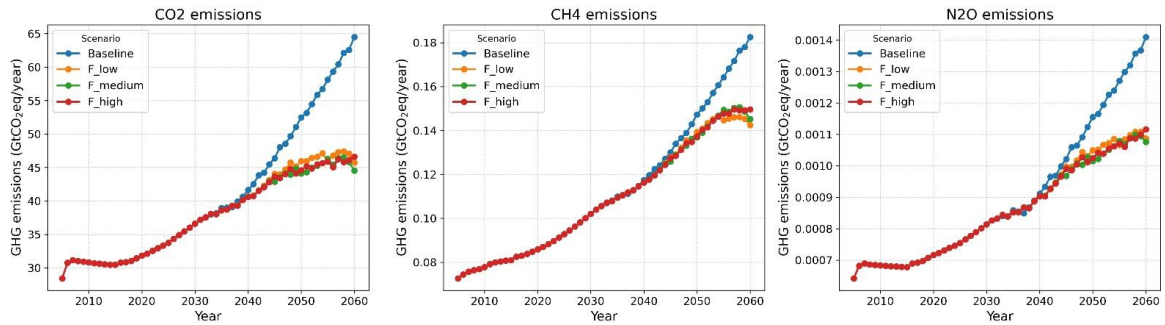


Figure 37: Impact on global GHG energy emissions (CO<sub>2</sub>, CH<sub>4</sub>, NO<sub>2</sub>) based on simulations of policy scenarios under storyline F.

Table 42: Summary table of the global GHG energy emissions in 2060 for storyline F.

Scenario (2060)	CO <sub>2</sub> (Gt yr <sup>-1</sup> )	Δ vs Baseline (Gt yr <sup>-1</sup> )	CH <sub>4</sub> (Gt yr <sup>-1</sup> )	Δ vs Baseline (Gt yr <sup>-1</sup> )	N <sub>2</sub> O (Gt yr <sup>-1</sup> )	Δ vs Baseline (Gt yr <sup>-1</sup> )
Baseline	64.50	—	0.18	—	0.00	—
F_low	45.74	-18.74	0.14	-0.04	0.00	0.00
F_medium	44.52	-19.98	0.14	-0.04	0.00	0.00
F_high	46.61	-17.89	0.15	-0.03	0.00	0.00

### 3.6.3.6 Global GHG emissions

#### Key insights from Table 43 and Figure 38

- Rooftop-first delivers the largest emissions cut, while over-restrictive siting can backfire:** Prioritising rooftop solar (F\_low) cuts 2060 global GHGs by ~18.7 Gt CO<sub>2</sub>-eq. Adding ground-mounted PV (F\_medium) offers only marginal extra benefit. However, full land-class protection (F\_high) reverses some gains (-2 Gt vs F\_medium), as overly strict siting slows clean-energy deployment and keeps fossil generation online.
- Mitigation hinges on scale, not just siting:** Siting rules matter most when paired with ambitious solar build-out. Forest safeguards (e.g. 50% protection) offer strong biodiversity value at low climate cost, but excluding cropland/grassland risks higher emissions unless total PV capacity also grows. Ultimately, emissions cuts depend more on replacing fossil fuels than on panel location.

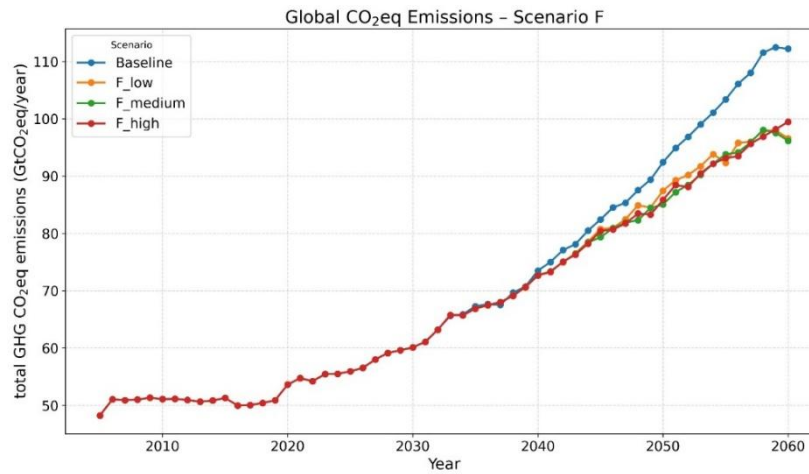


Figure 38: Impact on global GHG CO<sub>2</sub>eq emissions based on simulations of policy scenarios under storyline F.

Table 43: Summary table of the global GHG Emissions in 2060 for storyline F.

Scenario	Total GHG emissions (Gt CO <sub>2</sub> -eq yr <sup>-1</sup> )	Absolute change vs Baseline (Gt)	Relative change vs Baseline
Baseline	112.22	—	—
F_low	96.56	-15.66	-13.9 %
F_medium	96.17	-16.05	-14.3 %
F_high	99.48	-12.74	-11.4 %

### 3.6.3.7 EU27 GHG emissions

#### Key insights from Table 44 and Figure 39

- Prioritizing rooftop solar (Rooftop-first) delivers only modest emissions reductions**, with stricter siting rules offering diminishing returns: directing new PV to rooftops while preserving half of EU forests (F\_low) reduces 2060 emissions by ~0.10 Gt CO<sub>2</sub>-eq (-1.5%). Adding open-space PV with full farmland protection (F\_medium) provides little additional benefit, and overly restrictive siting (F\_high) slightly delays clean-energy rollout. However, these differences have a negligible impact on global temperature outcomes.
- Accelerating capacity is more impactful than adjusting location**: All scenarios shift emissions by <0.2 Gt on a 6-Gt baseline—showing that PV scale, not siting, drives decarbonisation. Rooftop-first policies with moderate safeguards are climate- and biodiversity-positive, but broader exclusion zones need to be paired with faster PV expansion and fossil fuel phase-out to remain effective.

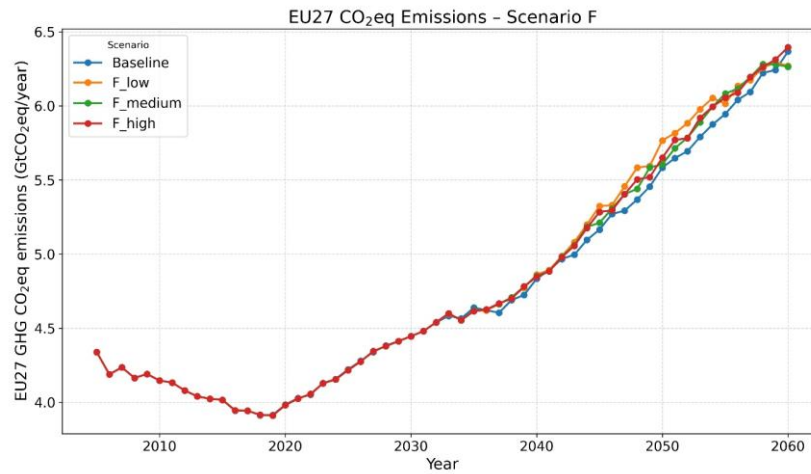


Figure 39: Impact on EU27 GHG CO<sub>2</sub>eq emissions based on simulations of policy scenarios under storyline F.

Table 44: Summary table of the U27 GHG Emissions in 2060 for storyline F.

Scenario	Total GHG emissions (Gt CO <sub>2</sub> -eq yr <sup>-1</sup> )	Absolute change vs Baseline (Gt)	Relative change vs Baseline
Baseline	6.366	—	—
F_low	6.271	-0.096	-1.5 %
F_medium	6.263	-0.103	-1.6 %
F_high	6.396	+0.029	+0.5 %

### 3.6.4 Policy recommendations

**Recommendation 16: Make rooftop solar the default to reduce land conflict.** Prioritizing solar panels on buildings can raise renewable electricity shares by 4–5 percentage points without using new land. The EU should expand its Solar Rooftop Initiative—mandating rooftop PV on new buildings and supporting adoption through grants and fast-track permitting. A rooftop-first strategy could cut power-sector CO<sub>2</sub> by 1–2%, while avoiding land-use pressures from ground-mounted solar.

**Recommendation 17: Safeguard agricultural land and sensitive ecosystems from solar sprawl.** Utility-scale solar should be directed to low-impact sites, avoiding prime cropland, permanent grasslands, and intact habitats. Strict siting rules can prevent the loss of food-producing land and biodiversity with minimal impact on renewable energy output. Model scenarios show that protecting croplands and pastures cuts land loss by ~40% compared to unconstrained deployment, while keeping PV out of forests helps preserve carbon stocks and habitats. The EU and member states should embed these safeguards in permitting processes—for example, by requiring environmental assessments and prohibiting ground-mounted solar in Natura 2000 areas and high-grade farmland. These measures ensure solar expansion supports, rather than compromises, food security and conservation.

**Recommendation 18: Pair land-conscious solar siting with an accelerated fossil fuel phase-out and renewable scale-up.** Protecting forests and croplands is important, but it must not slow the clean energy transition. The analysis shows that relocating where solar panels go—such as prioritizing rooftops—yields only modest emissions cuts (~14% at best), because the climate benefit depends far more on how much fossil generation is displaced than on siting. Stricter exclusion zones should be matched with higher solar and wind deployment targets to avoid bottlenecks. Crucially, siting policies must support—not distract from—core decarbonization measures like carbon pricing, fossil subsidy removal, and coal phase-out deadlines. A sustainable solar strategy means doing both: protecting key landscapes while decisively eliminating fossil fuels.

### 3.7 Integrating Marine & Terrestrial Renewables with Sustainable Land Management

#### 3.7.1 Definition of the storyline

‘Integrating Marine and Terrestrial Renewables with Eco-Friendly Land Management’ takes a forward-thinking, integrative approach to tackling climate change and enhancing energy security. By combining various renewable energy sources with sustainable afforestation and grassland management practices, this approach aims to reduce environmental impact and stimulate economic development and rural revitalisation. Successful implementation will require strong cross-sector collaboration, innovative financial solutions, technological progress and active community engagement, ultimately paving the way for a sustainable, resilient future.

This storyline is highly relevant for several reasons, as it addresses multiple interconnected challenges facing modern society, ranging from climate change to energy security and rural economic development.

The integration of offshore and onshore wind, solar photovoltaics and hydroelectric power in the storyline supports the EU Renewable Energy Directive and the European Green Deal by promoting a diversified energy mix that strengthens grid stability, reduces dependency on fossil fuels and increases energy security. This transition is essential for meeting the EU’s 2050 carbon neutrality target, as it substantially reduces greenhouse gas emissions while reinforcing the resilience of the energy system.

Land-based solutions such as afforestation, sustainable grassland management and the protection of key productive and natural rural areas complement the energy transition by enhancing carbon sequestration and contributing to the biodiversity goals set out in the EU’s 2030 Biodiversity Strategy. These practices also ensure that the expansion of renewable energy does not undermine natural ecosystems, thereby aligning with the Common Agricultural Policy and EU environmental conservation objectives.

From an economic perspective, this approach has the potential to promote rural revitalisation and job creation in sectors such as green energy, sustainable agriculture, and land management. It supports the European Green Deal’s vision of a fair transition by promoting innovation and investment through instruments such as green bonds and carbon credits, in line with the EU Recovery Plan. Finally, its cross-sectoral approach reflects core EU governance principles by promoting coordinated strategies across

the energy, agriculture, and environmental sectors. With built-in flexibility and responsiveness to innovation, this approach aligns with EU adaptive management practices, strengthening Europe's capacity to lead a sustainable, climate-resilient transformation.

### 3.7.2 Scenarios

In the analysis, three illustrative scenarios are examined, each representing increasing levels of policy ambition across several land-use-related domains and RES deployment. The policies included are the following: solar PV on land, land protection from solar, onshore wind energy, offshore wind energy and ocean RES, hydropower (dammed and run-of-river), afforestation, and regenerative grassland management. The scenarios capture varying degrees of land-use competition and ecosystem protection arising from renewable energy expansion and land-based climate mitigation. In the *Low* scenario, competition between land use and solar PV is minimal: 50% of forest areas are protected from ground-mounted solar infrastructure, and solar capacity expansion proceeds according to current trends (historically observed expansion trajectories), as well as both dammed and run-of-river hydropower. Onshore and offshore wind energy and ocean RES are deployed at maximum expansion capacities. The model was developed under the assumption that onshore wind deployment does not contribute to land-use competition. Regenerative grassland grazing is implemented on 20% of global grasslands, and afforestation efforts are limited to 20% of globally suitable land.

The *Medium* scenario reflects a moderate level of policy ambition. Ground-mounted solar PV reaches maximum capacity expansion, while grasslands and croplands are fully protected from solar development and forest protection remains at 50%. Wind, hydropower and ocean RES capacity expansions are increased to maximum expansion capacities. Regenerative grazing and afforestation efforts are scaled to 60% of suitable grassland and land areas, respectively, reflecting strengthened land-based climate strategies.

The *High* scenario represents the most ambitious policy configuration, marked by intensified competition for land. Ground-mounted solar PV is expanded to maximum capacity, and all forest, grassland, and cropland areas are fully protected from solar infrastructure. Onshore and offshore wind energy, along with ocean RES and both types of hydropower, are developed at maximum plausible capacity expansion rates. Simultaneously, regenerative grassland management and afforestation are extended to all suitable areas, maximizing carbon sequestration and ecosystem restoration potential.

Table 45: Specifications of the parameters of the seven policies simulated in the 3 scenarios proposed (low, medium, medium, high) for storyline G: Integrating marine and Terrestrial Renewables with sustainable land management.

Storyline G	Policies	Scenarios of implementation intensity		
		G_Low	G_Medium	G_High
Integrating marine and Terrestrial Renewables with sustainable land management	Sustainable management of solar installations	Protection of 50% of forests from conversion to Solar energy infrastructure	Protection of 50% of forests, 100% of grasslands and cropland from conversion to Solar energy infrastructure	Protection of 100% of forests, grasslands and cropland from conversion to Solar energy infrastructure
	Afforestation	Afforestation on 20% of suitable land	Afforestation on 60% of suitable land	Afforestation on 100% of suitable land
	Grassland management	20% of global grasslands under regenerative grazing	60% of global grasslands under regenerative grazing	100% of global grasslands under regenerative grazing
	Offshore wind and ocean RES	Maximum capacity expansion of Offshore wind and ocean RES	Maximum capacity expansion of Offshore wind and ocean RES	Maximum capacity expansion of Offshore wind and ocean RES
	Onshore wind RES	Maximum capacity expansion of Onshore wind	Maximum capacity expansion of Onshore wind	Maximum capacity expansion of Onshore wind
	Increase in PV energy production	Continuation of current trends	Maximum capacity expansion of solar ground-mounted arrays	Maximum capacity expansion of solar ground-mounted arrays
	Hydroelectric power plants (dammed and run- of-river)	Continuation of current trends	Maximum capacity expansion of Hydroelectric power plants	Maximum capacity expansion of Hydroelectric power plants

### 3.7.3 Results of simulation

This section presents the results of the simulation of scenarios from Table 45, assessing their combined impacts compared to the baseline on the key output variables as identified in Table 1: Global temperature change, Global and EU land use change, Global share of RES in PE, Global energy emissions and Global and EU GHG emissions.

### 3.7.3.1 Global temperature change

Key insights from Table 46 and Figure 40

- **Low-conflict renewables deliver major climate benefits without large land-use trade-offs.** Prioritizing offshore wind, dual-use onshore winds, and other RES that do not compete for land, cuts projected 2060 warming by  $\sim 0.16$  °C—achieved with minimal impact on land systems.
- **Maximizing all renewable and nature-based levers nearly triples mitigation.** Combining accelerated renewables with full afforestation and regenerative land use can reduce warming by up to 0.45 °C. Land-sector measures amplify, rather than substitute, fossil fuel displacement.
- **Early deployment and balanced siting are essential.** Rapid action before 2040—especially in wind and afforestation—is critical to stay on the 1.5 °C pathway. Moderate siting rules can enable near-maximal cooling without jeopardizing project delivery.

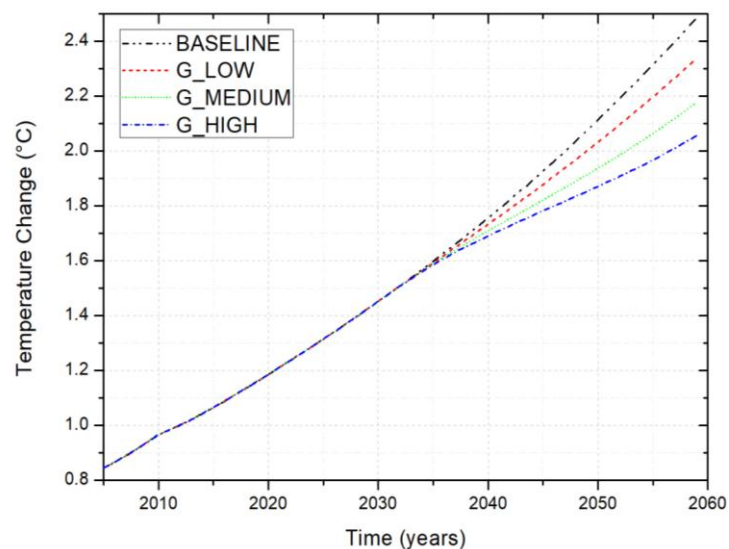


Figure 40: Impact on global temperature change based on simulations of policy scenarios under storyline G.

Table 46: Summary table of the global temperature change in 2060 for storyline G.

Scenario (2060)	Global $\Delta T$ 2060 (°C)	$\Delta$ vs Baseline (°C)
Baseline	2.531	—
G_low	2.375	-0.156
G_medium	2.209	-0.322
G_high	2.083	-0.449

### 3.7.3.2 Global land use change

Key insights from Table 47 and Figure 41

- **Afforestation and improved land stewardship drive major land-use gains.** Full deployment increases global forest cover by  $\sim 20$  M km<sup>2</sup> (+42 %), supported by afforestation, protection of existing

forests, and regenerative grazing that repurposes ~9 M km<sup>2</sup> of pasture without reducing livestock output.

- **Integrated strategies enable large-scale forest expansion with minimal food trade-offs.** Cropland loss remains modest (-9 %). Smart solar siting shifts PV to areas unused for other purposes (such as grasslands, croplands, forests), maintaining RES growth while preserving natural and agricultural lands. Integrated land–energy packages (G\_medium/G\_high) vastly outperform single levers, highlighting the synergy between decarbonization and land conservation.

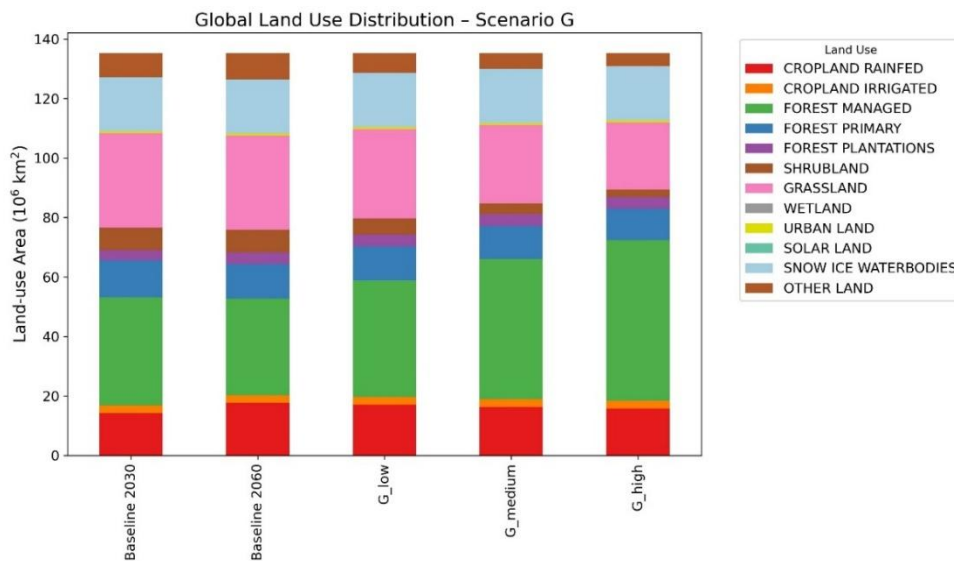


Figure 41: Impact on global land-use change under the policy simulation scenarios of storyline G by 2060, compared to the baseline year 2030 (T0) and the baseline scenario (business-as-usual).

Table 47: Global land-use change by 2060 under storyline G scenarios compared to baseline.

Land-use category	Baseline 2060 (M km <sup>2</sup> )	G_low 2060 (M km <sup>2</sup> )	Δ vs baseline	G_medium 2060 (M km <sup>2</sup> )	Δ vs baseline	G_high 2060 (M km <sup>2</sup> )	Δ vs baseline
Cropland	20.17	19.66	-0.51	18.94	-1.23	18.35	-1.82
Forest	48.14	54.59	+6.46	62.16	+14.02	68.56	+20.43
Grassland	31.59	30.05	-1.54	26.26	-5.33	22.54	-9.05
Other land + shrubland	16.42	11.99	-4.43	8.91	-7.51	6.82	-9.60

### 3.7.3.3 EU27 land use change

Key insights from Table 48 and Figure 42

- **Afforestation and integrated land use strategies drive substantial forest gains with minimal food trade-offs.** Moving from G\_low to G\_high increases forest area by ~1 M km<sup>2</sup> (+50 %), largely by

converting grasslands and low-value “other” land. Cropland is mostly preserved, even rising in G\_medium, with only a modest decline (–5 %) in G\_high under the most ambitious RES mix.

- **Smart solar siting supports renewables without displacing key land uses.** Excluding cropland and grassland from PV siting shifts solar to degraded or non-productive areas, reducing pressure on productive land. Integrated land-energy packages deliver non-linear gains—tripling forest expansion with limited cropland impact from G\_low to G\_medium—highlighting the synergy between afforestation, grassland restoration, and low-conflict renewable deployment.

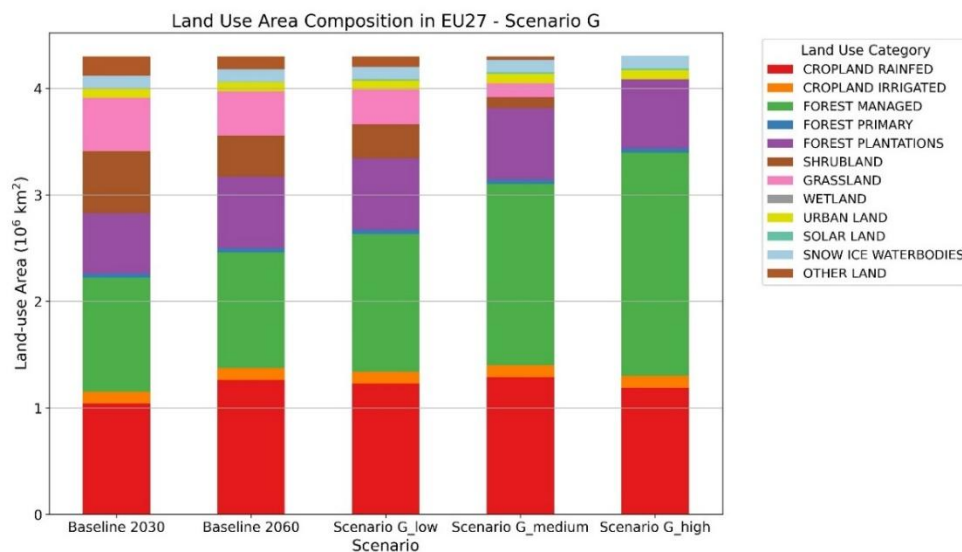


Figure 42: Impact on EU27 land-use change under the policy simulation scenarios of storyline G by 2060, compared to the baseline year 2030 (T0) and the baseline scenario (business-as-usual).

Table 48: Global land-use change by 2060 under storyline G scenarios compared to baseline.

Land-use category	Baseline 2060 (M km <sup>2</sup> )	G_low 2060 (M km <sup>2</sup> )	Δ vs baseline	G_medium 2060 (M km <sup>2</sup> )	Δ vs baseline	G_high 2060 (M km <sup>2</sup> )	Δ vs baseline
Cropland	1.37	1.34	–0.03	1.40	+0.03	1.30	–0.07
Forest	1.80	2.00	+0.20	2.41	+0.61	2.78	+0.98
Grassland	0.41	0.32	–0.09	0.13	–0.28	0.00	–0.41
Other land + shrubland	0.51	0.42	–0.09	0.13	–0.38	0.00	–0.51

### 3.7.3.4 Global share RES in PE

#### Key insights from Table 49 and Figure 43

- **Low-conflict renewables can nearly double global RES share without major land trade-offs.** Offshore wind and compatible onshore wind policies boost renewable energy from ~12 % to over 22 % by 2060—achieving substantial progress with minimal pressure on productive land.

- **Full rollout with land protection still pushes RES almost to 25 %.** Even under strict siting rules (G\_high), shielding forests, croplands, and grasslands, the renewable share reaches ~25 %, thanks to expanded offshore and ocean-based sources. This demonstrates that smart technology mixes can meet energy goals while protecting nature.
- **Early action and integration are key.** All scenarios stay close to baseline until ~2040; only timely policy enables the 2040s build-out needed to realize the full 10–12 pp gain. Maximum impact comes when renewable deployment is paired with nature-based land management, proving that synergy—not trade-off—is the path to climate and biodiversity success.

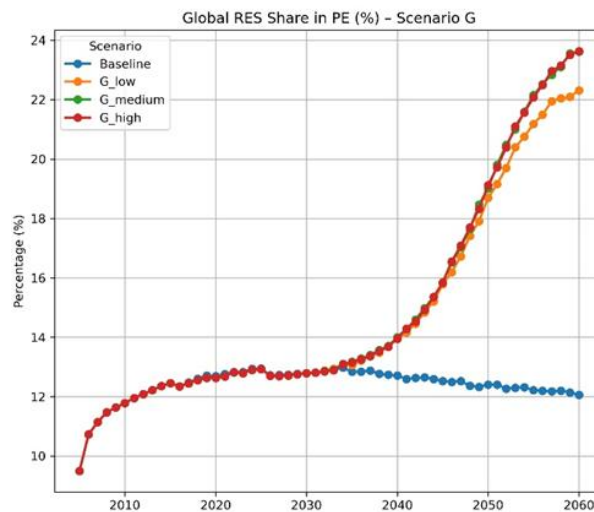


Figure 43: Impact on global RES in PE (%) based on simulations of policy scenarios under storyline G.

Table 49: Summary table of the global RES in PE (%) in 2060 for storyline G.

Scenario	RES share in PE 2060 (%)	Δ vs Baseline 2030 (pp)
Baseline 2030	12.79	—
Baseline 2060	12.06	– 0.73
G_low	22.31	+ 8.95
G_medium	23.62	+ 10.40
G_high	23.64	+ 10.10

### 3.7.3.5 Global energy emissions

#### Key insights from Table 50 and Figure 44

- **Rapid RES deployment drives deep CO<sub>2</sub> cuts, while land measures reduce potent non-CO<sub>2</sub> gases.** Across all ambition levels, energy-sector emissions fall ~29–30 % (~19 Gt by 2060), mainly by displacing fossil fuels with wind, PV, and hydro. Simultaneously, land stewardship actions cut methane and N<sub>2</sub>O by ~20 %, adding ~1 Gt CO<sub>2</sub>-eq in mitigation—highlighting the value of combining energy and land-sector strategies.

- **Most gains are achieved at medium ambition, but integration still matters.** G\_medium captures nearly the full mitigation benefit, with only marginal improvements from G\_high. Yet integrated packages (RES build-out + afforestation + grazing reform) outperform any single action, confirming that well-coordinated land-energy planning is essential to meet Paris-aligned climate targets without biodiversity trade-offs.

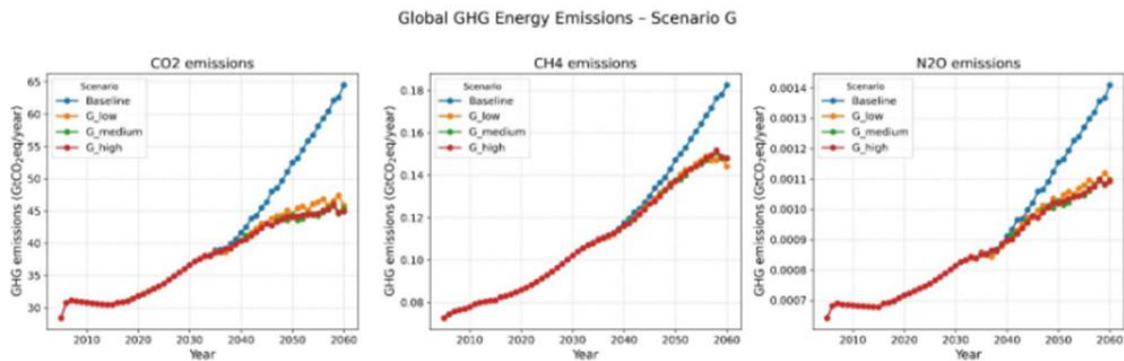


Figure 44: Impact on global GHG energy emissions (CO<sub>2</sub>, CH<sub>4</sub>, NO<sub>2</sub>) based on simulations of policy scenarios under storyline G.

Table 50: Summary table of the global GHG energy emissions in 2060 for storyline G.

Scenario (2060)	CO <sub>2</sub> (Gt yr <sup>-1</sup> )	Δ vs Baseline (Gt yr <sup>-1</sup> )	CH <sub>4</sub> (Gt yr <sup>-1</sup> )	Δ vs Baseline (Gt yr <sup>-1</sup> )	N <sub>2</sub> O (Gt yr <sup>-1</sup> )	Δ vs Baseline (Gt yr <sup>-1</sup> )
Baseline 2060	64.506	—	0.1826	—	0.00141	—
G_low	45.871	-18.635	0.1442	-0.03840	0.001098	-0.00031
G_medium	45.358	-19.148	0.1482	-0.03436	0.001097	-0.00031
G_high	44.925	-19.581	0.1479	-0.03466	0.001092	-0.00032

### 3.7.3.6 Global GHG emissions

#### Key Insights Table 51 and Figure 45

- **Clean-energy deployment is the dominant emissions lever—amplified by land-based solutions.** Even low-conflict renewables (G\_low) cut 2060 emissions by ~24 Gt (-21 %), while layering in afforestation and regenerative grazing (G\_medium) boosts this to ~38 Gt (-34 %). The land sector adds value, but only when energy ambition is already strong.
- **Full integration of land and energy measures unlocks nearly half of the global mitigation potential.** The G\_high package—with strict solar siting, 100 % afforestation, and full grazing reform—reaches ~52 Gt avoided emissions (-46 %), placing global trajectories below 1990 levels. Coordinated land-energy planning is essential to deliver Paris-aligned outcomes without undermining biodiversity or food systems.

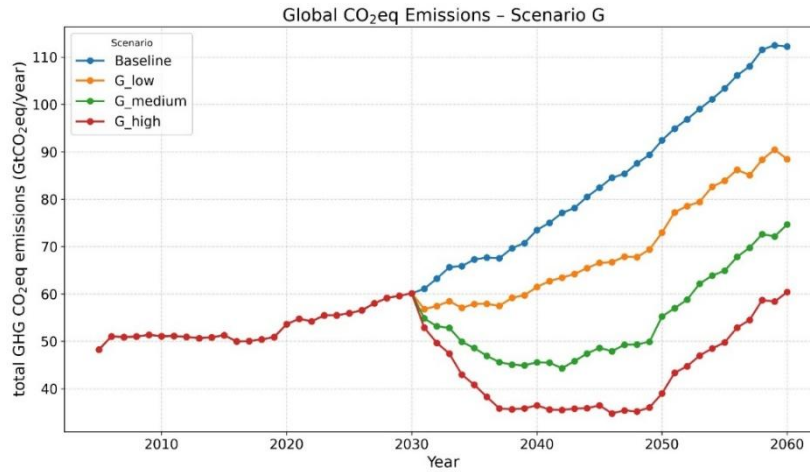


Figure 45: Impact on global GHG CO<sub>2</sub>eq emissions based on simulations of policy scenarios under storyline G.

Table 51: Summary table of the global GHG Emissions in 2060 for storyline G.

Scenario	Total GHG emissions (Gt CO <sub>2</sub> -eq yr <sup>-1</sup> )	Absolute change vs Baseline (Gt)	Relative change vs Baseline
Baseline	112.22	—	—
G_low	88.44	-23.78	-21.2 %
G_medium	74.66	-37.56	-33.5 %
G_high	60.39	-51.83	-46.2 %

### 3.7.3.7 EU27 GHG emissions

#### Key insights Table 52 and Figure 46

**Scaling low-conflict renewables delivers major cuts—amplified by full RES deployment and nature-based solutions.** Offshore/ocean wind already reduce EU energy emissions by ~8 % (–0.53 Gt), while adding ground-mounted PV, hydro, and full wind capacity (G\_medium) more than doubles the benefit to –1.30 Gt (–20 %). Land measures like afforestation and grassland restoration (G\_high) lift the reduction to ~2 Gt (–31 %), with one-third of the gain from new carbon sinks.

**Integrated land-energy planning enables deep decarbonisation without harming food systems or biodiversity.** Even under strict siting rules that exclude cropland and grassland, renewable growth is preserved by shifting PV to unproductive or degraded land. The G\_high package demonstrates that coordinated and simultaneous action is essential to achieve substantial GHG emission reductions while maintaining food production and biodiversity goals. However, despite effective mitigation in some sectors, climate targets remain out of reach in this scenario, with temperature change still reaching 2°C.

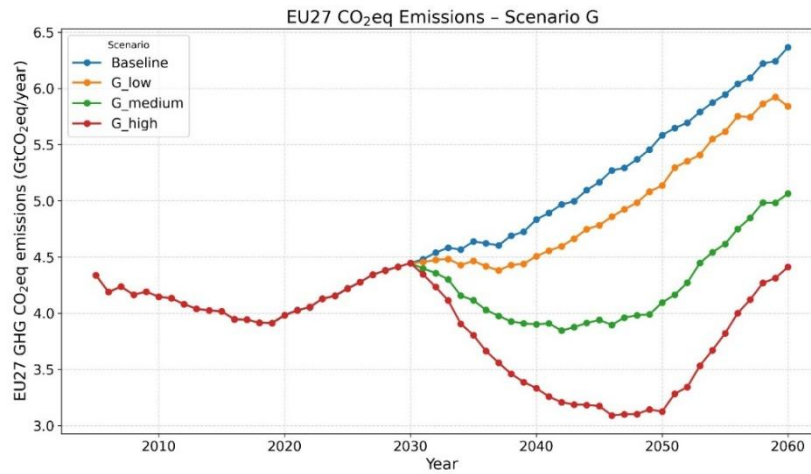


Figure 46: Impact on EU27 GHG CO<sub>2</sub>eq emissions based on simulations of policy scenarios under storyline G.

Table 52: Summary table of the U27 GHG Emissions in 2060 for storyline G.

Scenario	Total GHG emissions (Gt CO <sub>2</sub> -eq yr <sup>-1</sup> )	Absolute change vs Baseline (Gt)	Relative change vs Baseline
Baseline	6.366	—	—
G_low	5.840	-0.527	-8.3 %
G_medium	5.064	-1.302	-20.5 %
G_high	4.411	-1.956	-30.7 %

### 3.7.4 Policy recommendations

**Recommendation 19. Pursue an “all-of-the-above” renewable energy strategy with emphasis on offshore resources.** The integrated scenario shows that rapid clean energy deployment is the primary driver of deep emissions cuts: even a partial package focusing on low-conflict renewables slashed global GHG emissions by over 20% (≈24 Gt) by 2060. To replicate this, the EU should massively scale up offshore wind farms, which tap abundant wind at sea without using land, along with onshore wind and solar in low-impact areas (e.g. brownfields). Implementing the EU Offshore Renewable Energy Strategy to reach on the order of 300 Gigawatt (GW) of offshore wind by mid-century would align with the model’s ambition. At the same time, technologies like rooftop solar, floating solar, and wind in sparsely populated areas should be expanded to displace as much fossil generation as possible. This broad renewable push – prioritizing marine and other low-conflict sources – can achieve most of the needed emissions reduction while minimizing pressure on terrestrial ecosystems.

**Recommendation 20: Pair ambitious renewable deployment with bold land restoration and protection.** Climate mitigation and ecological restoration must advance in tandem. A medium-integrated scenario—combining strong clean-energy expansion with 60 % implementation of nature-based measures—already doubles land-sector emission cuts compared to a renewable-only approach. Building on this synergy, the EU and Member States should implement large-scale afforestation, peatland restoration,

and regenerative grazing, aligned with the EU Biodiversity and Forest Strategies. These actions enhance carbon sinks without compromising food security and can deliver up to ~0.3 °C of additional avoided warming by 2060 in high-ambition pathways. However, once land protection reaches its limits—e.g., full exclusion of forests, biodiverse grasslands, and prime farmland—further climate gains depend on scaling renewables fast enough to keep emissions falling. Therefore, policies like the EU Nature Restoration Law must be fully implemented alongside Fit for 55<sup>4</sup>, and strengthened by commitments such as 100 % renewable electricity or net-zero energy by 2040. Coordinated action across land and energy will ensure that nature-based solutions and clean power mutually reinforce, rather than constrain, deep decarbonisation.

**Recommendation 21: Adopt an integrated cross-sector strategy that aligns climate, biodiversity, and food security goals.**

The modeling shows that coordinating ambition across energy, land, and agriculture delivers far greater benefits than pursuing each in isolation. Moving from low to moderate integration nearly doubled forest gains and deepened emission cuts, while pushing to the highest ambition brought diminishing returns unless clean-energy deployment was scaled accordingly. Policymakers should target this “sweet spot” by advancing substantial—though not absolute—land protections in parallel with a massive renewables build-out. This requires cross-sector planning: energy, agriculture, and environment ministries must co-develop national climate strategies to ensure aligned and mutually reinforcing targets. For instance, safeguarding all high-value ecosystems and farmland should be matched with a ramp-up in offshore wind or rooftop PV. Tools like the WILIAM model can help optimize this balance. More broadly, Europe should embrace a unified policy framework—linking the Climate Law, Biodiversity Strategy, and Common Agricultural Policy—to reward actions that advance multiple objectives. A fully integrated approach not only avoids land-energy trade-offs, but also secures food supply, restores ecosystems, and accelerates the energy transition. With this holistic model, the EU27 can lead the way toward a globally sustainable future.

## 4 Conclusions

The document presents the comprehensive outcomes of the simulations at both European Union (EU) and global scales using the **Within Limits Integrated Assessment Model (WILIAM)** of selected **Land-based Adaptation and Mitigation Solutions (LAMS)** from the RethinkAction catalogue. The simulations carried out with the WILIAM model have yielded critical insights into the impacts of various policies on key indicators such as global temperature change, greenhouse gas (GHG) emissions, and land use change. The results consistently demonstrate that the combined implementation of various policy measures generates synergistic benefits that surpass those achievable through isolated interventions, as already pointed out recently [Stechemesser2024]. For instance, integrating forest protection, forest biomass management, regenerative grazing, and dietary changes can lead to a significant reduction in GHG

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<sup>4</sup> <https://www.consilium.europa.eu/en/policies/fit-for-55/>

emissions and provide co-benefits for biodiversity and health. Transitioning to more sustainable diets, such as flexitarian or plant-based models, in addition to behavioural change, is crucial for climate mitigation and land sparing. Even moderate dietary changes can reduce global temperature increase. The combination of full regenerative agriculture with a significant dietary shift, can nearly halve meat demand at both EU and global scales, freeing up substantial cropland and grassland for other uses and biodiversity protection. Expanding forest areas and implementing grassland management practices on a large scale are fundamental for climate change mitigation. Full afforestation can contribute to a one-third reduction in net GHG emissions in the EU and globally by 2060 compared to the baseline. Accelerating the deployment of renewable energy sources (RES), particularly solar photovoltaics (PV) and wind energy (onshore and offshore), is a primary factor for decarbonizing the energy sector and reducing GHG emissions. Strategies that prioritize rooftop solar can substantially increase the share of RES in global primary energy and reduce CO<sub>2</sub> emissions from the energy sector. Managing and limiting biomass use is critically important to avoid excessive forest exploitation and overreliance on biomass for all final energy uses, which could lead to a drastic reduction in the global EROI and jeopardize the availability of high levels of net energy. While urban policies have a smaller direct impact on global temperature, managing urban sprawl is vital for limiting the consumption of forests and land. Many proposed measures not only mitigate climate change but also generate significant co-benefits for biodiversity, public health, food security, and socio-economic development. International cooperation is essential to extend these benefits beyond EU borders.

Finally, it is crucial to emphasize the importance of fostering continuous collaboration, further refining simulation methodologies. These elements are indispensable for supporting policymakers in designing robust strategies that can drive sustainable and resilient socio-ecological transitions. The integrated approach outlined in this report, which aligns the EU Climate Law, Biodiversity Strategy, and Common Agricultural Policy, is fundamental for achieving climate neutrality goals, protecting biodiversity, and ensuring food security.

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## 5 Annex I: Summary table of policy recommendations

In Table 53, all the policy recommendations defined at EU level and their detailed descriptions are reported.

Table 53: Summary table of policy recommendations and their description.

Nº	Recommendation	Description
1	Encourage a shift toward flexitarian and/or plant-based diets together with promoting regenerative agriculture	The results from model simulations indicate that shifting consumer behaviour and fostering regenerative agriculture could deliver substantial emission reductions, agricultural land use reduction and temperature reduction. Progress could be fostered by (i) making “sustainable and healthy” (flexitarian and/or plant-based) menus the default option in schools, hospitals and other publicly funded kitchens, (ii) rolling out an easy-to-read environmental label for food products, and (iii) running coordinated communication campaigns that present plant-based meals as tasty, modern and good for health.
2	Relocate land to more efficient land uses	In the high application scenario of regenerative agriculture and shift in diets, the EU could save up to 80 million hectares of grassland and cropland. This freed-up land could be relocated to forests and other carbon-rich ecosystems, increasing the carbon sink and fostering also a voluntary carbon market building on Regulation EU 2024/3012 on the Carbon Removals Certification Framework (CRCF) which could provide tradable credits for verified carbon sequestration and increase biodiversity as co-benefit.
3	Promote partnerships that spread regenerative standards beyond Europe	Approximately half of the global benefits from the high scenario application of regenerative agriculture with shift in diets occurs outside the EU, underscoring the importance of global cooperation. International cooperation could improve environmental performance worldwide.
4	Promote regenerative grazing systems to reduce greenhouse gas emissions from the agricultural sector	Supply-side measures like improved grazing management can deliver important benefits in terms of greenhouse gas emissions reduction. Further, protecting and restoring permanent grasslands can preserve soil carbon and biodiversity. The Common Agricultural Policy (CAP) eco-schemes and the voluntary carbon market linked to the EU Carbon Removal and Carbon Farming Regulation should be leveraged to reward regenerative grazing and sustainable feed production systems, ensuring that intensive feed monocultures are minimized.
5	Accelerate the shift toward sustainable diets to cut feed demand	Synergistic effects can be obtained by combining supply and demand measures. Policymakers should expand campaigns and incentives (e.g. public procurement of plant-based meals, improved food labeling, education programs) to encourage lower meat consumption. This demand-side shift would maximize the mitigation benefits obtained by a conversion to regenerative grazing systems, while freeing up extensive cropland and pasture for other uses. A shift toward more plant-based diets also aligns with health guidelines, creating win-win outcomes for climate and public health.

Nº	Recommendation	Description
6	Align dietary shifts with land-use strategy to restore ecosystems and meet climate targets	A scenario where 50% of global population shifts to plant-based diets could spare up to ~80 million hectares of EU grassland and cropland by 2060. Governments should anticipate this by developing plans to restore a portion of retired pasture and feed-crop land into carbon-rich ecosystems or alternative crops. For example, reforestation or rewilding areas formerly used for intensive feed can sequester carbon and boost biodiversity. The EU Nature Restoration Law and LULUCF targets should incorporate these opportunities, backed by voluntary carbon credit markets to reward farmers for turning excess farmland into forests or wetlands.
7	Support farmers through the transition	A decline in livestock product demand will impact farmers who rely on feed and meat markets. To ensure a just transition, the EU and Member States could extend the Just Transition support envisioned by the European Green Deal to rural areas. This would include advisory services and training to help livestock and feed-crop farmers shift to new income streams – for instance, growing plant proteins (pulses, legumes) for human consumption, agroforestry, or eco-tourism. Diversifying farm production with guidance and low-interest loans will reduce socioeconomic disruptions as feed production scales down, while also improving EU protein self-sufficiency.
8	Scale up afforestation and grassland restoration efforts as a core climate strategy	Large-scale ecosystem restoration is indispensable for transformative climate change mitigation: in the ambitious scenario over half of the GHG reduction came from afforestation and regeneration of grasslands. EU and national policies should significantly expand tree-planting programs (e.g. contribute to the “3 billion trees by 2030” pledge) and incentivize restoring degraded grasslands. Full afforestation (+55% of the forest area) contributes to a net GHG emissions reduction in the EU and globally by one third compared to the baseline, by 2060. To maximize returns, restoration initiatives must be well-funded and coupled with sustainable forest management so that new forests persist as long-term carbon sinks.
9	Implement integrated land-energy planning to avoid trade-offs	Policies that jointly consider renewable energy expansion and protection and restoration of ecosystems can prevent trade-offs in terms of land-use change. For instance, national energy and climate plans (NECPs) and spatial plans should be coordinated to ensure that when land is set aside for nature (afforestation zones, protected habitats), energy strategies compensate by using other resources (offshore wind, urban solar, efficiency improvements). An integrated approach will minimize the risk of an “emissions rebound” at intermediate ambition and instead allow land-focused policies to fully contribute to climate goals.
10	Leverage synergies between renewables and ecosystem restoration for co-benefits	When designed together, land and energy measures can reinforce each other: strict solar siting rules free up land for reforestation without significantly hurting clean energy output, and healthy forests and grasslands can in turn support the renewable transition (for example, by providing sustainable biomass or improving grid resilience against heatwaves and floods). The EU should promote projects that combine these aims – for instance, solar farms on low-quality land coupled with adjacent habitat restoration, or wind parks that fund local reforestation. By deploying renewables in a nature-sensitive way, the EU can achieve climate neutrality while also enhancing food security and biodiversity. The high-ambition model pathway demonstrated this complementarity, aligning EU climate, biodiversity, and food-system objectives without large cropland loss

Nº	Recommendation	Description
11	Encourage efficient use of land to manage urban sprawl	The competition between land use and urban expansion policies is generally thought to be crucial to preventing urban expansion from consuming forests or fertile land. However, even at high levels of urban sprawl, the scenarios indicate that it is possible to keep cropland loss to only ~5% by 2060, despite high population and economic growth. Member States should establish urban growth boundaries or incentivize the redevelopment of brownfield sites, ensuring that new housing and infrastructure are accommodated within existing urban footprints. EU cohesion and recovery funds can support cities in upgrading infrastructure and increasing housing density (e.g. through public transport projects and vertical development), enabling them to absorb growth without outward sprawl. By intensifying land use in urban areas, Europe can protect rural land and help preserve productive soils and natural areas.
12	Combine ambitious afforestation with strong land protections to maximize land-sector mitigation	Large-scale tree planting is the single largest contributor to land-based emissions cuts—accounting for around half of total mitigation in the high scenario—while preserving existing natural land is essential to avoid backsliding. Policymakers should adopt a dual strategy: set bold afforestation and reforestation targets aligned with the EU Forest Strategy, while simultaneously strengthening land-use policies that curb urban encroachment on high-carbon and high-biodiversity landscapes. This includes restoring degraded areas, incentivizing forest expansion on marginal farmland or pasture, and using zoning laws and conservation easements to protect peri-urban forests and agricultural belts. The model’s most ambitious tree-cover expansion increased global forest area by +13% without major cropland losses and delivered deep carbon reductions. Such a "maximalist" approach could cut EU land-use emissions by 20–30% by 2050. Co-benefits include enhanced biodiversity, soil health, and natural flood defenses, reinforcing the need for integrated instruments like the EU Nature Restoration Law and national conservation frameworks.
13	Integrate urban growth with forest conservation through spatial planning and targeted investment	To unlock the full mitigation and biodiversity benefits of afforestation, cities and surrounding regions must be planned in tandem. Urban expansion should be matched by parallel commitments to conserve or restore green spaces—through national rules requiring reforestation offsets for land take, or municipal urban greening plans aligned with housing development. At the same time, the EU and Member States should provide financial and technical support to make this integration feasible. Instruments like the Just Transition Fund and Regional Development Fund can help cities invest in brownfield regeneration, green transport, and livable density, while CAP rural development programs and carbon credit schemes can reward landowners who establish peri-urban forests or green belts. This coordinated urban–rural approach ensures that afforestation and densification reinforce one another, allowing cities to grow sustainably while nearby landscapes deliver carbon, biodiversity, and social co-benefits. It represents a balanced strategy to align climate mitigation with broader sustainability goals.
14	Adopt holistic policy packages that integrate climate, energy, and land objectives to be pursued simultaneously to mutual benefit	Adopt holistic policy packages that integrate climate, energy, and land objectives to be pursued simultaneously to mutual benefit to maximize co-benefits and create a more robust path to climate neutrality. When forest protection, forest bioenergy, regenerative grazing, and dietary change are implemented together, the outcomes include a significantly ~20% cut in EU GHG emissions by mid-century – while supporting biodiversity and healthier diets.

Nº	Recommendation	Description
15	Design and implement policy packages that mirror synergies in forest sector, grazing practices, bioenergy from biomass and sustainable diets	Design and implement policy packages that promote synergies in forest sector, grazing practices, bioenergy from biomass and sustainable diets including for example sustainable forest management and reforestation programmes, thus increasing carbon sequestration and boosting biomass fuel supply, coupled with spread of guidelines and campaigns fostering a shift towards more sustainable and healthy diets, and support to farmers to encourage a shift to sustainable practices especially for grazing lands. Biomass use should be carefully managed to prevent its rapid exploitation in pursuit of higher net energy availability as final energy.
16	Make rooftop solar the default to reduce land conflict	Prioritizing solar panels on buildings can raise renewable electricity shares by 4–5 percentage points without using new land. The EU should expand its Solar Rooftop Initiative, mandating rooftop PV on new buildings and supporting adoption through grants and fast-track permitting. A rooftop-first strategy could cut power-sector CO <sub>2</sub> by 1–2%, while avoiding land-use pressures from ground-mounted solar.
17	Safeguard agricultural land and sensitive ecosystems from solar sprawl	Utility-scale solar should be directed to low-impact sites, avoiding prime cropland, permanent grasslands, and intact habitats. Strict siting rules can prevent the loss of food-producing land and biodiversity with minimal impact on renewable energy output. Model scenarios show that protecting croplands and pastures cuts land loss by ~40% compared to unconstrained deployment, while keeping PV out of forests helps preserve carbon stocks and habitats. The EU and member states should embed these safeguards in permitting processes, for example, by requiring environmental assessments and prohibiting ground-mounted solar in Natura 2000 areas and high-grade farmland. These measures ensure solar expansion supports, rather than compromises, food security and conservation.
18	Pair land-conscious solar siting with an accelerated fossil fuel phase-out and renewable scale-up	Protecting forests and croplands is important, but it must not slow the clean energy transition. The analysis shows that relocating where solar panels go—such as prioritizing rooftops—yields only modest emissions cuts (~14% at best), because the climate benefit depends far more on how much fossil generation is displaced than on siting. Stricter exclusion zones should be matched with higher solar and wind deployment targets to avoid bottlenecks. Crucially, siting policies must support—not distract from—core decarbonization measures like carbon pricing, fossil subsidy removal, and coal phase-out deadlines. A sustainable solar strategy means doing both: protecting key landscapes while decisively eliminating fossil fuels.
19	Pursue an “all-of-the-above” renewable energy strategy with emphasis on offshore resources	The integrated scenario shows that rapid clean energy deployment is the primary driver of deep emissions cuts: even a partial package focusing on low-conflict renewables slashed global GHG emissions by over 20% (~24 Gt) by 2060. To replicate this, the EU should massively scale up offshore wind farms, which tap abundant wind at sea without using land, along with onshore wind and solar in low-impact areas (e.g. brownfields). Implementing the EU Offshore Renewable Energy Strategy to reach on the order of 300 Gigawatt (GW) of offshore wind by mid-century would align with the model’s ambition. At the same time, technologies like rooftop solar, floating solar, and wind in sparsely populated areas should be expanded to displace as much fossil generation as possible. This broad renewable push – prioritizing marine and other low-conflict sources – can achieve most of the needed emissions reduction while minimizing pressure on terrestrial ecosystems.

Nº	Recommendation	Description
20	Pair ambitious renewable deployment with bold land restoration and protection	Climate mitigation and ecological restoration must advance in tandem. A medium-integrated scenario—combining strong clean-energy expansion with 60 % implementation of nature-based measures—already doubles land-sector emission cuts compared to a renewable-only approach. Building on this synergy, the EU and Member States should implement large-scale afforestation, peatland restoration, and regenerative grazing, aligned with the EU Biodiversity and Forest Strategies. These actions enhance carbon sinks without compromising food security and can deliver up to ~0.3 °C of additional avoided warming by 2060 in high-ambition pathways. However, once land protection reaches its limits—e.g., full exclusion of forests, biodiverse grasslands, and prime farmland—further climate gains depend on scaling renewables fast enough to keep emissions falling. Therefore, policies like the EU Nature Restoration Law must be fully implemented alongside Fit for 553 and strengthened by commitments such as 100 % renewable electricity or net-zero energy by 2040. Coordinated action across land and energy will ensure that nature-based solutions and clean power mutually reinforce, rather than constrain, deep decarbonisation.
21	Adopt an integrated cross-sector strategy that aligns climate, biodiversity, and food security goals	The modeling shows that coordinating ambition across energy, land, and agriculture delivers far greater benefits than pursuing each in isolation. Moving from low to moderate integration nearly doubled forest gains and deepened emission cuts, while pushing to the highest ambition brought diminishing returns unless clean-energy deployment was scaled accordingly. Policymakers should target this “sweet spot” by advancing substantial—though not absolute—land protections in parallel with massive renewables build-out. This requires cross-sector planning: energy, agriculture, and environment ministries must co-develop national climate strategies to ensure aligned and mutually reinforcing targets. For instance, safeguarding all high-value ecosystems and farmland should be matched with a ramp-up in offshore wind or rooftop PV. Tools like the WILLIAM model can help optimize this balance. More broadly, Europe should embrace a unified policy framework—linking the Climate Law, Biodiversity Strategy, and Common Agricultural Policy—to reward actions that advance multiple objectives. A fully integrated approach not only avoids land-energy trade-offs, but also secures food supply, restores ecosystems, and accelerates the energy transition. With this holistic model, the EU27 can lead the way toward a globally sustainable future.



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