IAM COMPACT

Expanding Integrated Assessment Modelling:
Comprehensive and Comprehensible Science
for Sustainable, Co-Created Climate Action

Responsive science in support of climate policymaking

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Land-use policies and renewable energy expansion

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- **Introduction-Research Questions**
  - ✓ Motivation and workshop (stakeholders' insights)
  - ✓ Key research questions
- **Methods**
  - ✓ Model applied and geographical scope
  - ✓ Scenario design
- **Results**
  - ✓ Analysis of impacts of bioenergy penetration in EU
  - ✓ Analysis of solar PV penetration in EU
- **Conclusions**
  - ✓ Key takeaways and policy implications

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Motivation: land requirements of renewable energy deployment

- **Land key role in climate and for providing resources:**
  - Regulation (uptake and emit GHGs) 11% of total GHG emissions is from land use change
  - Global competition for land: Provide with resources vital for society
  - The rapid deployment of renewable energy could intensify global competition for land (local opposition already happening).
  - Focus is on two types of renewable energy:
    - Solar power generation
    - Bioenergy (biomass extraction from forest).

Source: https://paisajesteruel.org/manifestacion-aliente-renovables-si-pero-no-asi

Source: FAO/FO-5616/H. Hiraoke

Workshop *"Land Use & Renewable Energy* → Stakeholders feedback → Research questions

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❑ **Objective:**

Assess the impacts of expanding solar PV and bioenergy in the European Union (EU), with a particular focus on land-use competition, carbon emissions, and sustainable resource management

❑ **Key research questions addressed:**

- What are the **land-use implications of large-scale solar PV deployment** in the EU?
  - ➢ *Particular attention is given to **land competition** and the impacts in terms of **carbon emissions** under different deployment scenarios*

- How does an ambitious renewable energy scenario based on bioenergy (in particular, **from biomass from forests**) **affect land demand (including impacts outside the EU),** and put **pressure on forest biomass and ecological** boundaries?
  - ➢ *This question investigates the trade-offs between energy transition goals and ecological, societal and agricultural sustainability.*

- Which **policy mechanisms** can mitigate the adverse impacts of land-intensive renewable energy expansion while aligning with climate and energy objectives?
  - ➢ *Potential benefits of **integrated energy and land-use policy frameworks**: exploring how such policies could improve planning, resource efficiency, and sustainability outcomes*

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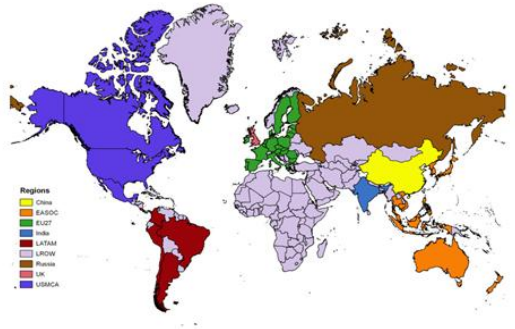
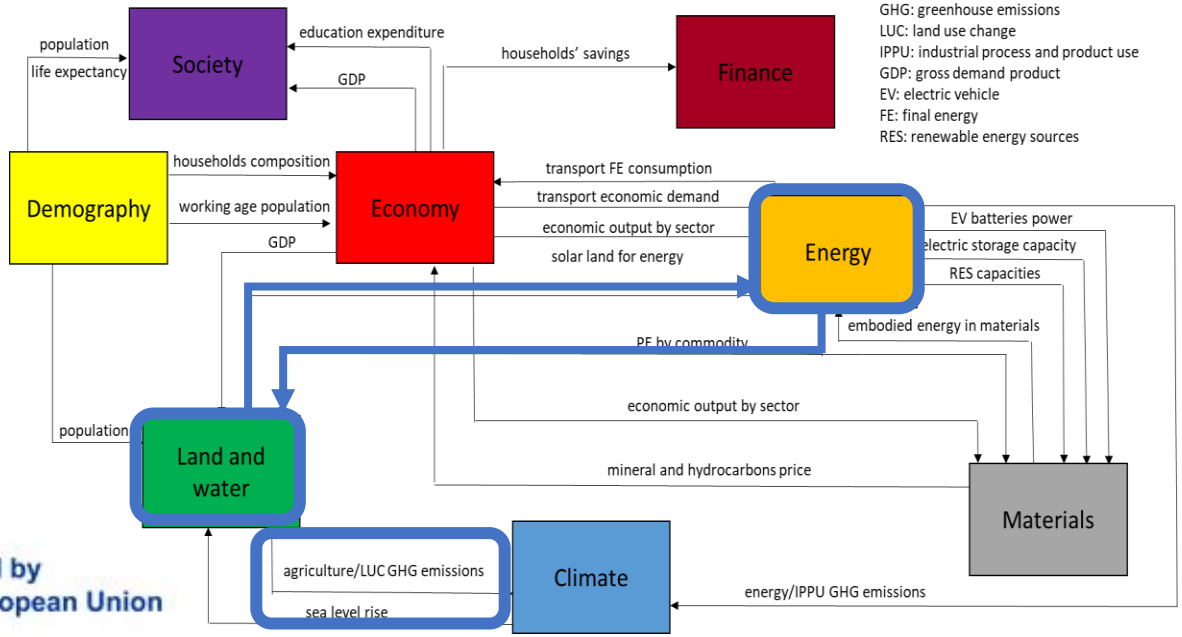
- **Geographical scope:** EU-27 region

- **Model: WILIAM IAM**
  - Systems dynamics: systems connected (boxes)
  - It simulates interactions among energy, land, and climate systems at global scale, with regional disaggregation that includes EU-27
  - Joint assessment of land and energy policies, including emissions.



WILIAM structure overview



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Two different analysis.

1. Analysis of impacts of bioenergy penetration in EU

		Land-based policies				
Scenario	**Concept**	**Afforestation**	**Primary Forest Protection**	**Managed Forest Protection**	**Biomass Extraction Limit**	**Forestry Self-Sufficiency**
REFERENCE SCENARIOS						
Baseline	Continue historic trends	None	None	None	None	None
NDC- LTT	Short and long-term policy ambition set by EU countries: High bioenergy and solar PV penetration	Medium	High	Medium	Low	None
POLICY SCENARIOS						
NDC-LTT-Self-Sufficiency	Application of land-based policies focused on EU forest preservation (limits on forest biomass extraction and relocating roundwood production to ensure self-sufficiency)	Medium	High	Medium	High	High
NDC-LTT-Afforestation	Application of more ambitious afforestation policy in order to offset the impacts of increased demand for biomass	High	High	Medium	High	High

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Two different analysis.

2. Analysis of the impacts of solar PV penetration in EU

		Land-based policies	
Scenario	**Concept**	**Solar PV siting policies**	**Land protected from solar PV**
REFERENCE SCENARIOS			
Baseline	Continue historic trends	None	None
NDC- LTT	Short and long-term policy ambition set by EU countries: High bioenergy and solar PV penetration	Medium	High
POLICY SCENARIOS			
Baseline-land-based policies	Application of land-based policies: siting solar PV and protection from solar PV deployment that could increase land competition	Yes. Prioritizing less carbon rich areas and with ecological value	Yes. Protecting forest and cropland
NDC-LTT-land-based policies	High bioenergy and solar PV penetration and apply land-based policies and application of land-based policies: siting solar PV and protection from solar PV deployment that could increase land competition	Yes. Prioritizing less carbon rich areas and with ecological value	Yes. Protecting forests and cropland

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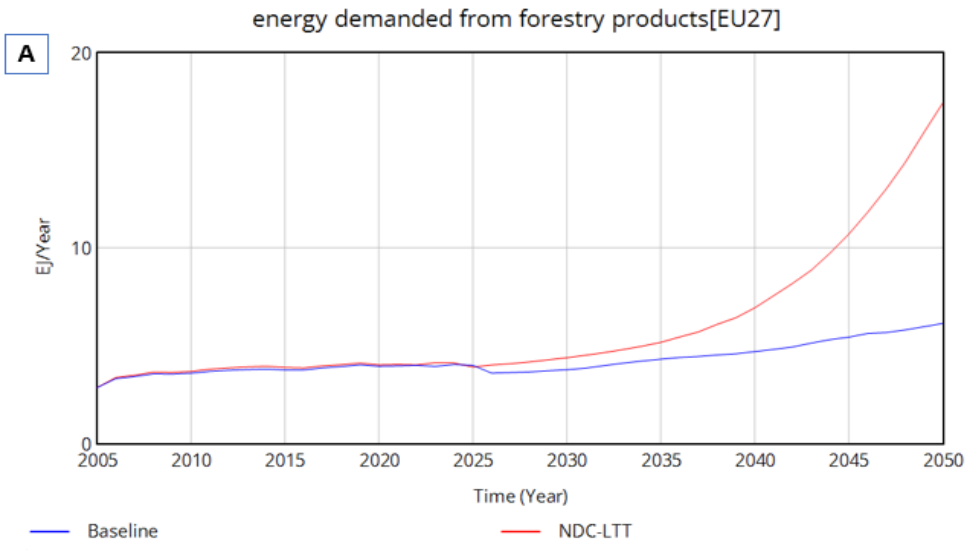
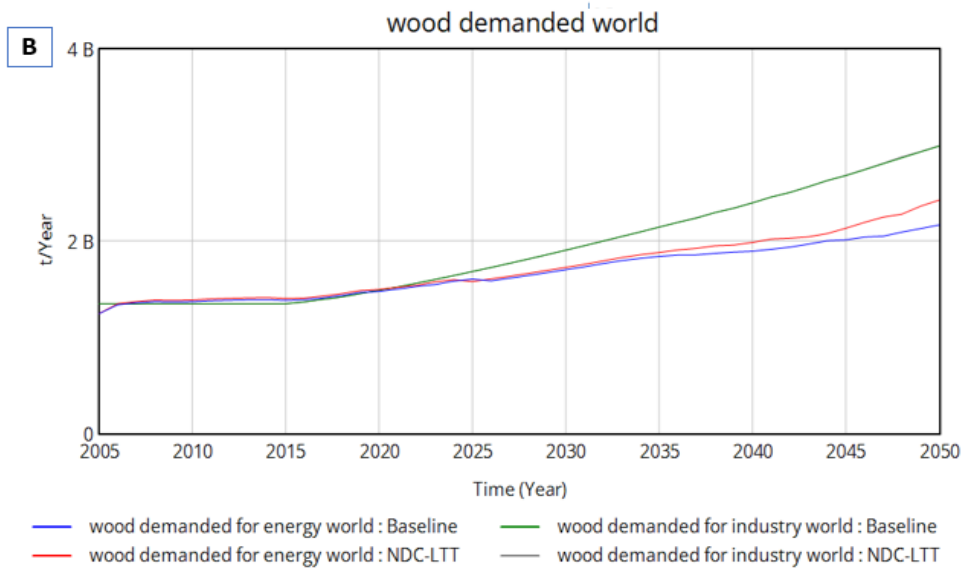
1. Analysis of impacts of bioenergy penetration in EU

Baseline and NDC-LTT

Demand of energy from forestry product in EU27



Wood demanded to supply energy and industry demand (global)



Increase in energy demanded from forestry (biomass from forest) under EU policies
→ increase is mostly for energy demand

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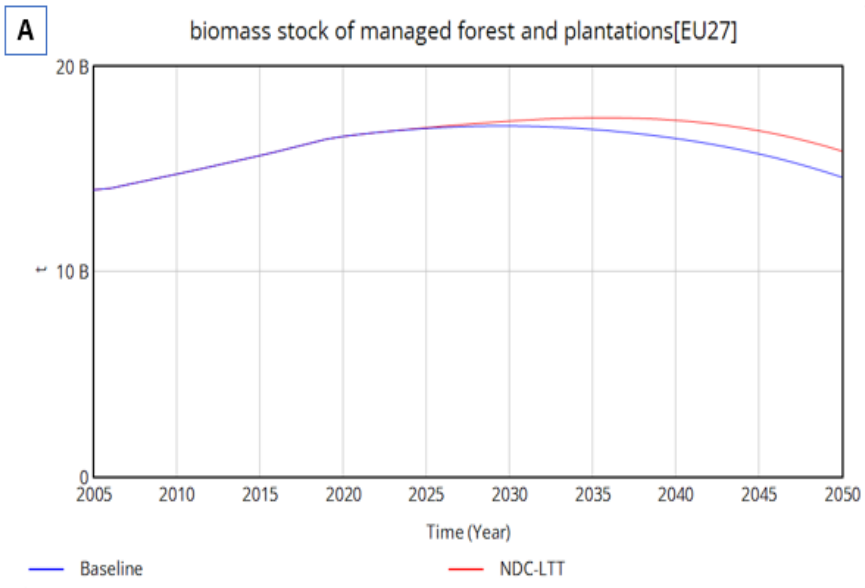
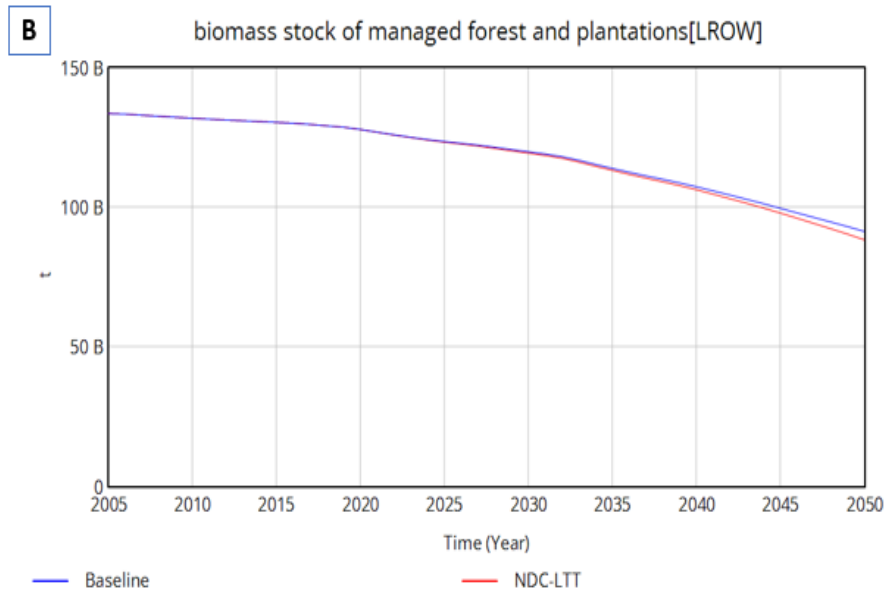
1. Analysis of impacts of bioenergy penetration in EU

Biomass stock - Baseline and NDC-LTT

EU-27



LROW (*Africa, Middle East, other)*



NDC-LTT : moderate afforestation→ (7% increase in planted forests by 2050 relative to the managed area in 2005) but decline from 2035

NDC-LTT : moderate afforestation in EU-27, but demand remains constant: stocks of biomass in other regions worsen

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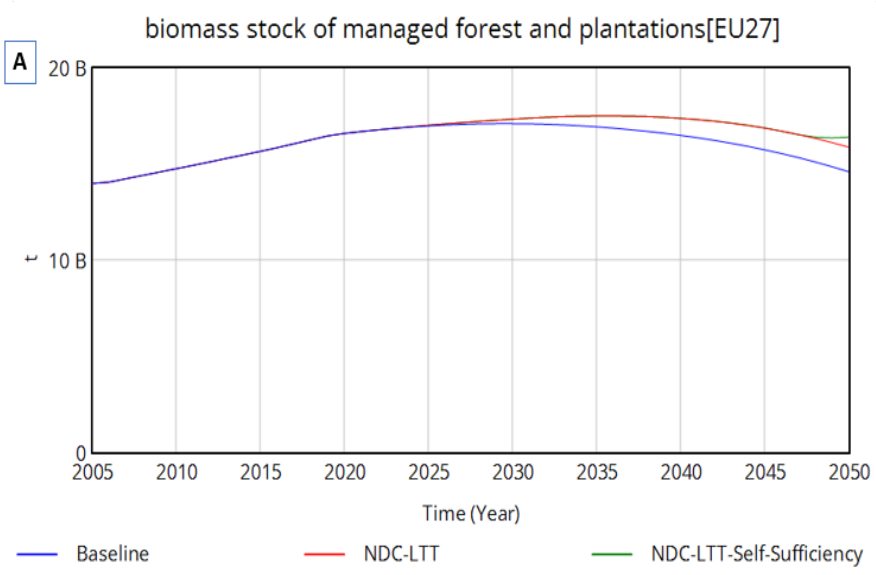
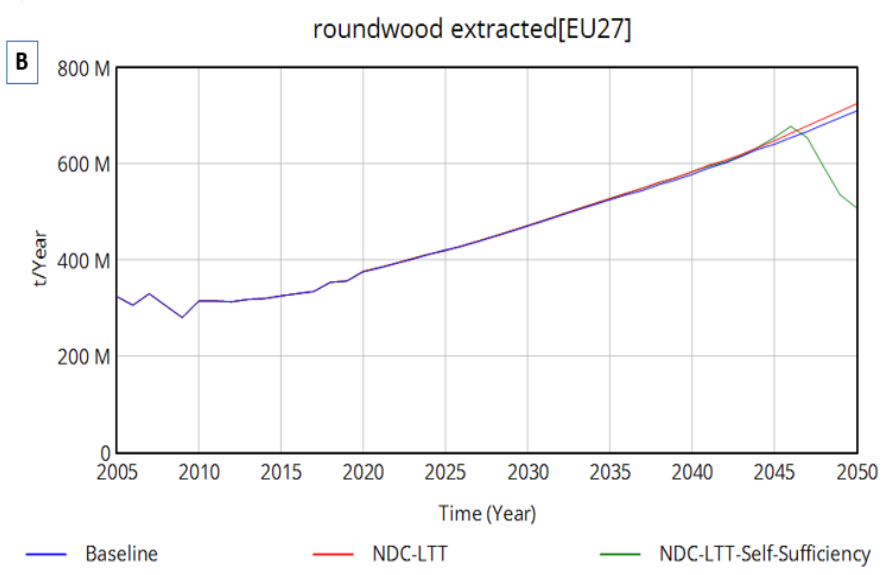
1. Analysis of impacts of bioenergy penetration in EU

The NDC-LTT-Self-Sufficiency Scenario: Application of land-based policies focused on **EU forest preservation** (limits on forest biomass extraction and relocating roundwood production to ensure self-sufficiency)





This scenarios reduces biomass stock removals progressively (end of the period) and minimise global spread effects

However this means that harvested roundwood is constrained at the end: EU demand is not satisfied due to the limits imposed.

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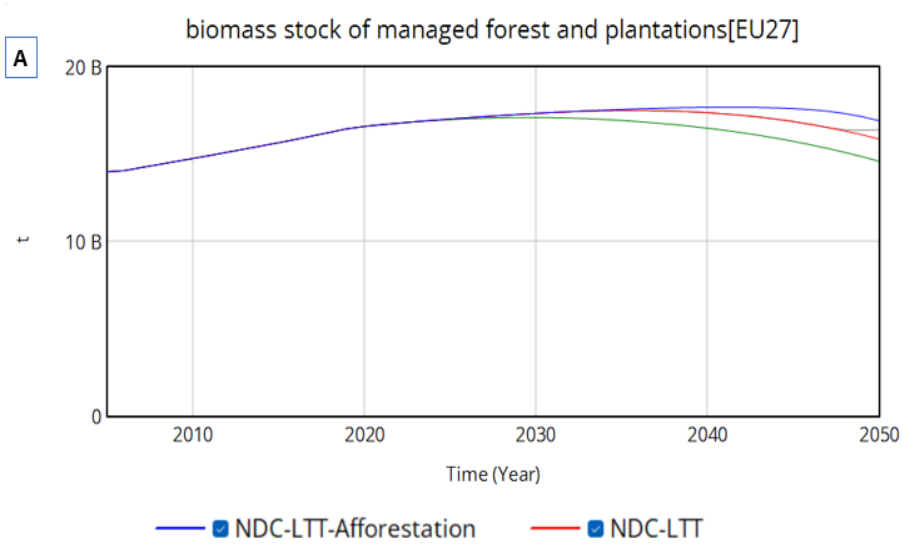
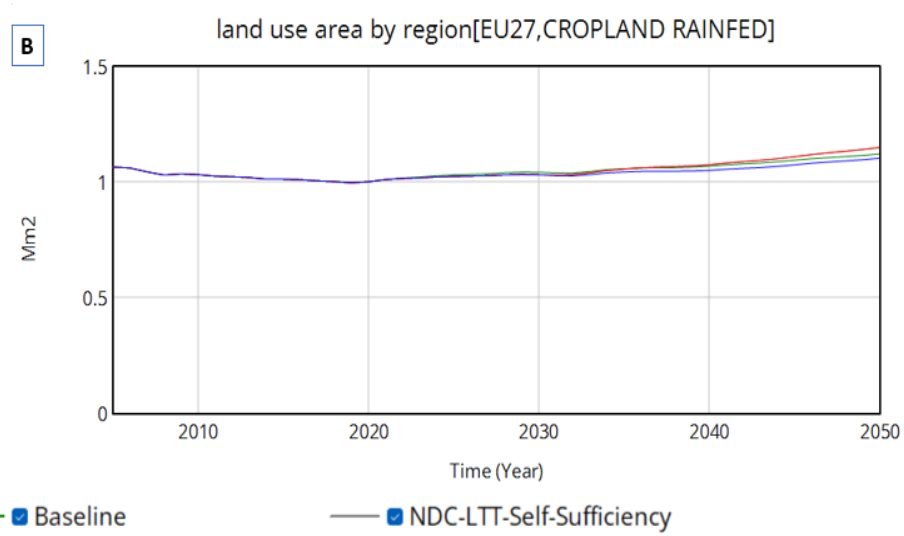
1. Analysis of impacts of bioenergy penetration in EU

The NDC-LTT-Afforestation: Application of **more ambitious afforestation policy** in order to offset the impacts of increased demand for biomass





High afforestation→ new planted forests equivalent to 24% of the managed forest area in 2005. This prevents its decline until 2045 and it satisfies demand

However, forest expansion begins to encroach on cropland, leading to a slight reduction in agricultural area

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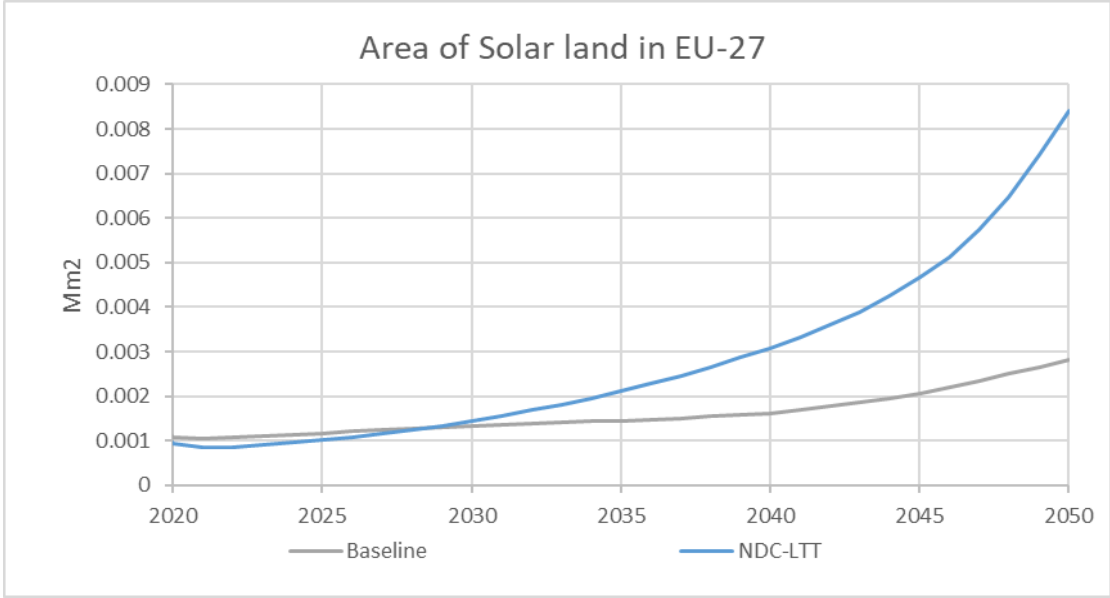
2. Analysis of solar PV penetration in EU

Baseline and NDC-LTT

Land use types	Initial percentage of the current distribution of solar PV in EU
CROPLAND_RAINFED	52,40%
CROPLAND_IRRIGATED	1,59%
FOREST_MANAGED	10,52%
FOREST_PRIMARY	0,00%
FOREST_PLANTATIONS	10,52%
SHRUBLAND	8,94%
GRASSLAND	10,31%
SNOW_ICE_WATERBODIES	0,002%
OTHER_LAND	5,71%



Remarkable growth of area devoted to solar uses in the NDC-LTT compared to the Baseline: around **half of these installations located on rainfed cropland** (historical patterns in EU) (Ferreras-Alonso et al., 2024)

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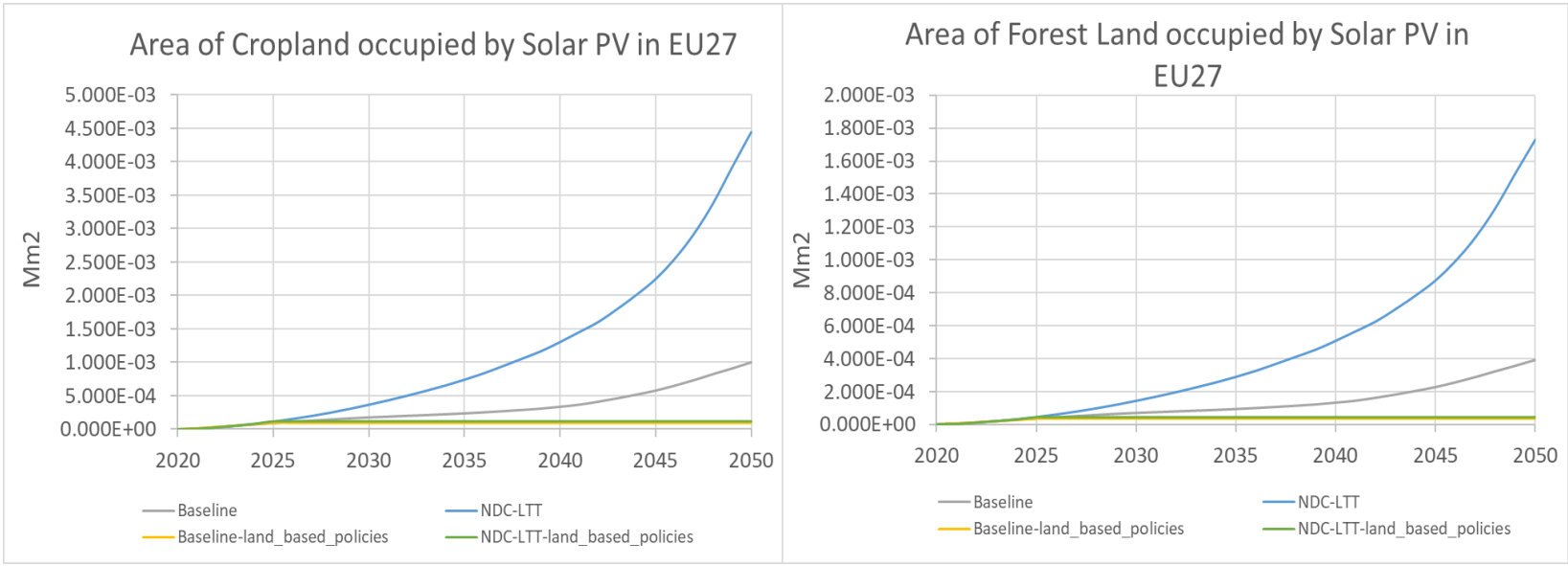
2. Analysis of solar PV penetration in EU

Land-based policies scenarios: 1) siting solar PV and 2) protection from solar PV deployment that could increase land competition



Area occupied by solar PV deployed on productive uses, like cropland and forest land are reduced, and therefore potential land competition (e.g. competition for food, wood, etc.).

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2. Analysis of solar PV penetration in EU

Land-based policies scenarios: 1) siting solar PV and 2) protection from solar PV deployment that could increase land competition

	Cumulated carbon emissions (GtC) 2020–2050 (associated to the deployment of solar PV on land)	% of carbon emissions with respect to Baseline and NDC-LTT scenario
Baseline	0.02	100%
Baseline-land-based policies	0.009	59%
NDC-LTT	0.06	100%
NDC-LTT-land-based policies	0.035	55%

Carbon emissions associated with Land Use Changes (LUC) are significantly lower in scenarios where land-based policies are implemented (less carbon-rich land use types prioritized)

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Key Policy Insights on Bioenergy from Forest Biomass. Integrated land-use and energy policies

- Rising EU biomass demand risks increasing pressure not only in EU but in global forest resources (especially vulnerable regions with not protection policies)
- High bioenergy use requires afforestation efforts beyond current policies; forest protection alone is insufficient.
- Regional self-sufficiency and more ambition afforestation policy eases global pressure while satisfying demand, but start to trigger land-use conflicts in EU with cropland.
- **Linking bioenergy targets to land-use sustainability metrics** (forest stock, management) ensures alignment with ecological limits.

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Key Policy Insights on solar PV generation. Integrated land-use and energy policies

- NDC-LTT scenario show rising solar PV deployment will increase land demand, much of it on rainfed cropland, causing land-use competition and higher land-use change emissions. This is because normally solar PV energy infrastructure are sit according to economic aspects not considering:
  - Potential ecological impact (biodiversity, landscape, emissions) and
  - Potential social impacts: conflicts with other land productive uses
- Integrating energy and land-use planning (solar siting /land protection forest/cropland areas):
  - Ease competition for other land related products, such as food, biomass, etc.
  - and reduces emissions and ecological trade-offs.

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Thank you!

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