Integrating agriculture and land-use aspects into TIMES Pan-EU

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1. Motivation

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   b) Land-use of the renewable energy technologies
   c) Modelling of a simplified agriculture sector and biomass cultivation

3. Result insights from a case study for Germany
1. Motivation

Why to model agriculture and land-use aspects in an energy system model?

**Agriculture**

Sector with the highest remaining emissions with a net zero climate target

**Land use**

Increasing competition due to increasing settlement and traffic area, new areas for renewable energies, new areas as carbon sinks

Assessment of the interdependencies with the energy sector may lead to other energy transformation pathways
2. Methodology and data
TIMES PanEU energy system model

System boundaries

Energy prices, Resource availability

Domestic sources e.g. Mining of biomass

Imports

Primary energy

Energy flows

Final energy

Prices

Energy flows

Emissions

Process energy

High temperature process heat

Heating area

Commercial and agriculture sector

Food demand

Light

Communication

Power

Households

Person kilometers

Transportation

Freight kilometers

Demands

Industry

Costs

Demand services

Capacities
2. Methodology and data

Overview of Nexus analysis with TIMES Pan-EU

- Detailed energy system
- Competition for bioenergy carriers within the sectors of the energy system

- Water for cooling
- Groundwater lowering for lignite open pits

- Land area for renewable energies and lignite mining
- Agriculture emissions

- Energy for agriculture

- Different land use categories
- Subsystem agriculture:
  - GHG emissions
  - Farming
  - Livestock

- Water for public and industrial demand
- Total water availability

irrigation
2. Methodology and data
Land-use of renewable energy technologies

Model results: capacity of renewable energy technologies

Land use factors of the renewable energy technologies

Land-use impacts of the future energy system
2. Methodology and data
Insights from data assessment: Land-use factors of the renewable energy technologies

- Comparison of 12 studies which analyse land-use factors
- Easy accessible data
- Wide range of resulting land-use factors in the literature
- Technological development influences the absolute value of the land-use factor

Sources:
McDonald et al., 2009.; Trainor et al., 2016.; STRATA, 2017.; EPRI, 2012.;
Milbrandt et al., 2014., Hernandez et al., 2015.; Koorey et al., 2010.;
Fthenakis et al., 2009.; Mckenna et al., 2020.; Schaffitzel, 2018.;
Fraunhofer ISE, 2019; Kelm et al., 2019.; P. Ruiz et al., 2019.
2. Methodology and data

Land-use factors of renewable energies and technological development of wind onshore technology

- Average capacity of a wind turbine increased in 15 years nearly 3 times
- Land-use factor for wind parks decreases with the increasing hub height and capacity of a single wind turbine

Source: https://strom-report.de/windenergie/#poster
2. Methodology and data
Land-use factors of renewable energies and technological development of free space PV

• Historic German development of the land-use factor of free space PV (grey) shows great technological improvements

• Projection of future land use of free space PV (ENSPRESO study on renewable energy potentials) (blue)

• Land-use data of renewable energies should be taken from a recent study for the simulation of the near future

• Land use assessment and assumptions for the renewable energies potentials should fit together

Data Source: T. Kelm et al., 2019 (grey), and P. Ruiz et al., 2019 (blue)
2. Methodology and data
Modeling of biomass cultivation and its potential

**MODELLED BIOMASS CROPS**
- Cultivation starchy biomass
- Cultivation sugar biomass
- Cultivation rape seed
- Short rotation forestry
- Cultivation Miscanthus

**YIELD FACTORS FROM MAGPIE**
- For each biomass type specific
- Option between rainfed and irrigated cultivation
- Irrigated cultivation has higher yields, but process has additional costs for building the irrigation infrastructure
- Water requirements from MAgPIE

**LAND AREA POTENTIAL FOR BIOMASS**
Equation to limit the whole biomass potential to an area:

\[
\text{energy output in PJ of different biomass types} \times \text{yield factor in ha/PJ} + (...) \leq \text{available land area}
\]

→ Used potential for the scenarios: 4,000,000 ha
2. Methodology and data
Modelling of a simplified agricultural sector in TIMES PanEU
2. Methodology and data
Modelling of a simplified agricultural sector in TIMES PanEU - data

- Statistical data of agricultural sector and products easily accessible for aggregated agricultural production
- Land use factors and emission factors were calculated for each country based on statistical values

- Biomass cultivation isolated from overall farming process
  - Emission factors from ProBas LCA database (direct emissions)

- LULUCF sector: measure of recultivation of peatland is considered as an exogenous assumption, area requirement and GHG savings according to literature for the case study [Hartje, Wüstemann, Bonn. 2015]
3. Result insights from a case study for Germany

Scenario definition

Comparison of a
- future with minimal negative emissions and the agriculture sector replaces a big share of the livestock demand by innovative meat products
- a future where BECCS technologies can be used to create more negative emissions and are only regulated by the limit of the biomass potential

Climate target | Technology options | Analysis level
--- | --- | ---
climate goal: net zero emissions in 2045, LULUCF sector: -40 Mt | additional measure in the agriculture sector (no BECCS technologies) | Reference energy system model
| BECCS technologies allowed | Nexus model | Reference energy system model
| | Nexus model | Reference energy system model
| | Optimized Nexus Model | Reference energy system model
3. Result insights from a case study for Germany

Bioenergy: Comparison from a regular energy system to the nexus energy system model

Scenario: additional measure in the agriculture sector, without BECCS option

- Bioenergy is not carbon neutral when agricultural sector is modelled in detail
- → Nexus modelling leads to less biomass demand if there is no BECCS option available
- Irrigation of biomass is applied
3. Result insights from a case study for Germany

Net electricity supply: Comparison from a regular energy system to the nexus energy system model

Nexus modelling leads to:

- Less biomass usage in the electricity sector
- More solar power usage
3. Result insights from a case study for Germany

Soil sealing for energy technologies

- More free space PV is built up in the Nexus model
- Assumption lignite mining pits are restored until 2050
- The area requirement where soil needs to be sealed for renewable energy technologies is quite little
- Refers to 0.4% of the German land area
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Overall area requirements for the energy transition

- Wind park area (area around wind turbines) can be used simultaneously for farming
- Agricultural area for forage plants and crops decreases because of additional measure (traditional meat demand decrease)
- New measure of the LULUCF sector: peatland recultivation
- Full usage of biomass potential of 4 m ha in the reference scenario could be realized
- No area scarcity in the scenario results
3. Result insights from a case study for Germany

Land area saving possibilities for renewable energy technologies

Wind parks and agricultural or forestry land use

Agri PV systems: potential of 53 GW in Germany

Recultivation of lignite mining pits → lake landscape → floating PV: potential of 34 GW, if 25% of the new lake area is covered

Could save 100,000 ha of land area for conventional free space PV
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Scenario definition

climate goal: net zero emissions in 2045, LULUCF sector: -40 Mt

additional measures in the agriculture sector (no BECCS technologies)

Reference energy system model

Nexus model

BECCS technologies allowed

Reference energy system model

Nexus model

Optimized Nexus Model
3. Result insights from a case study for Germany

Overall area requirements for the energy transition of BECCS scenarios

- Full biomass potential is used when BECCS options are allowed
- Measures of the LULUCF sector (peatland recultivation) and full usage of the high biomass potential (4 m ha) lead to too high area requirements
- Biomass potential should be minimized if conventional livestock demand stays the same
- Nexus modelling can identify too high renewable energy potentials
- Nexus+BECCS_opt scenario indicates a future scenario without land area scarcity (biomass potential is limited to 2.4 m ha)
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Bioenergy usage of BECCS scenarios

- BECCS technologies are favourite options
- Nexus model has the possibility to irrigate biomass cultivation
- Irrigation of biomass leads to 100 PJ more bioenergy and to 10 Mt more negative emissions in the nexus model (with 4 m ha biomass potential)
- If biomass potential is adjusted to optimal area, all biomass usages are minimized in favor of BECCS technologies
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Water withdrawal of the nexus+BECCS scenario

- If more than 20% of the renewable water resource is used it’s considered as water stress
- Biomass irrigation with the high biomass potential bears the risk of causing water stress
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Conclusion

- Simple agricultural sector allows the assessment of new research questions
- Nexus model can identify risks for land area or water scarcity → leads to new transformation pathways for the energy transition
- Biomass potential should be minimized and adapted to the interplay of different measures of the LULUCF and agriculture sector
- More cooperation between energy and agriculture sector necessary
- Land-use assessment of PV and wind technologies bear quite high uncertainties because of their technological development
- Dual land use possibilities for renewable energy technologies should be promoted
- Outlook: incorporation of afforestation measure in the LULUCF sector
Sources

- Sehn V., Blesl M., „The implications of national climate targets on the energy-water nexus applied on a case study of Germany“, 2019.
Thank you for your attention!

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3. Result insights from a case study for Germany
Possibilities of further reduction measures of the agriculture sector

- Applied measure for scenarios: innovative meat production
  - In-vitro meat and alternative meat products replace a big share of traditional meat production [ATKearney, 2019]
  - If development of the innovative products is applied according to the ATKearney study, 9.1 Mt CO2-eq and 4.9 m ha of agricultural land area could be saved

- Further possible measure: reduction of food waste
  - 14 % of food demand could be saved if food waste would be avoided [ISWA, 2012]
  - saves 4.5 Mt CO2-eq and 2.3 m ha of agricultural land area