**Universität Stuttgart**
*IER* Institut für Energiewirtschaft
und Rationelle Energieanwendung


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

Vera Sehn

# Contents

# 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

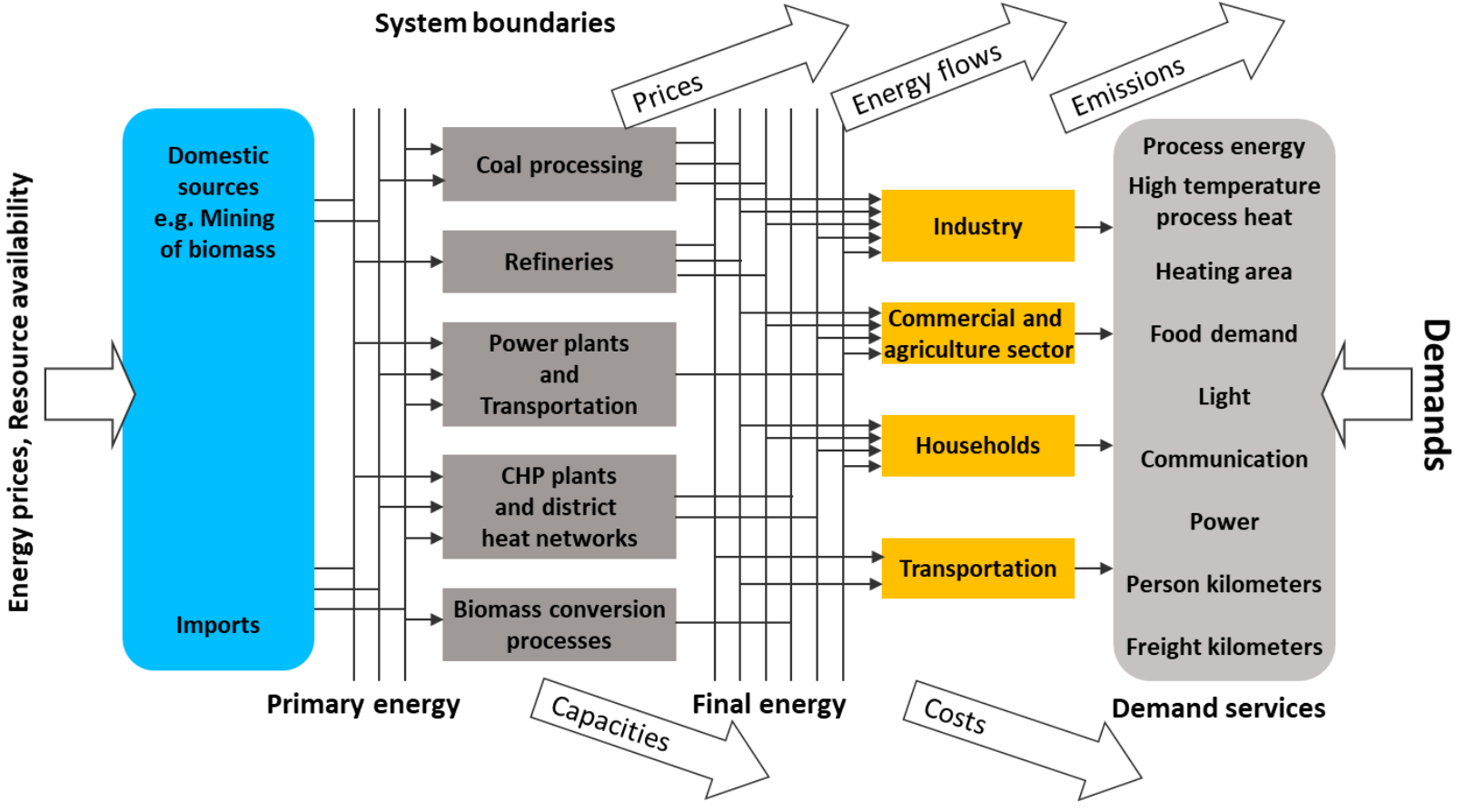
## Land use

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

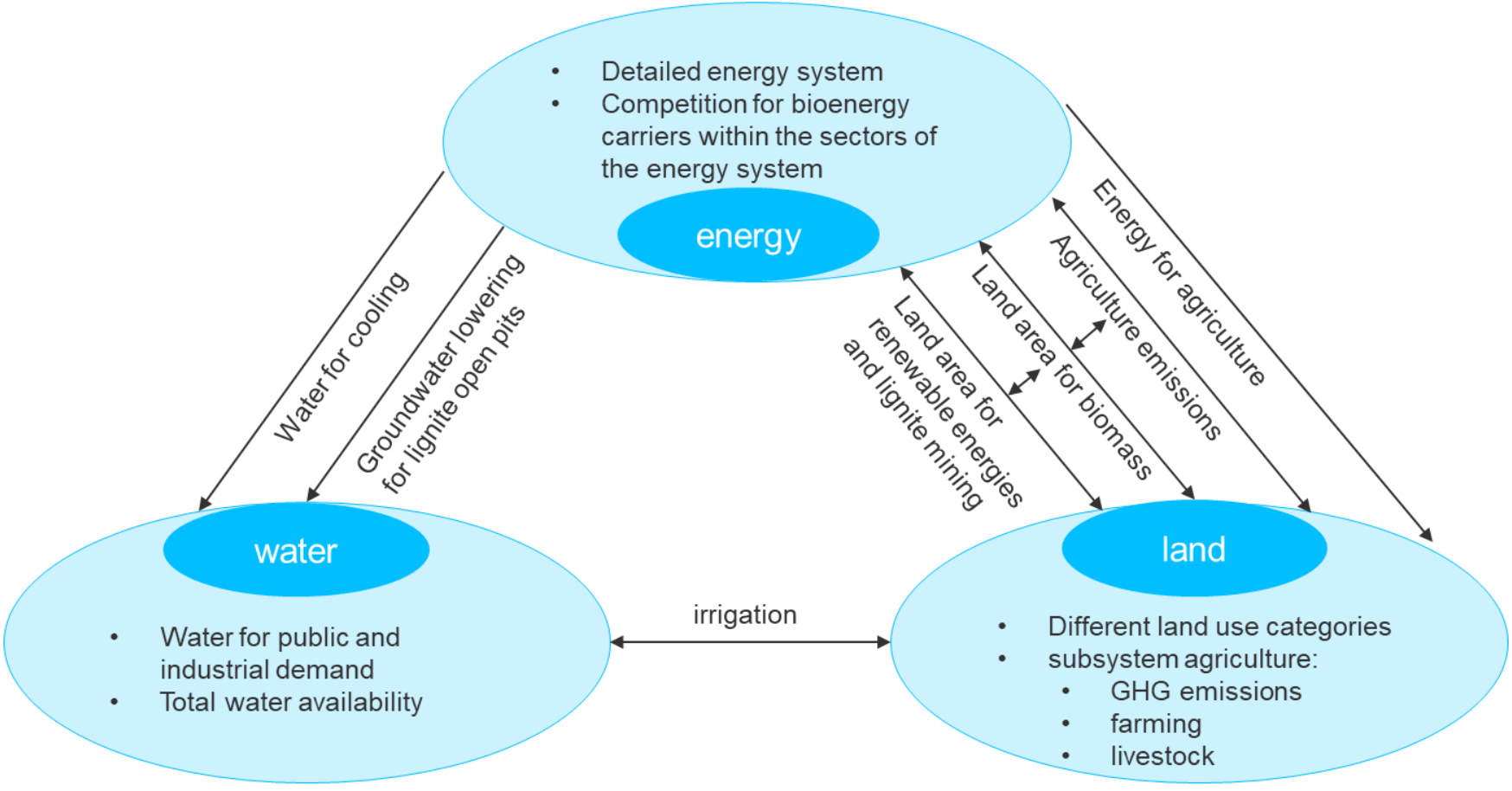
# 2. Methodology and data

TIMES PanEU energy system model



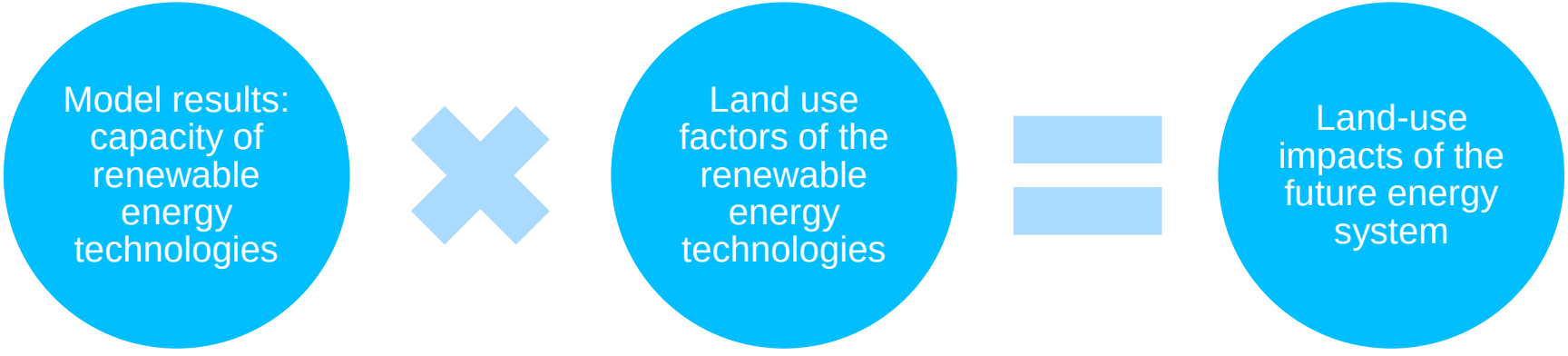
# 2. Methodology and data

Overview of Nexus analysis with TIMES Pan-EU



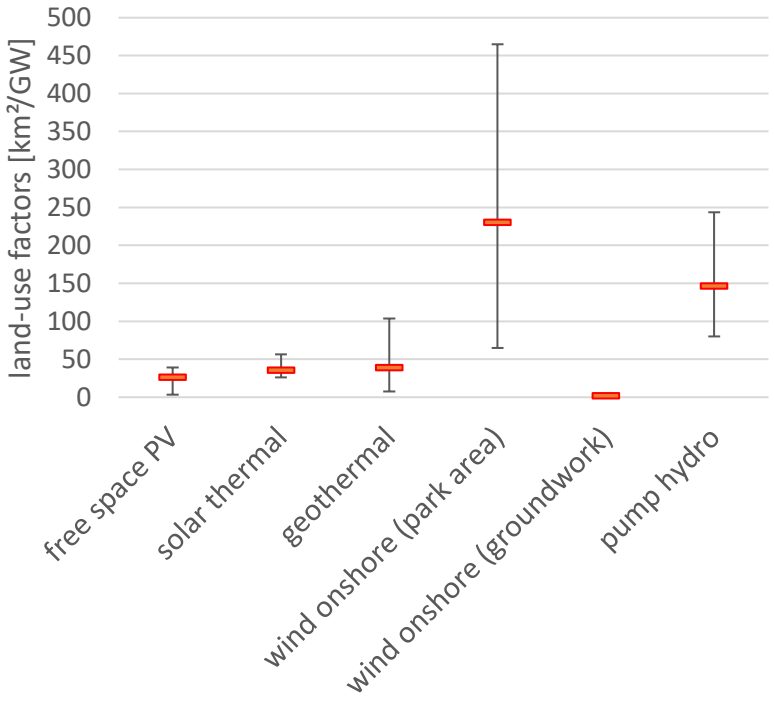
## 2. Methodology and data

Land-use of renewable energy technologies



# 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

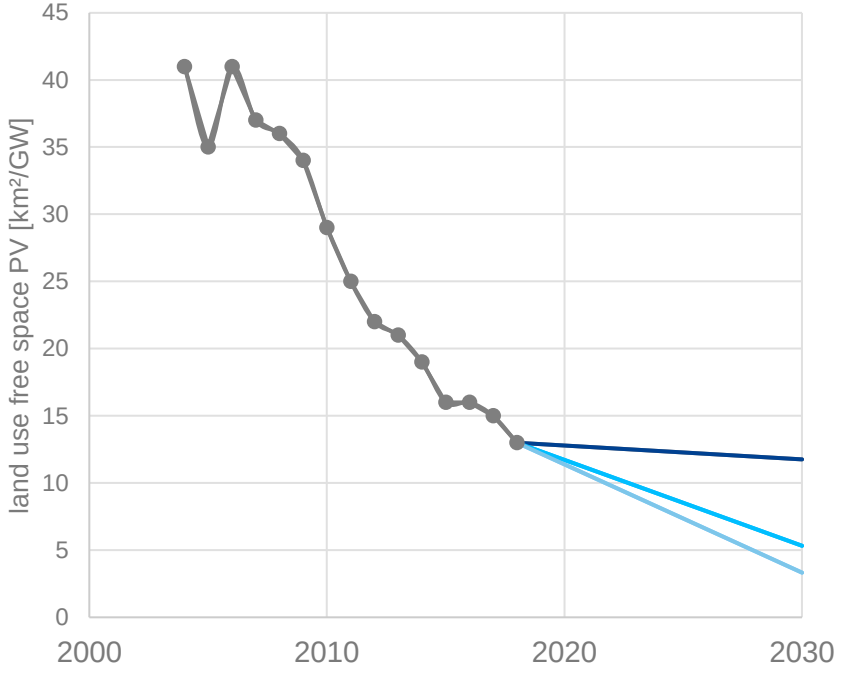
Land-use factors of renewable energies and technological development of wind onshore technology


Source: https://strom-report.de/windenergie/#poster

- 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

## 2. Methodology and data

Land-use factors of renewable energies and technological development of free space PV




Data Source: T. Kelm et al., 2019 (grey), and P. Ruiz et al., 2019 (blue)

- Historic German development of the land-use factor of free space PV (grey) shows great technological improvemtents
- 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 assesment and assumptions for the renewable energies potentials should fit togehter

# 2. Methodology and data

Modelling 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

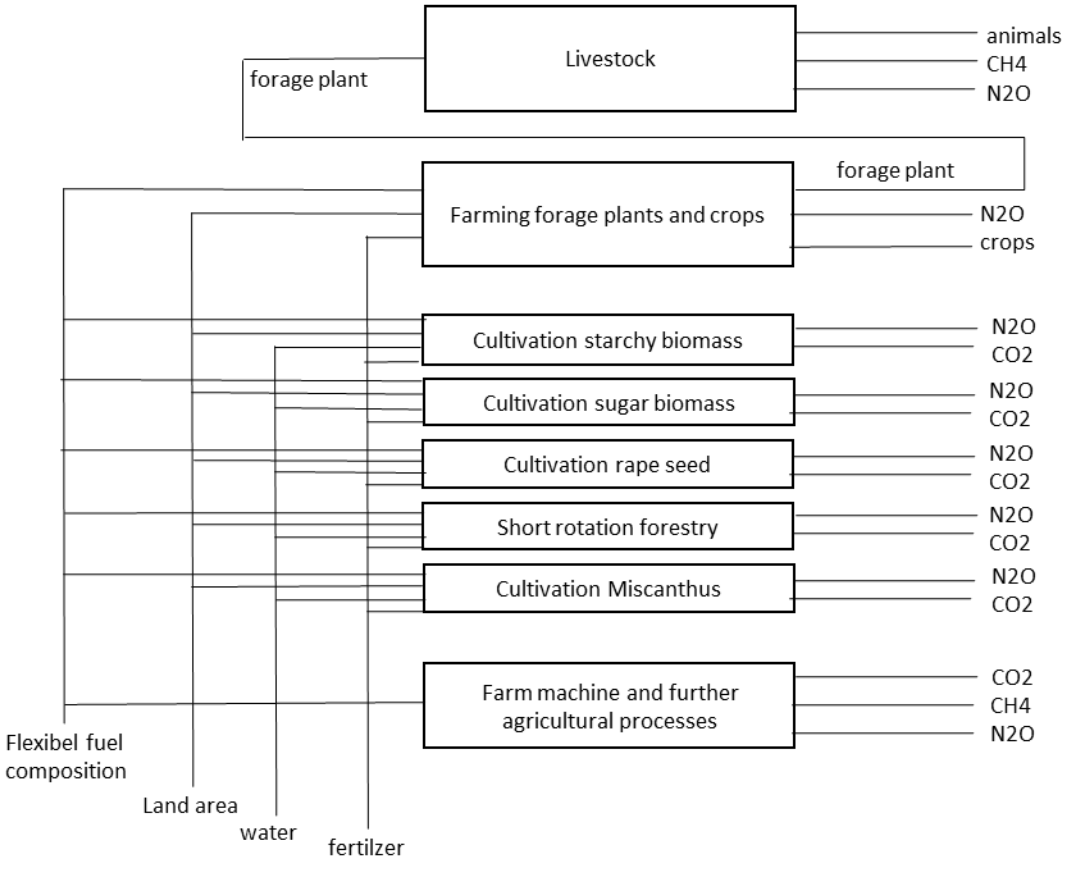
Equation to limit the whole biomass potential to an area:

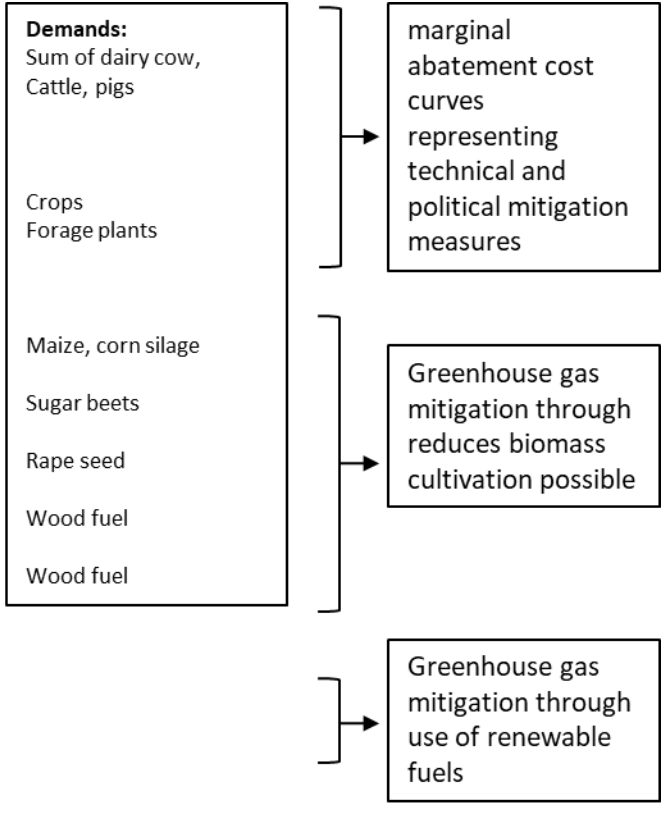
energy ouptut in PJ of different biomass types * yield factor in ha/PJ + (…) ≤ available land area

→ 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

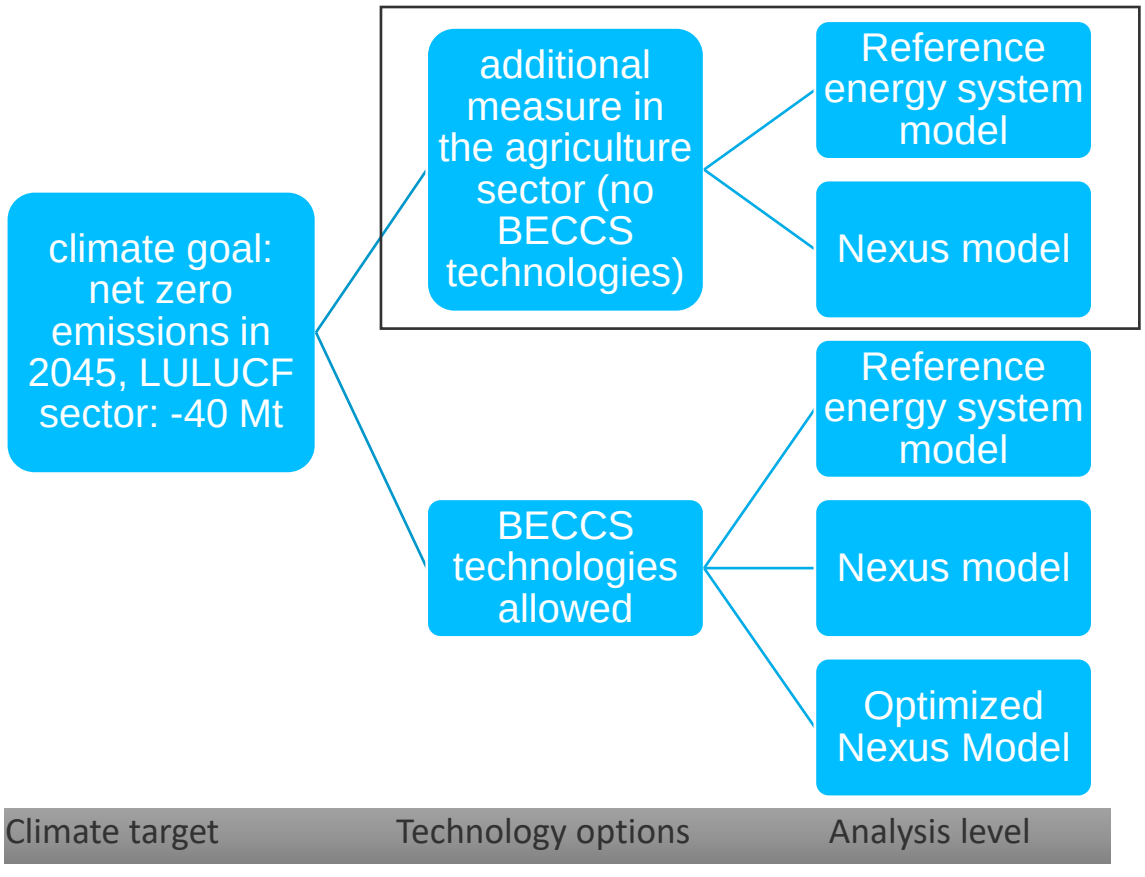
- Statistical data of agricultural sector and products easily accessible for aggregated agricultural production
- land use factors and emission factors were calculated for each country based on statistical values

- 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 a exogenious 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

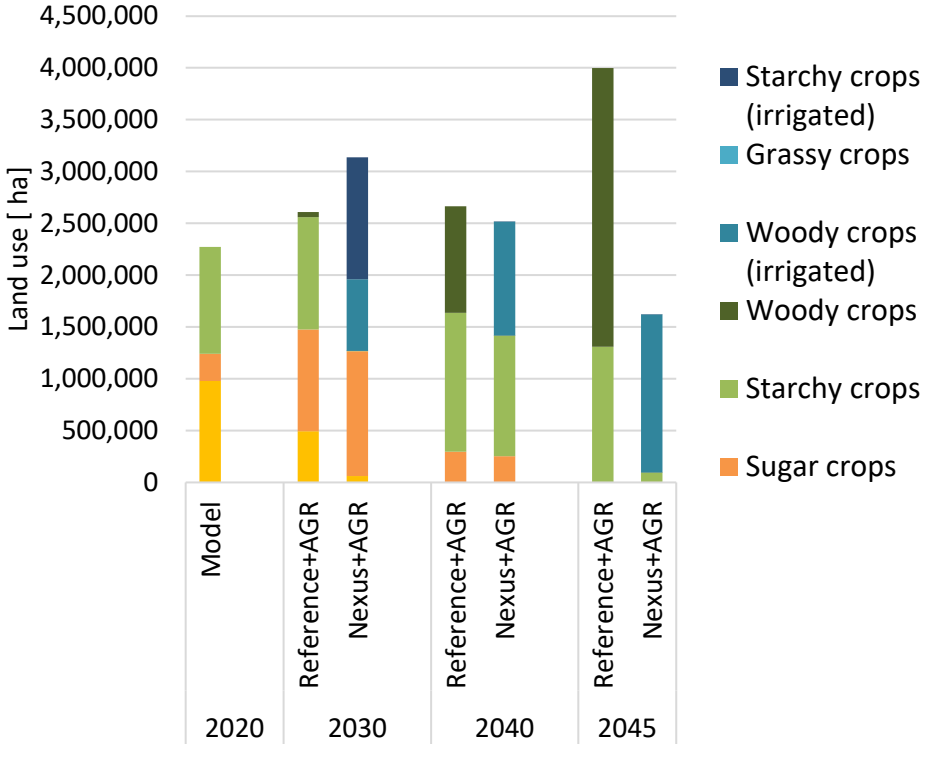



Comparison of a

- 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

# 3. Result insights from a case study for Germany

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

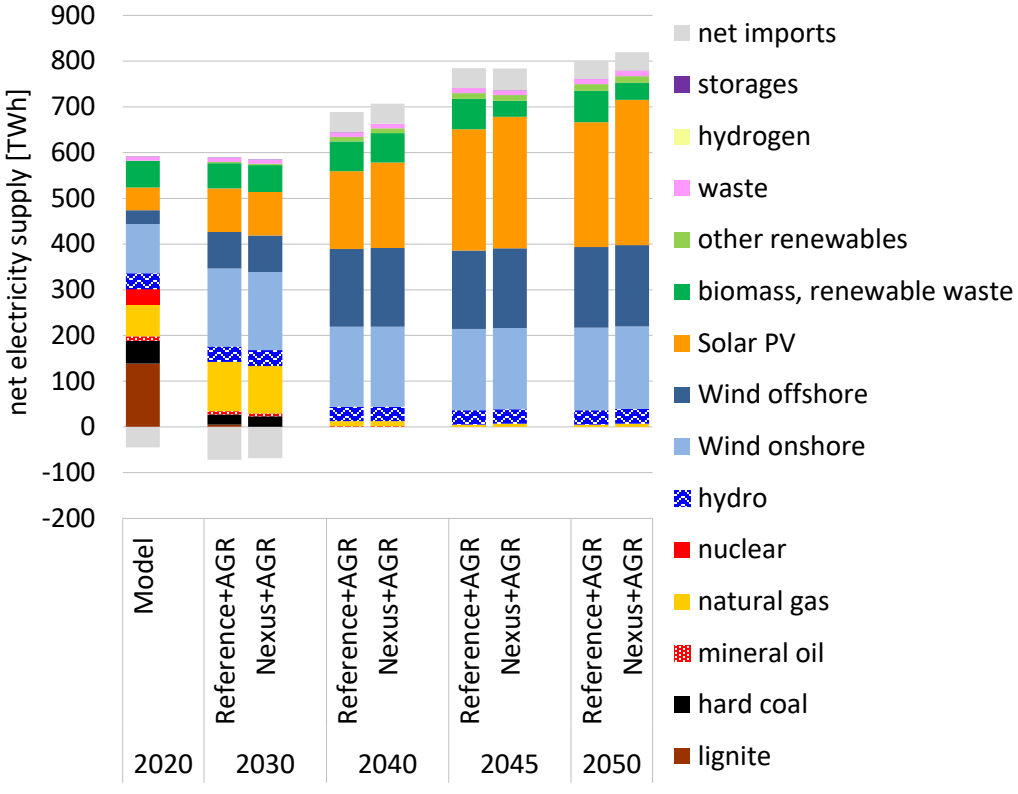



Scenario: additional measure in the agriculture sector, without BECCS option

- 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 sytem model

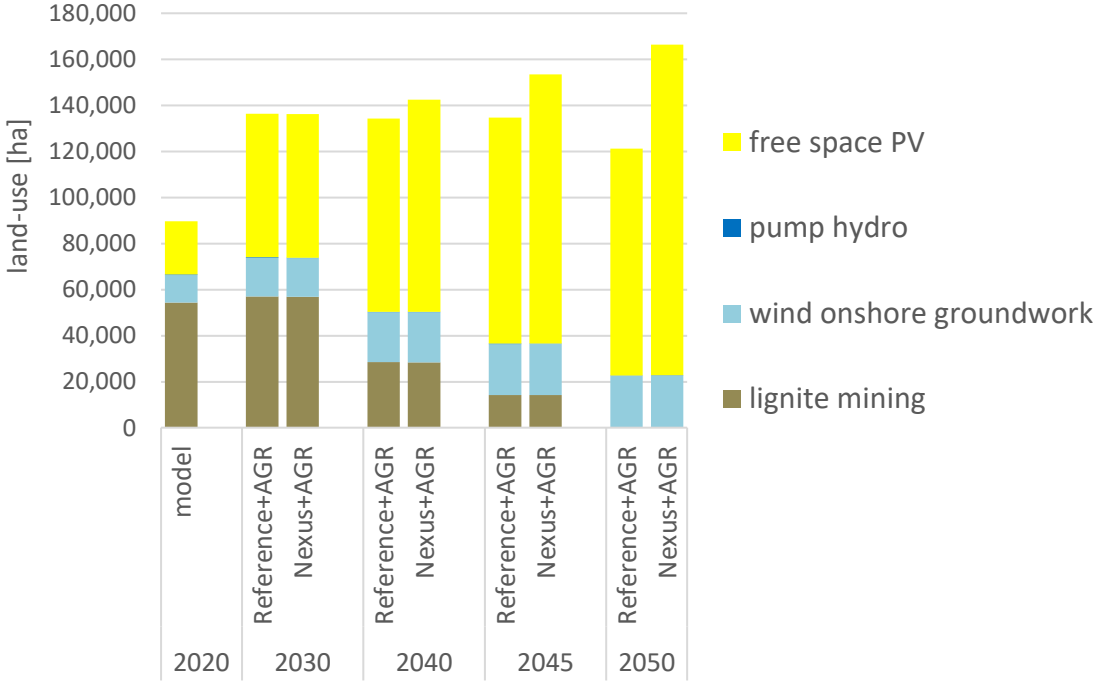



Nexus modelling leads to:

- Less biomass usage in the electricity sector
- More solar power usage

# 3. Result insights from a case study for Germany

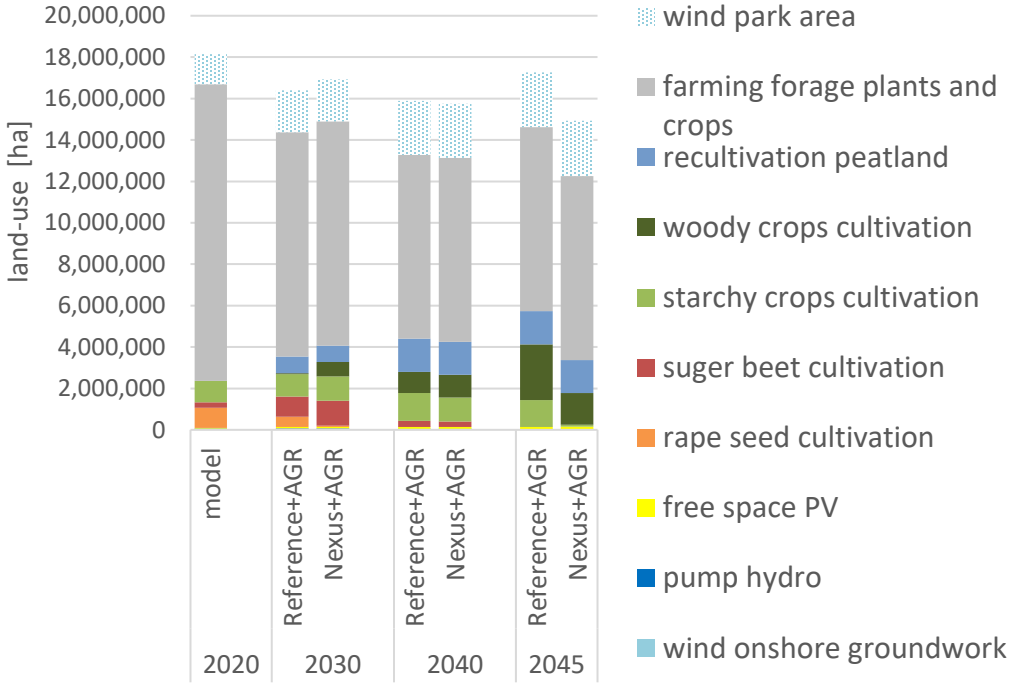
## Soil sealing for energy technologies




- 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

# 3. Result insights from a case study for Germany

## 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

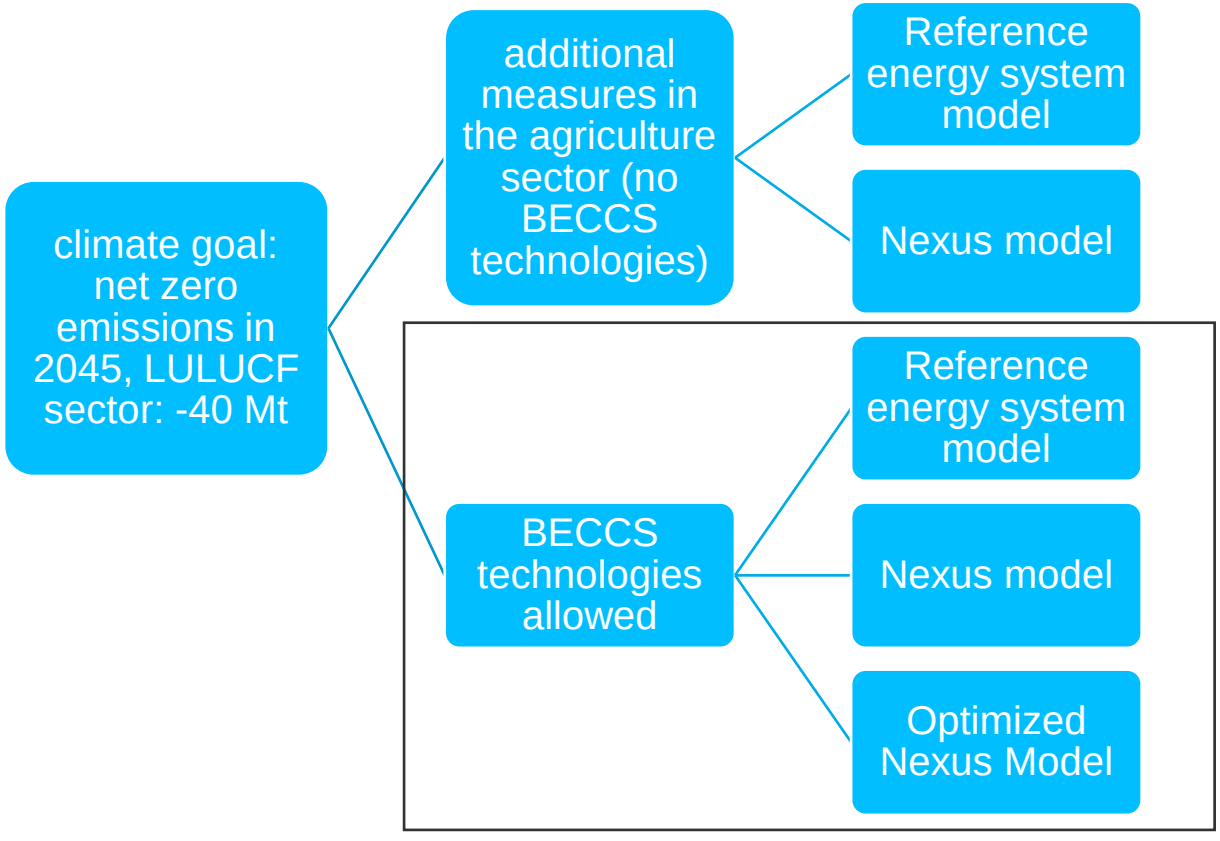
Agri PV systems: potential of 53 GW in Germany

Recultivation of lignite minig 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

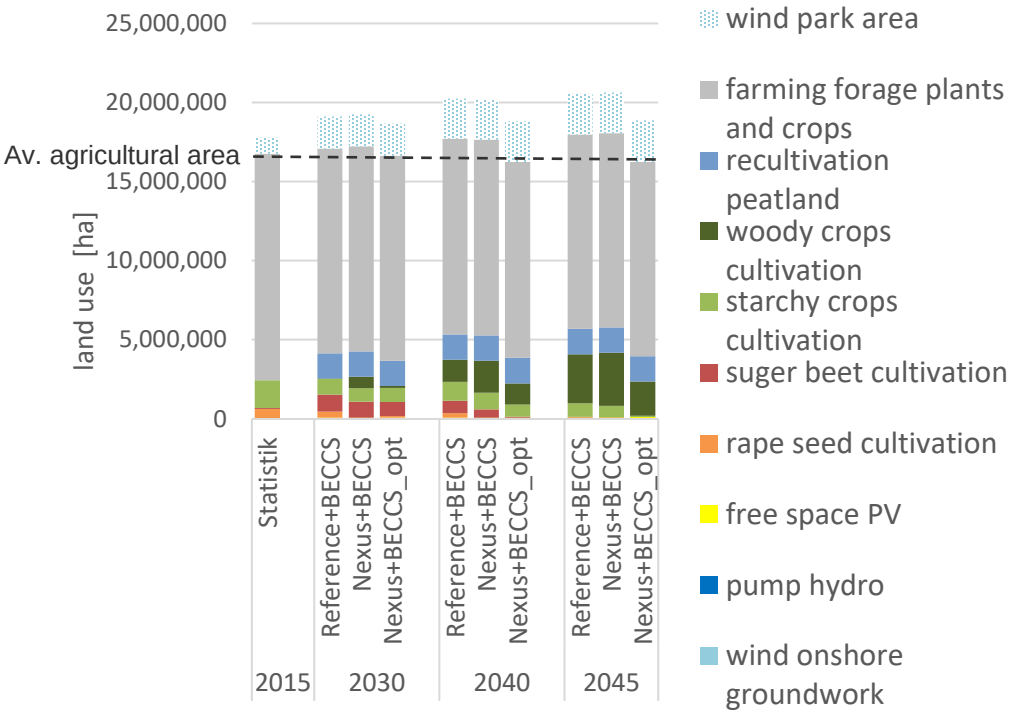
## 3. Result insights from a case study for Germany

Scenario definition



# 3. Result insights from a case study for Germany

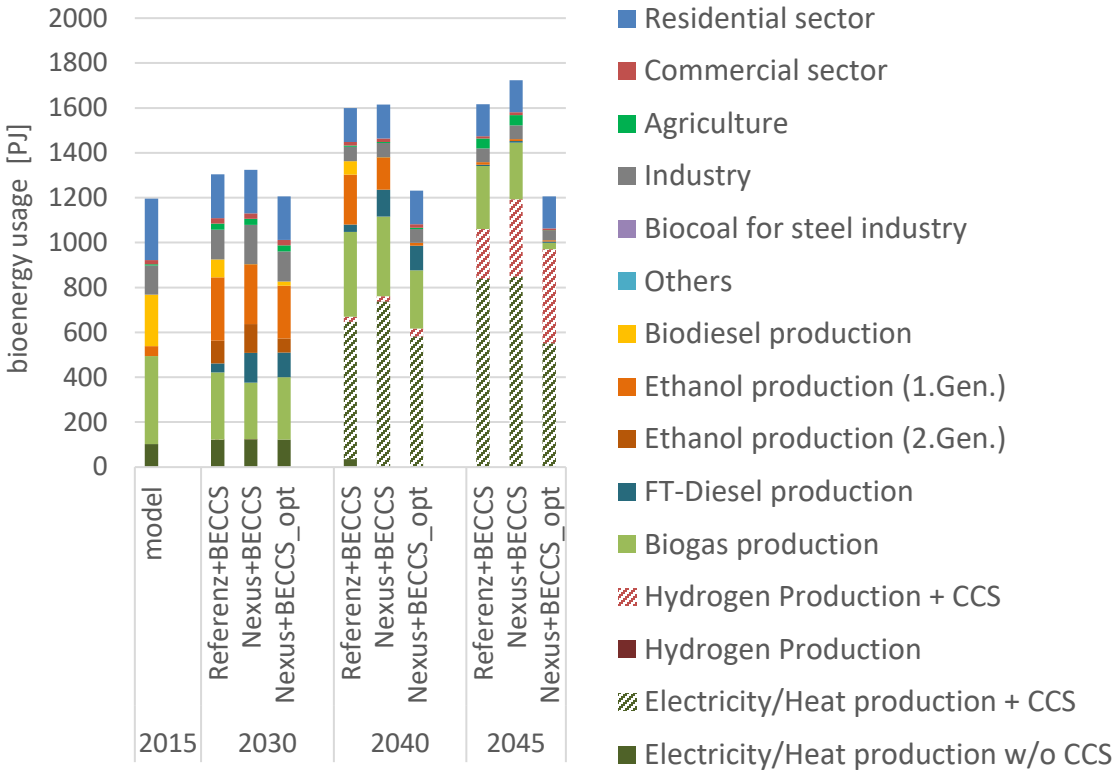
Overall area requirements for the energy transition of BECCS scenarios




- 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)

# 3. Result insights from a case study for Germany

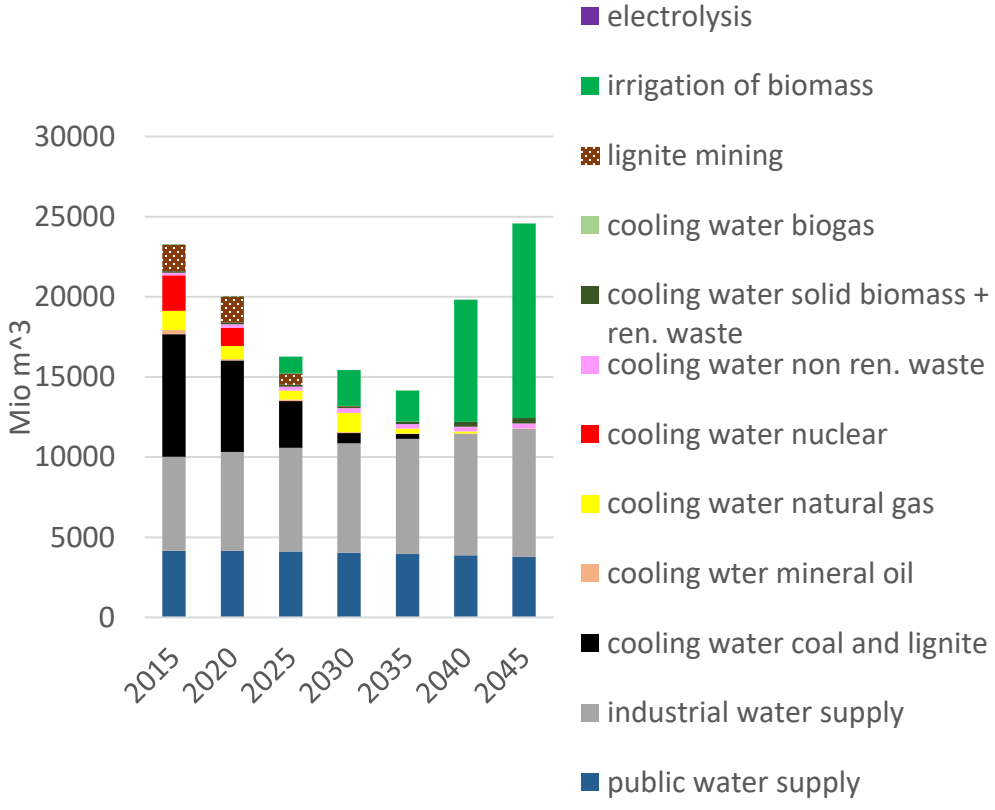
## Bioenergy usage of BECCS scenarios

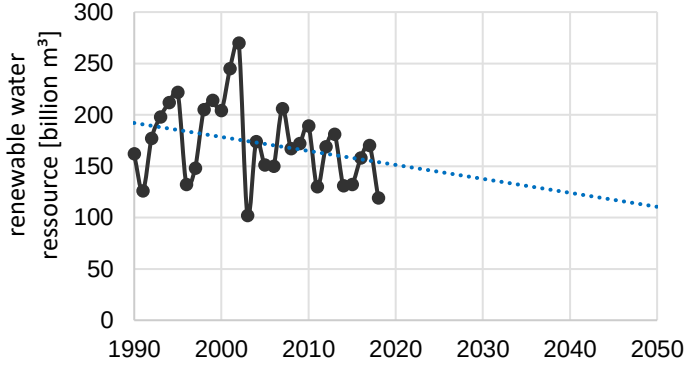



- BECCS technologies are favourite options
- Nexus model has the possibility to irrigate biomass cultivation
- Irrigation of biomass leads to 100 PJ more bioenergy and to 10 Mt more negative emissions in the nexus model (with 4 m ha biomass potential)
- If biomass potential is adjusted to optimal area,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

# 3. Result insights from a case study for Germany

Water withdrawal of the nexus+BECCS scenario




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

## 3. Result insights from a case study for Germany

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

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Universität Stuttgart
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und Rationelle Energieanwendung

# Thank you for your attention!

**Vera Sehn**

E-Mail Vera.sehn@ier.uni-stuttgart.de

Institute of energey economics and rational energy use

University Stuttgart

## 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 apllied 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