Setting up a Long-Term European Electricity System Model Incorporating Climate Change Effects

Fabian Gotzens, M.Sc.
PhD candidate

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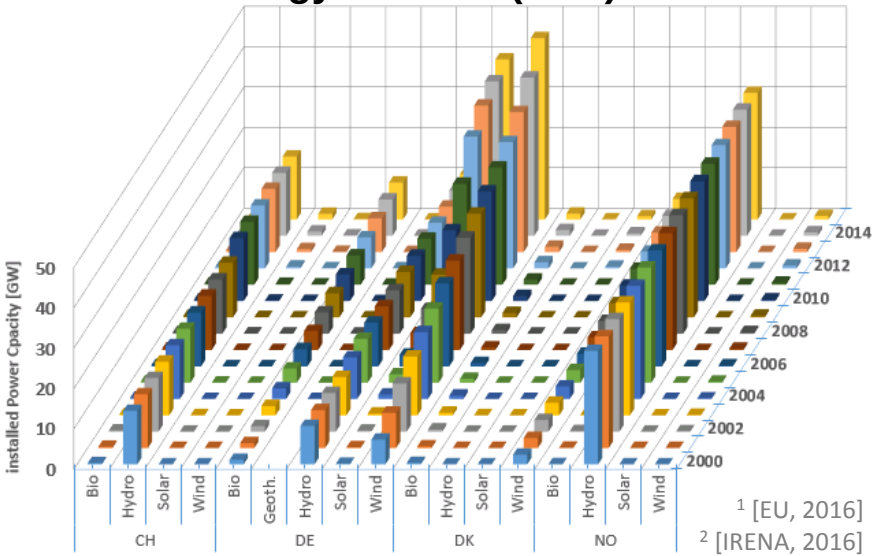
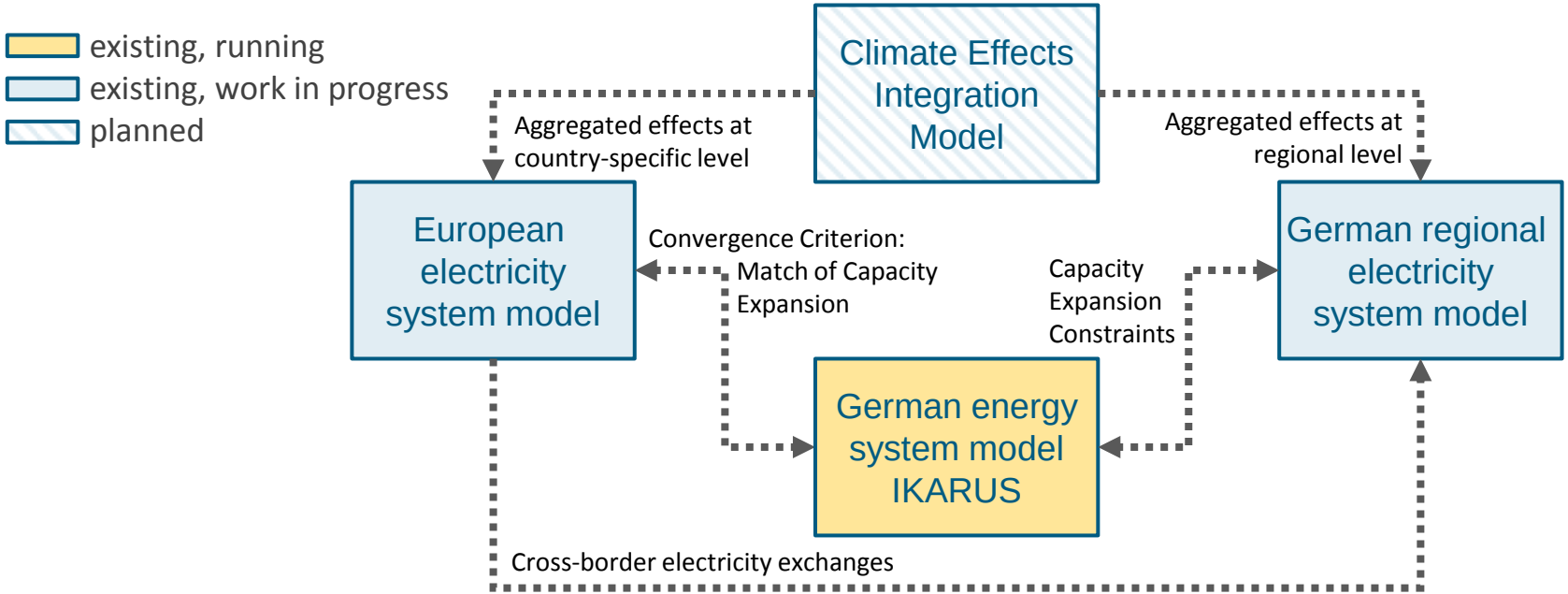
Motivation

- The EU sets itself ambitious energy and climate targets[1] until 2030
  - ≥ - 40% **greenhouse gas emissions** compared with 1990
  - ≥ 27% of total energy consumption from **renewable energy sources (RES)**
  - ≥ 27% increase in **energy efficiency**
- Expansion of RES develops differently according to country-specific goals and RES potentials[2]
- Climate change might influence RES potentials + the related political goals
- Policy advice is needed for the required fundamental change in energy systems



[1] [EU, 2016]
[2] [IRENA, 2016]

Overview of Employed Models



Main Research Question:

How, when and where might climate change effects impact the European electricity system?

European Electricity System Model

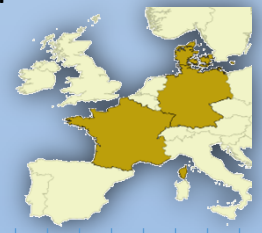
Work in progress

Technical Parameters
- Power plant database (technologies, fuels, efficiencies decommission pathways, …)
- RES geographical potentials
- RES temporal availability factors
- Cross-border transmission capacities
- CO_2 emission factors
- Demands per sector

TIMES Model

Paradigm
LP capacity expansion model

Regions
European countries



Years
2010–2050

Resolution
4 seasons, 2 weekdays, 24 hrs
= 192 time slices per year

Economical Parameters
- Fuel Prices
- CO_2 Prices
- Technology investment costs
- Fixed + variable O&M costs

Policy Parameters
- CO_2 reduction targets
- RES expansion goals

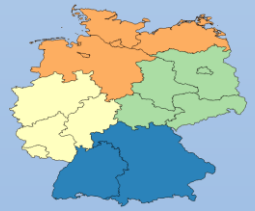
German Spatial Electricity System Model

Technical Parameters
- Power plant database (technologies, fuels, efficiencies decommission pathways, …)
- RES geographical potentials
- RES temporal availability factors
- Cross-border transmission capacities
- CO_2 emission factors
- Demands per sector

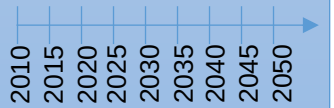
TIMES Model

Paradigm
LP capacity expansion model

Regions
German Regions



Years
2010–2050



Resolution
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Economical Parameters
- Fuel Prices
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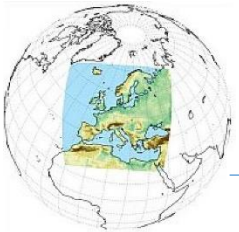
Policy Parameters
- CO_2 reduction targets
- RES expansion goals

Climate Effects Integration Model

Work in progress

WCRP CORDEX
EURO-CORDEX



Solar Irradiation

- Spatial resolution: 12-km pattern
- Temporal resolution: 3h
- Time Horizon: 2100

Near-surface windspeeds

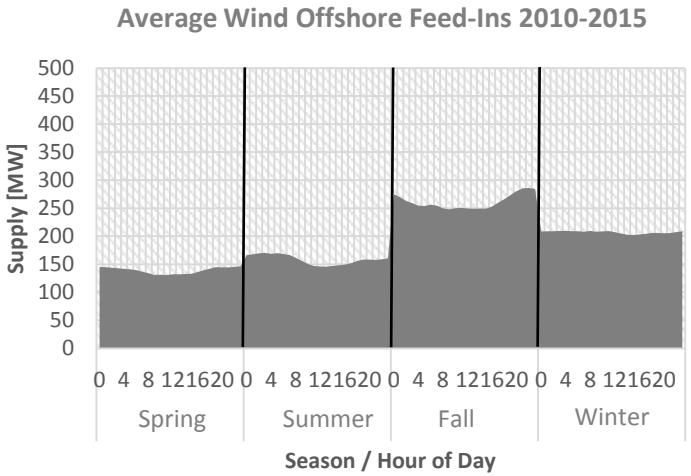
- Spatial resolution: 12-km pattern
- Temporal resolution: 3h
- Time Horizon: 2100
- Height: 10 m

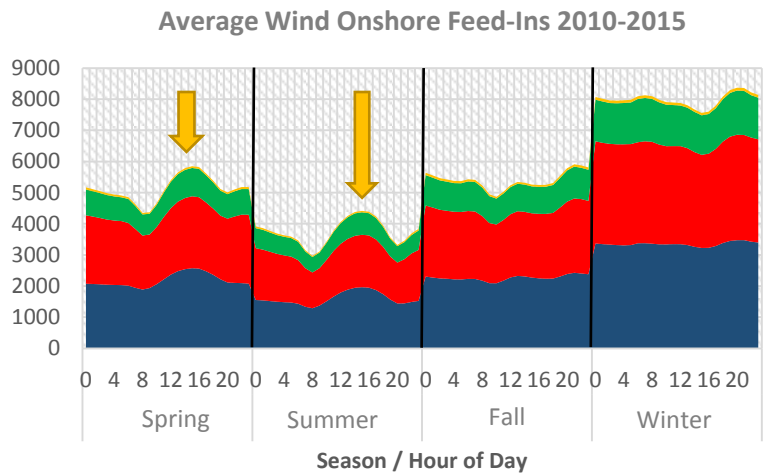
Climate Data Model

- Spatial allocation of cell pattern to countries
- Temporal disaggregation into hourly values
- Adjustment of wind heights via
  - surface roughness
  - turbine curves
  - clustering

- Final derivation of full load hours for wind and solar power for each region and year
- Possible integration of data from [Tobin et al., 2015]
- Planned cooperation with *Institute of Geophysics and Meterology, Univ. Cologne*

Pre-analysis of Historical RES Feed-Ins





- Average offshore wind feed-ins do **not** show a clear **intra-day temporal** dependence
- Interesting: Average onshore wind feed-ins show
  - **midday peaks in spring + summer**
  - rather flat patterns in fall + winter

→ Are these patterns subject to climate change? If yes, how is the impact on the electricity supply system?

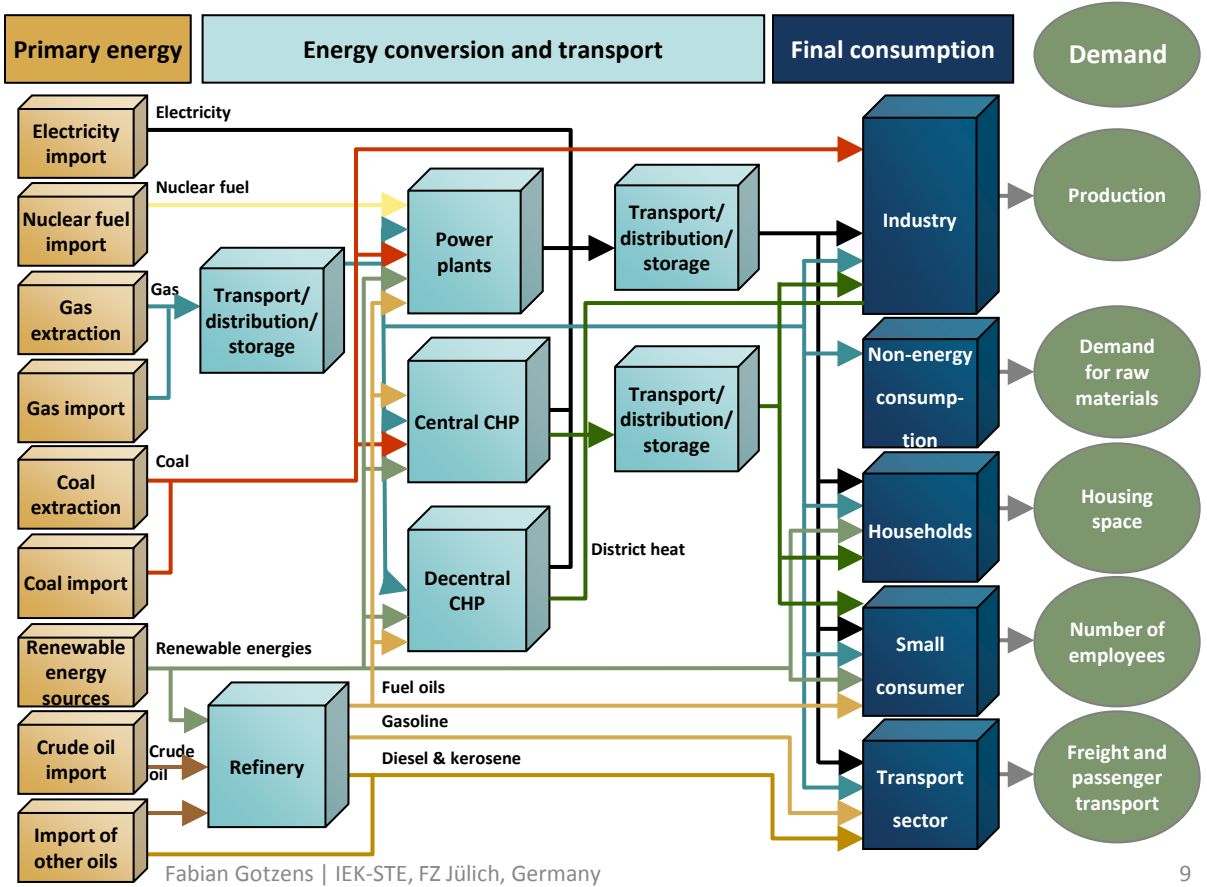
German energy system model IKARUS*

Model type:
Techno-economic bottom-up optimization model of the German energy system

Objective function:
minimizing of total system costs

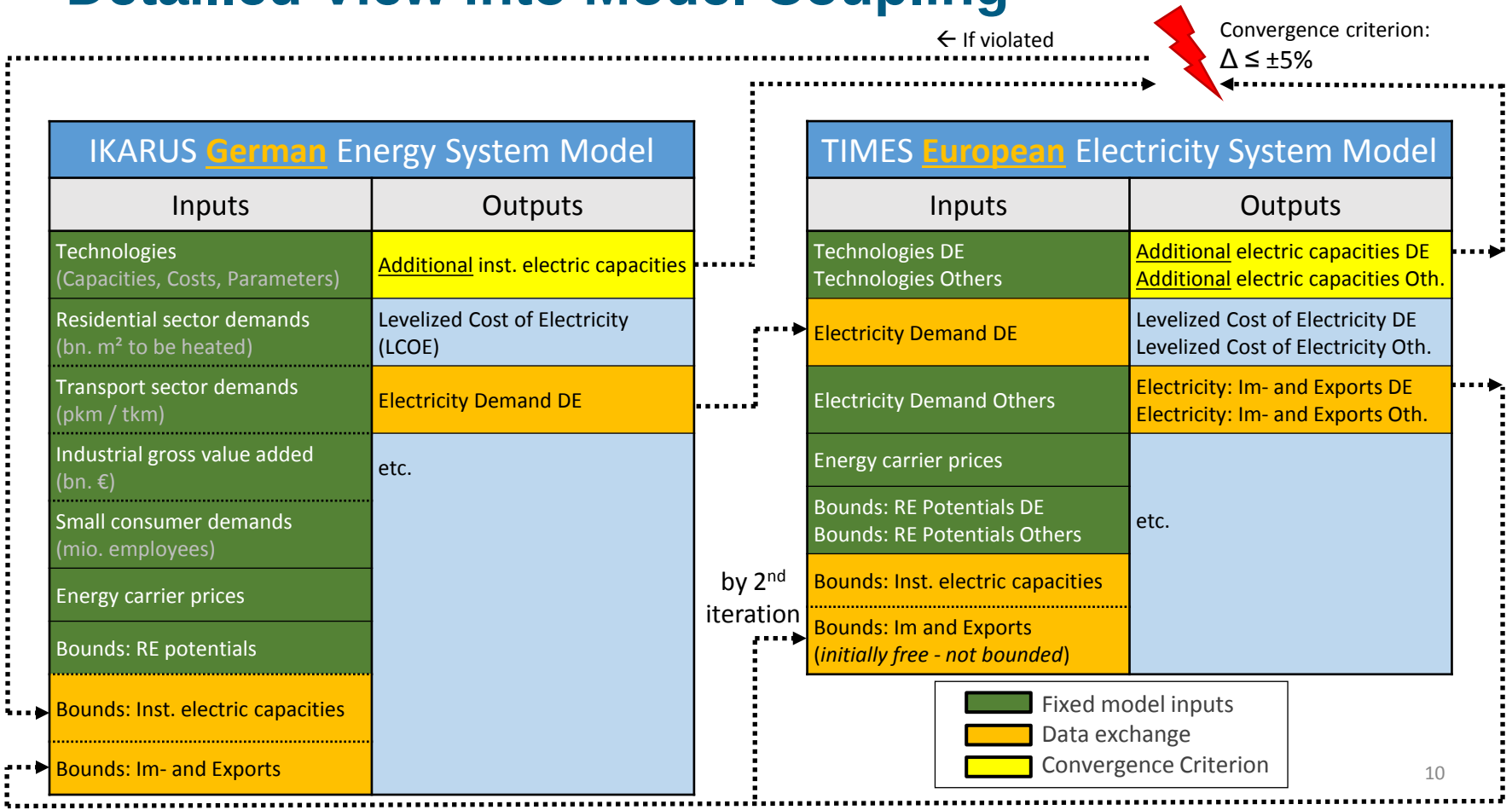
Model philosophy:
myopic
(no perfect forsight)

Time horizon:
until 2050
(in 5 years intervalls)



* IKARUS: Instruments for greenhouse gas reduction strategies

Detailled View into Model Coupling



Scenario Background

- Approach: Comparison with reference scenario

  → Consistent scenarios for European and German model needed

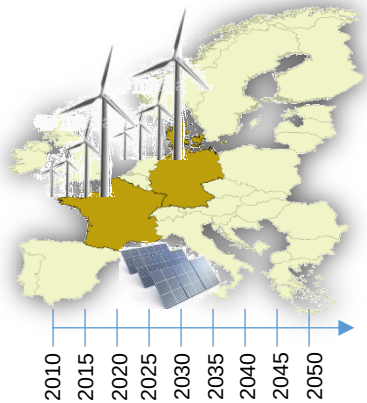
Reference Case

Usage and capacity expansion only subject to national constraints

Comparison

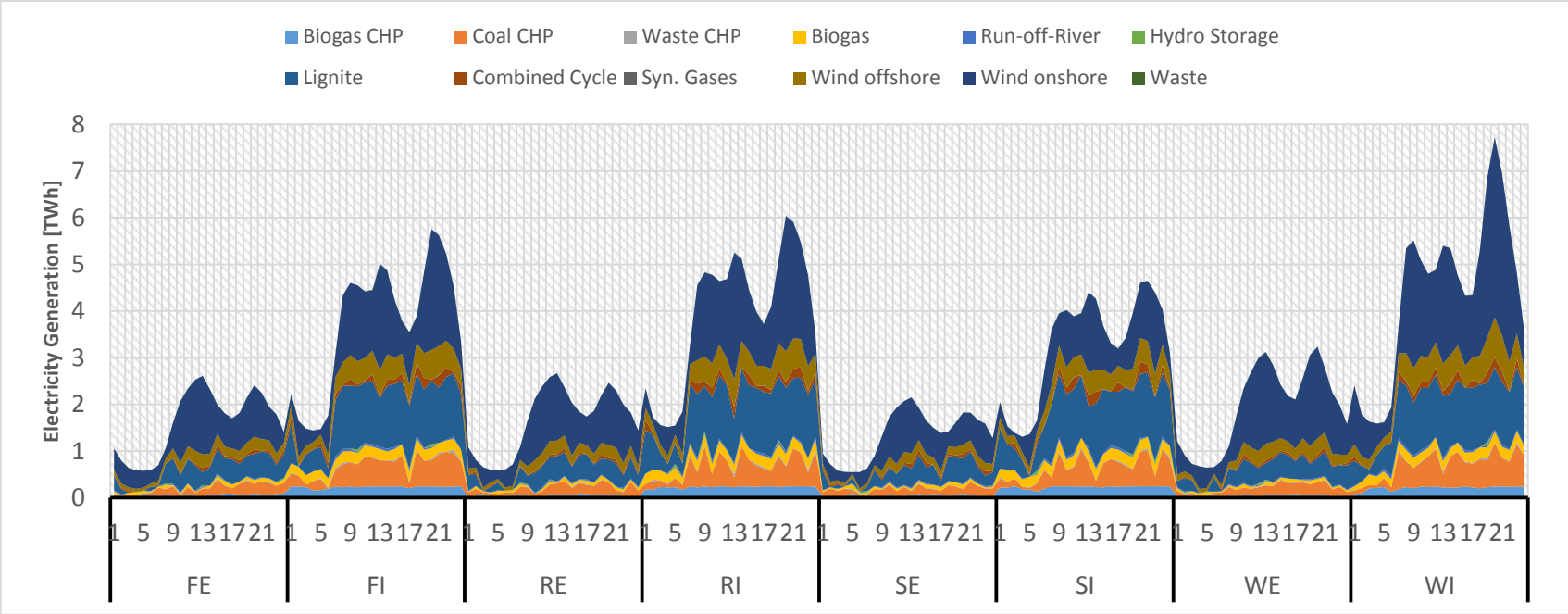
Climate Change Cases

Usage and capacity expansion additionally restricted by climate change impacts



- Sensitivity case study: Autarky aspects
  - Which countries will be able to supply energy self-sufficiently?
  - For those how could, what would be the additional costs per country?
  - Which countries will –due to limited potentials– still rely on energy imports?

Prelimary Exemplary Modeling Results



Finishing Model Approach and its Application

- Outlook and Next Steps
  - Development of the climate data integration model
  - Modeling of further European countries
  - Integration of storage devices
  - Integration of grid features

- Open Questions for Discussion
  - Adequate modeling of the future role of biogas?
  - ...optimal temporal resolution across scales?
  - ...decrease calculation time of double soft-coupling?

References

Slide	Source
3	**EU 2030 Energy & Climate Framework** *http://ec.europa.eu/clima/policies/strategies/2030/index_en.htm* **Renewable Expansion Data** *IRENA (2016), Renewable Energy Statistics 2016, The International Renewable Energy Agency, Abu Dhabi*
5,6	**ETSAP TIMES** Loulou et al. (2005), Documentation for the TIMES Model
7	**Tobin et al. (2016),** Climate change impacts on the power generation potential of a European mid-century wind farms scenario
8	**Wind Feed-In Data Germany** http://www.50hertz.com/de/Kennzahlen/Windenergie/Archiv-Windenergie http://www.amprion.net/windenergieeinspeisung http://www.tennettso.de/site/Transparenz/veroeffentlichungen/netzkennzahlen/tatsaechliche-und-prognostizierte-windenergieeinspeisung https://www.transnetbw.de/de/kennzahlen/erneuerbare-energien/windenergie **Picture TSOs** https://upload.wikimedia.org/wikipedia/commons/thumb/1/17/Regelzonen_deutscher_%C3%9Cbertragungsnetzbetreiber_neu.png/200px-Regelzonen_deutscher_%C3%9Cbertragungsnetzbetreiber_neu.png
9	*Heinrichs et al. (2015), IKARUS – a German energy system model, IEK-STE, FZ Jülich*

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