Can resource classes substitute spatial resolution in energy system models? A spatial scaling analysis.

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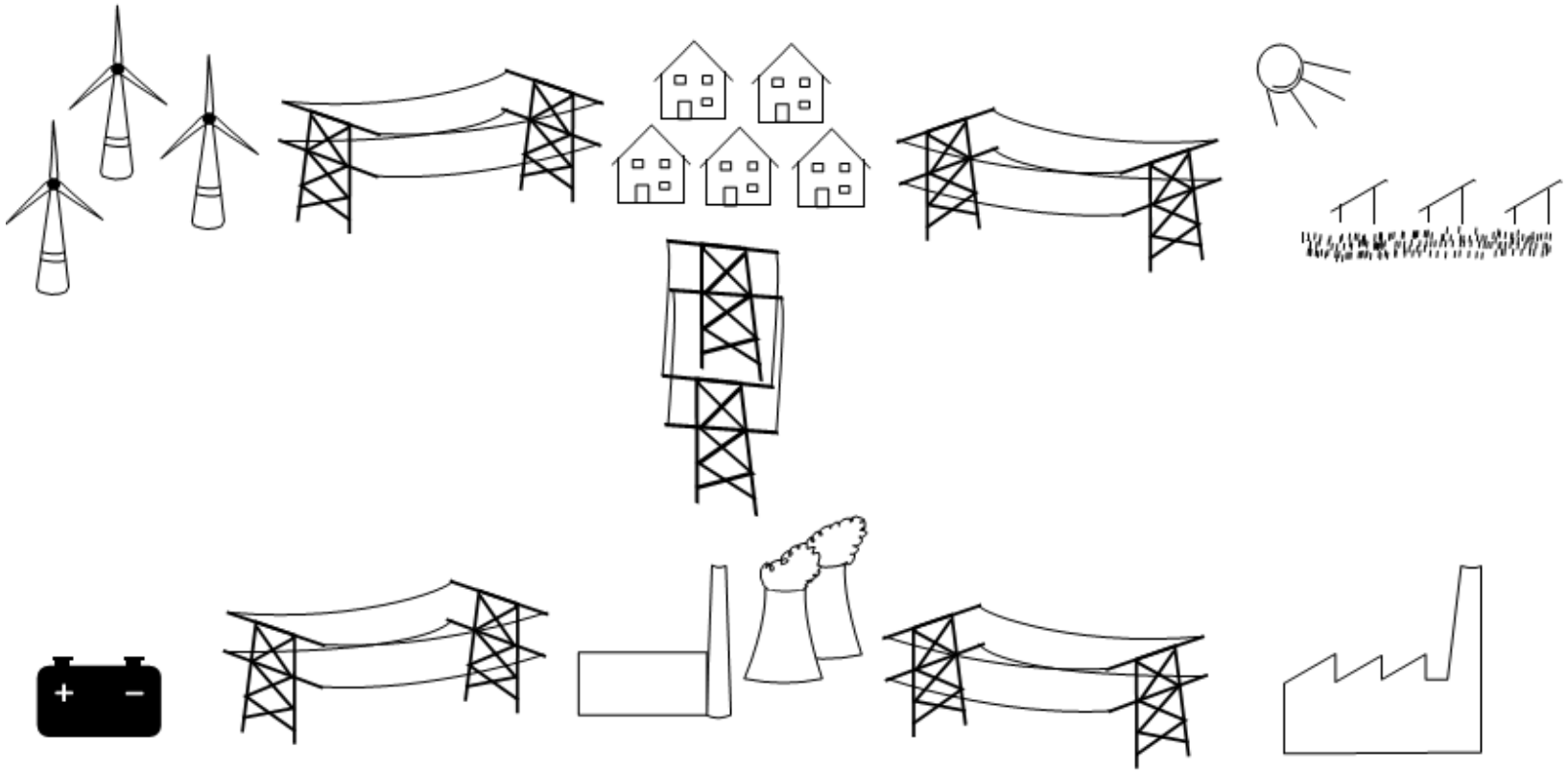
Key questions

- What influence do different levels of detail have on the modelling of Variable Renewable Energy (VRE) potentials?
  - technological detail
  - spatial resolution
  - how can we choose the best resource sites for the energy system
    - one approach: take only the best 20% of potential [1]
  - -> Can spatial resolution be partially substituted by resource classes?

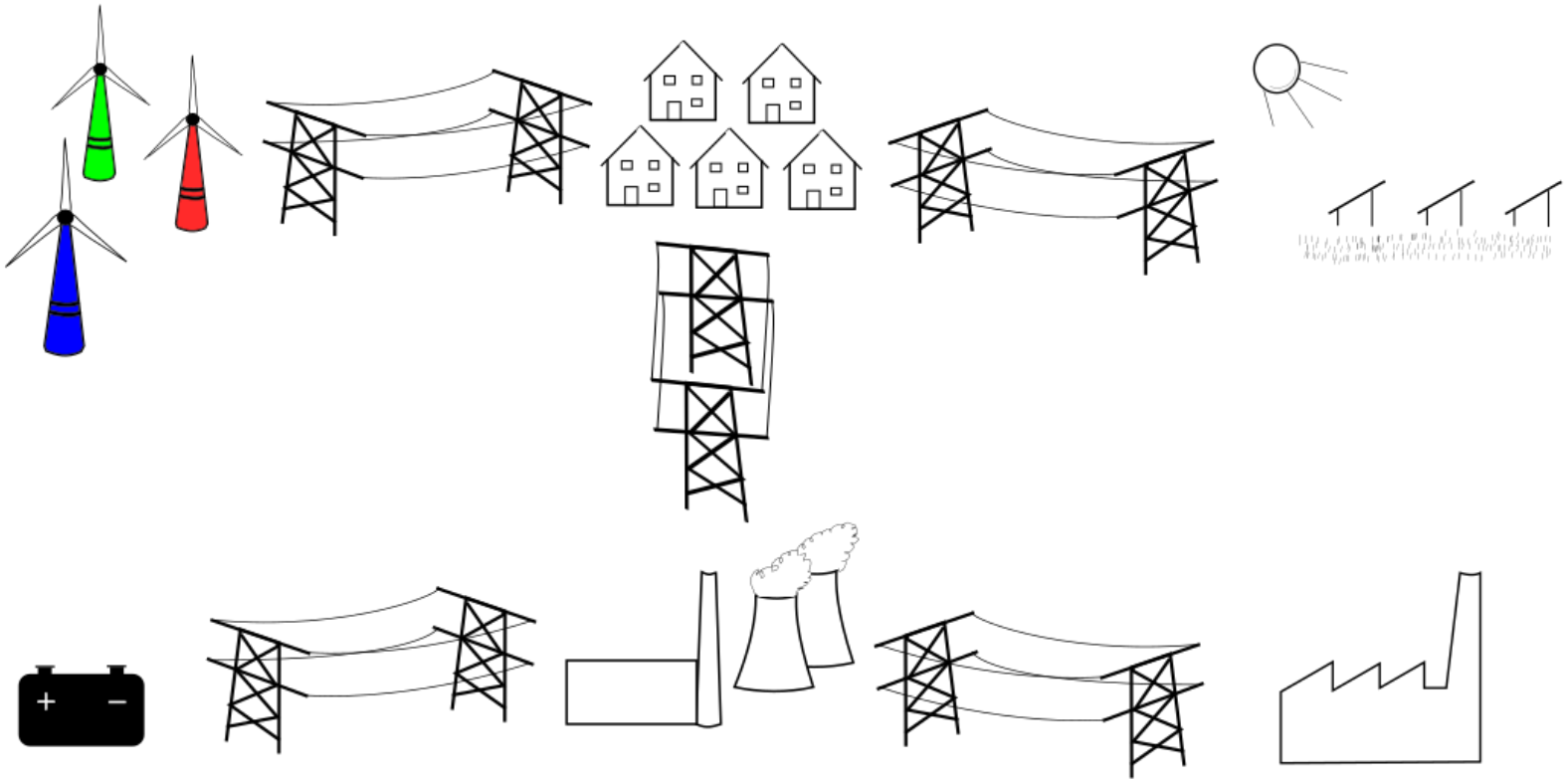
[1] Gils et al.*; 100% Renewable Energy Supply for Brazil --The Role of Sector Coupling and Regional Development*; Energies 2017

Complexity of an Energy System Model (ESM)



Methods

Resource classes



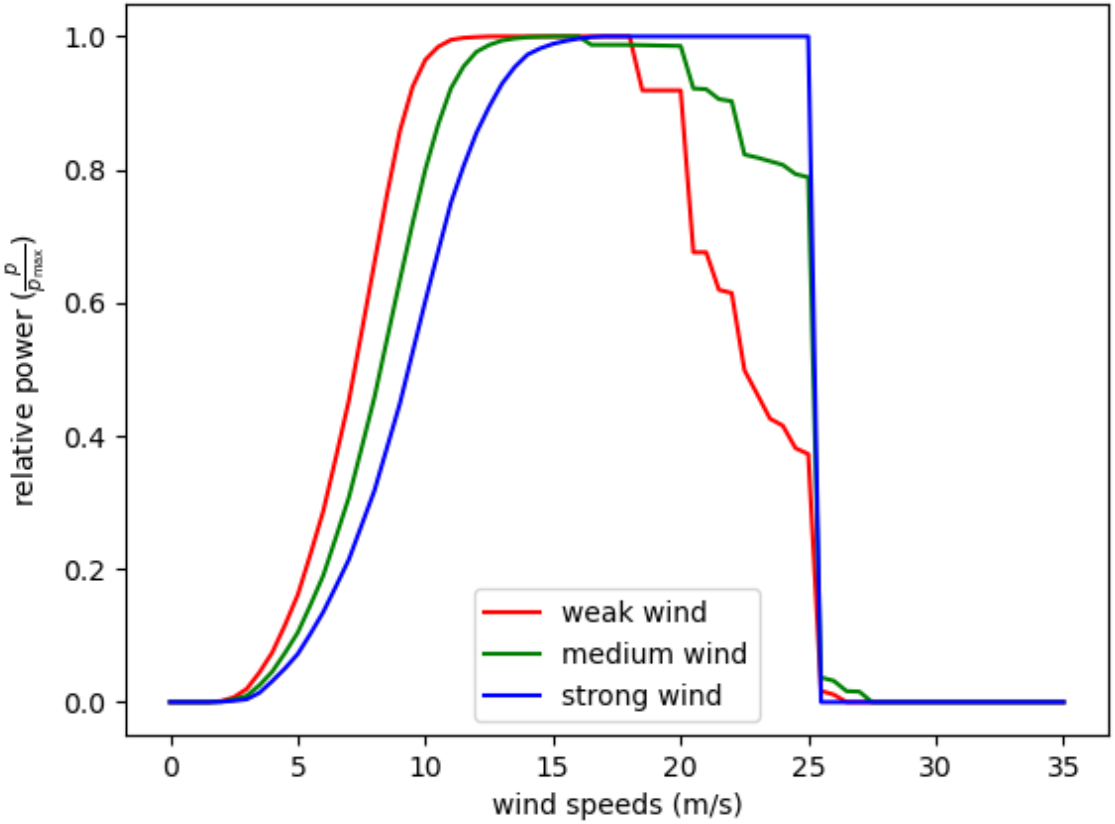
Model parameterisation

REMix-EnDAT is a tool to provide generation time series and cost potential curves for different technologies based meteorological and geographical maps.

- **temporal:**
  - full year time frame; resolution up to 8760h
- **spatial:**
  - raster resolution 0.083°x0.083° time resolved, 0.0083x0.0083° exclusion
  - Germany cut down to 345 onshore and 25 offshore regions
  - for initial analysis aggregated to one region
- **technological:**
  - wind onshore/wind offshore (with resource classes)
  - PV

Scholz, Yvonne *Renewable energy based electricity supply at low costs - Development of the REMix model and application for Europe.* Dissertation, Universität Stuttgart (2012) .

Turbine power curves



Averaged from set of turbine power curves from thewindpower.net

- weak wind < 0.25 kW/m²
- 0.25 < medium wind < 0.4
- strong wind > 0.4 kW/m²

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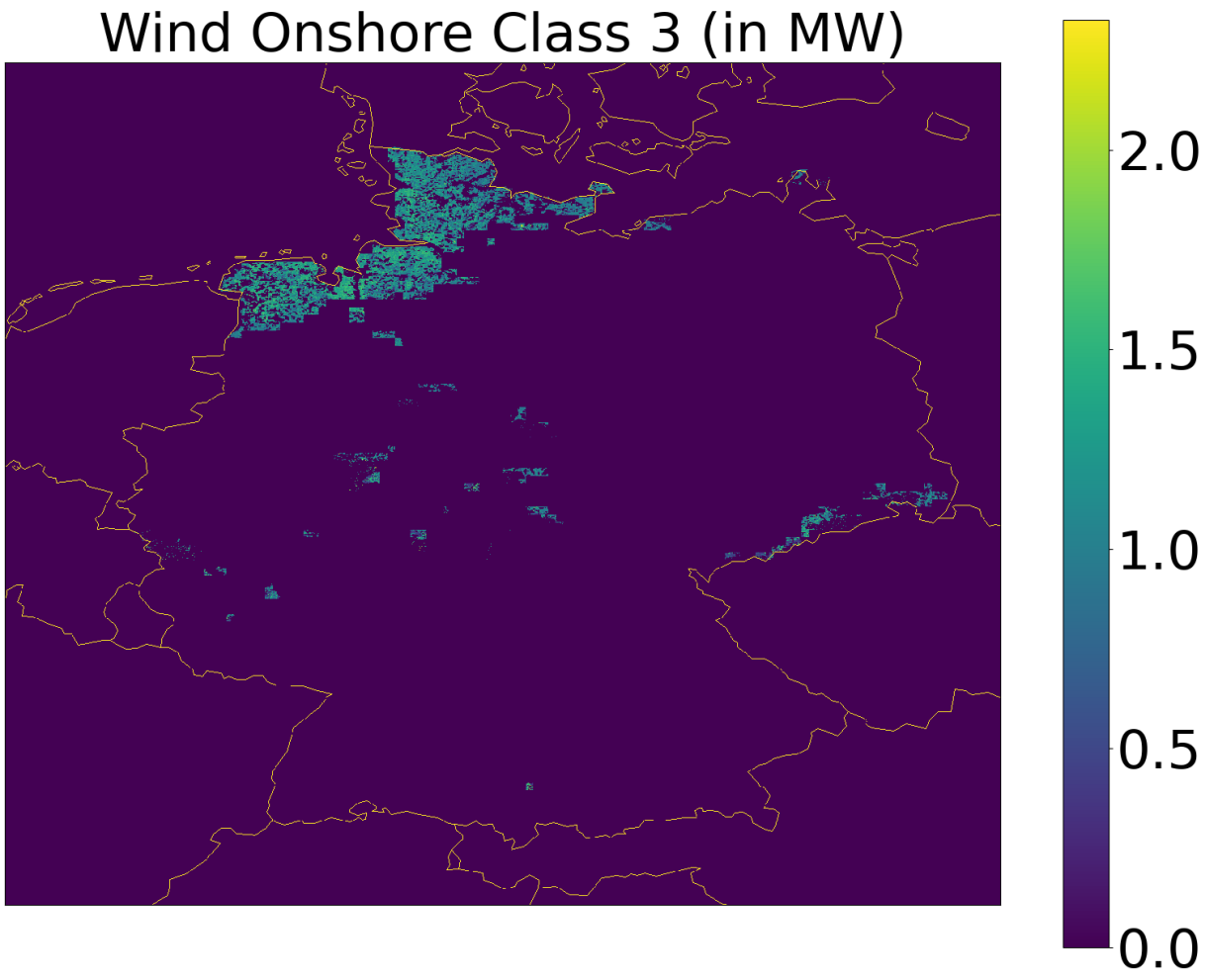
  - Example onshore wind:
    - Five resource classes: $< 6 < 7.5 < 8.5 < 10 < 50$ m/s
    - Three different turbine types with different power densities

Distribution of Resource Classes



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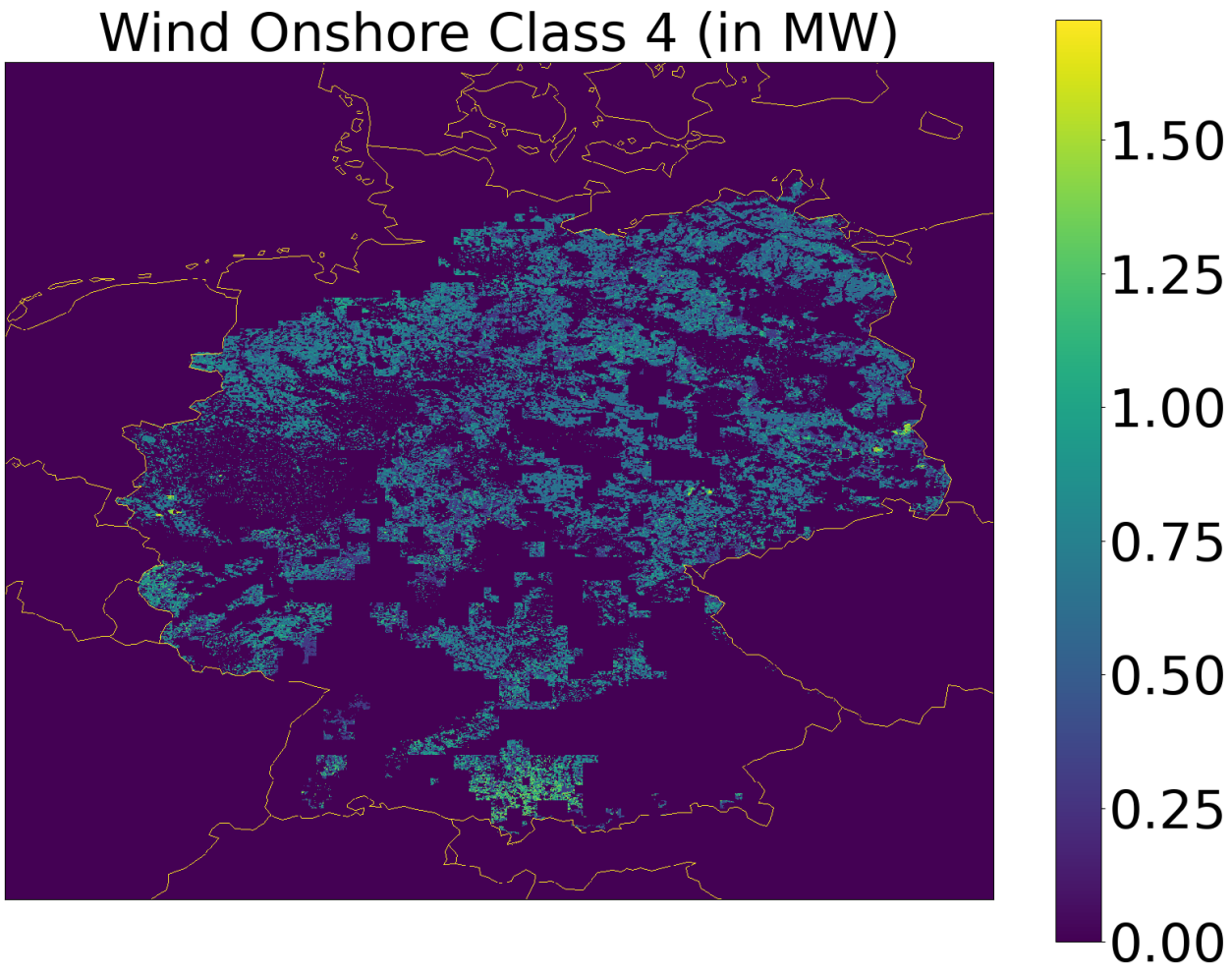

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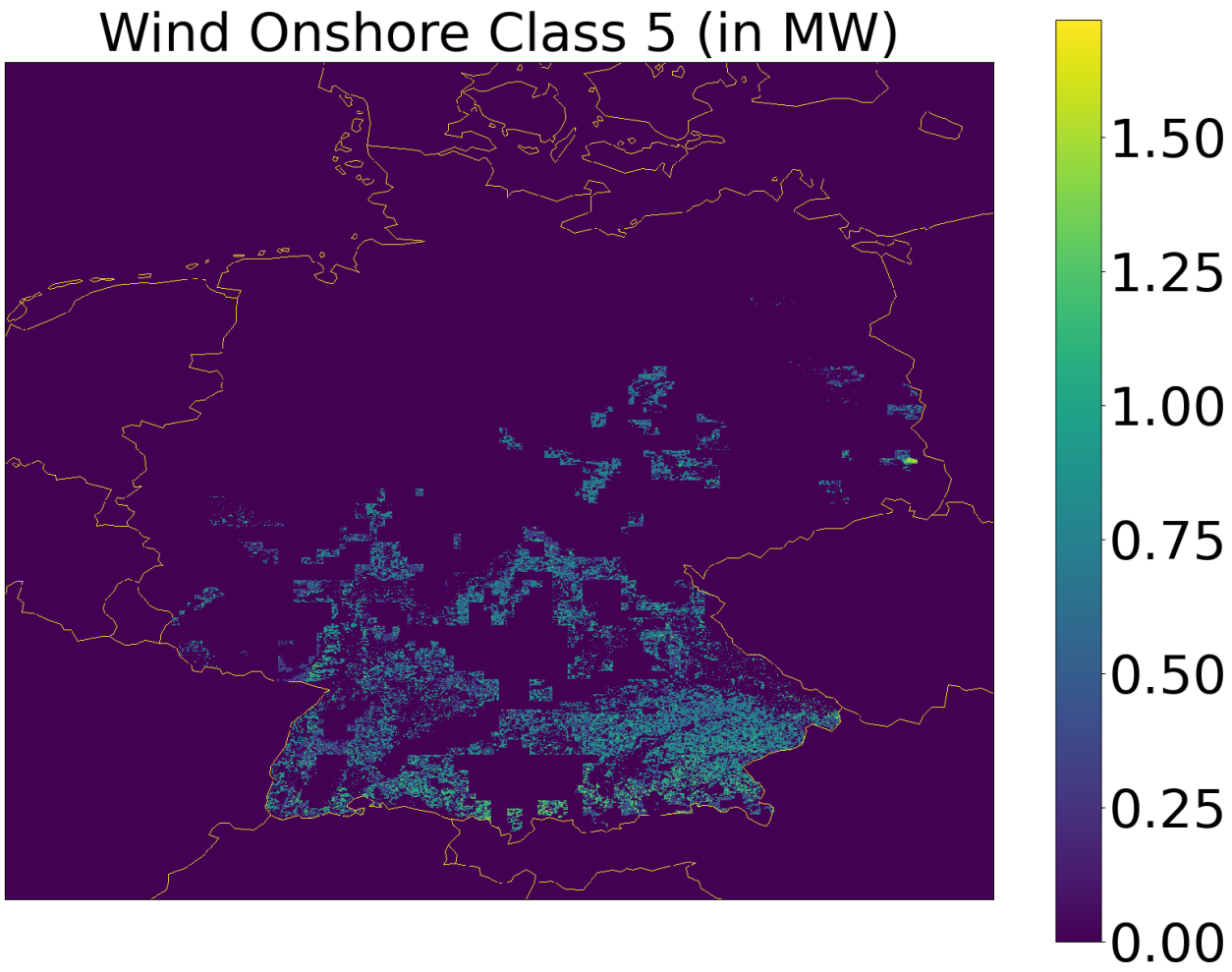
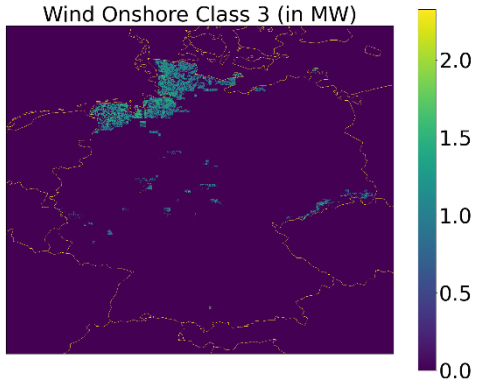
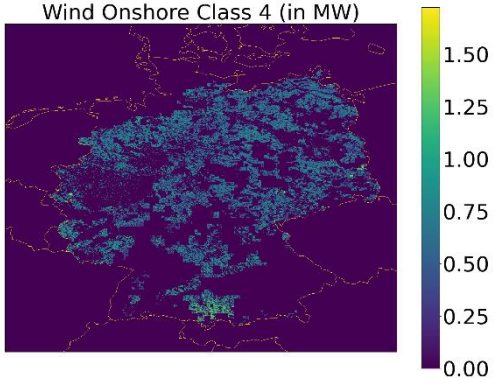
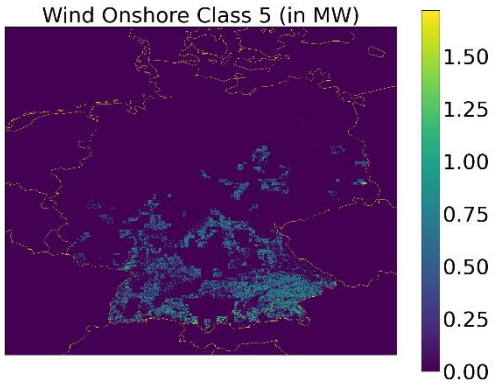


Distribution Resource Classes

- Class 3 in the North
- Class 4 evenly distributed
- Class 5 more towards the South







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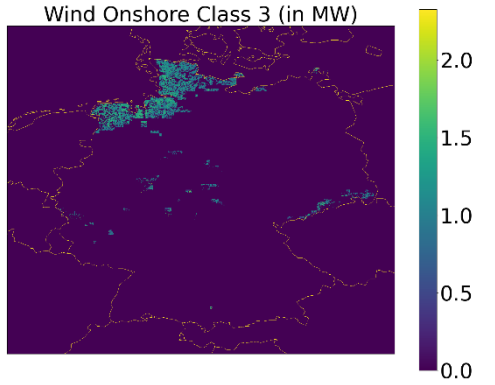
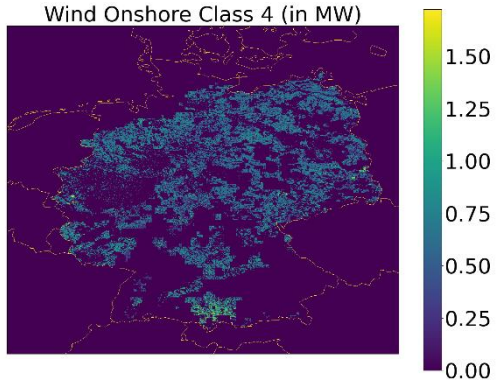
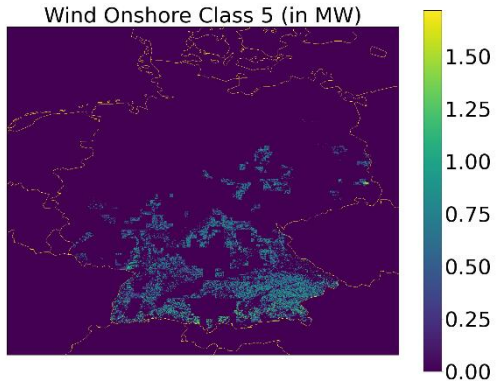
Class	Capacity (GW)	capacity factor	average wind speed (m/s)
3	34	0.42	7.5-8.5
4	129	0.37	6-7.5
5	54	0.22	<6







Maximal generation potential

- load duration curves
- all installation sites used
- no curtailment
- no transmission restraints

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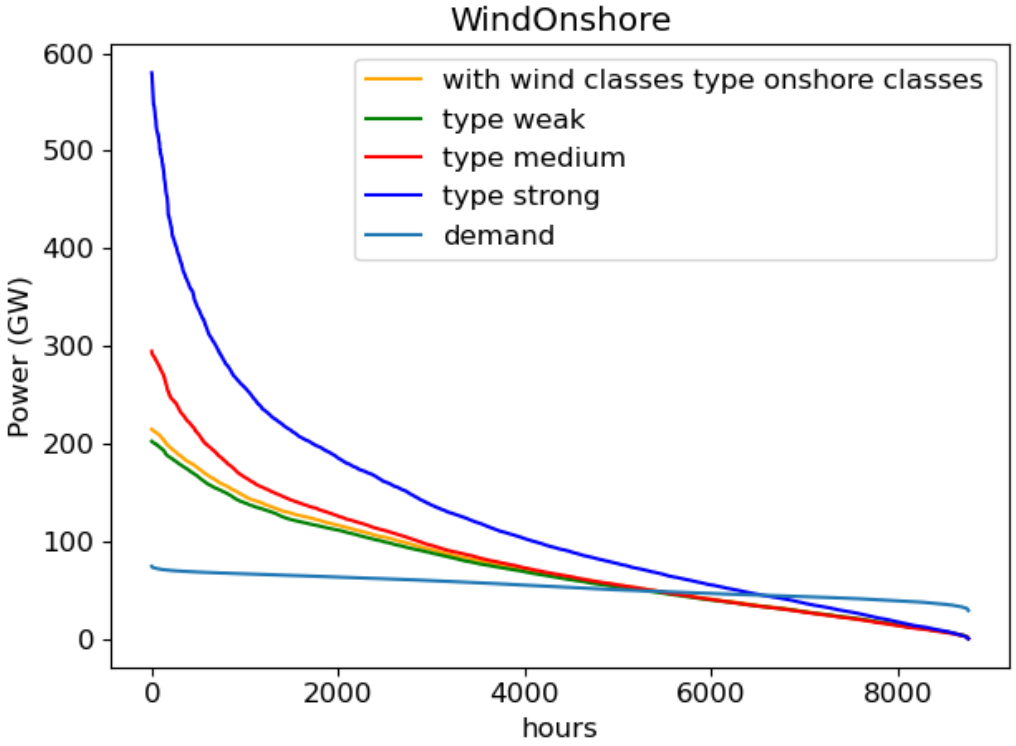
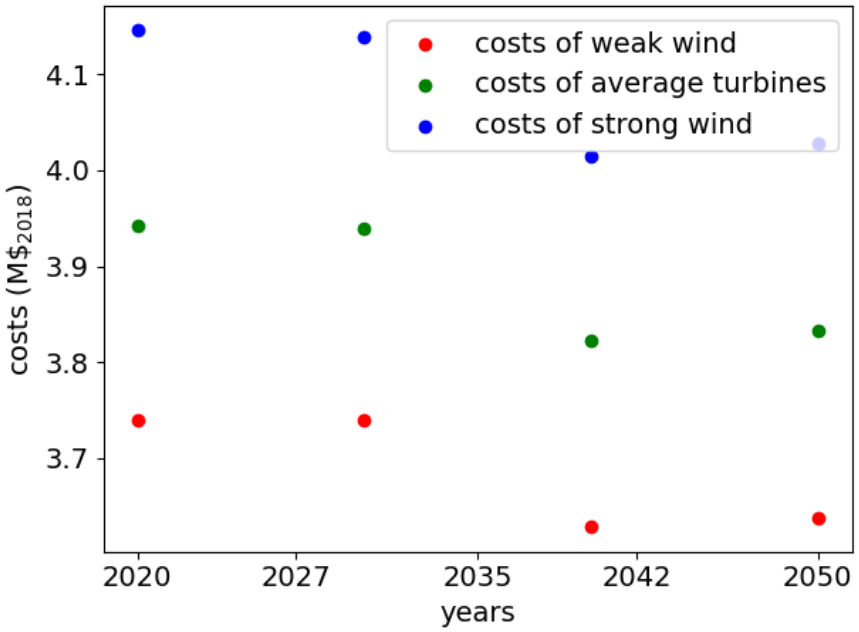


Cost extrapolation (different nameplate capacities)

absolute price



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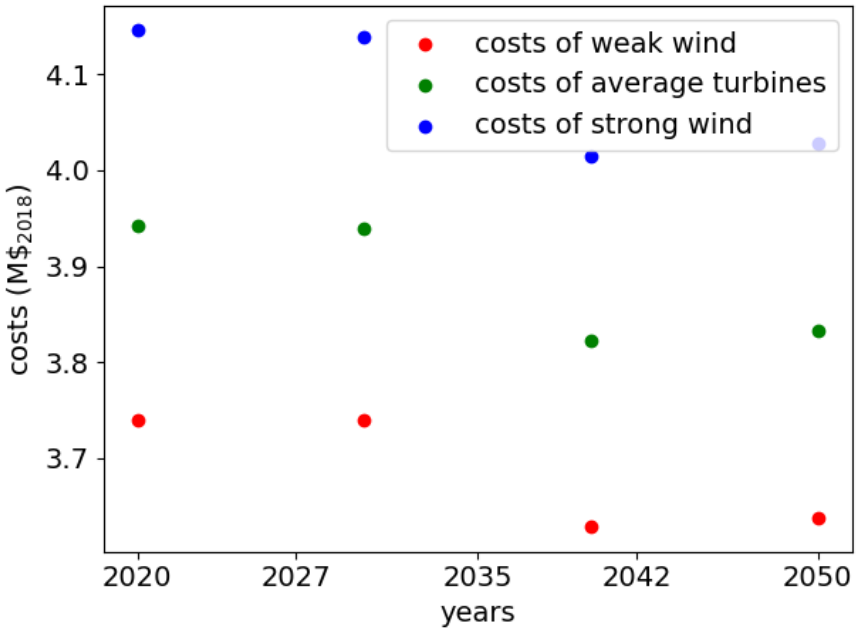
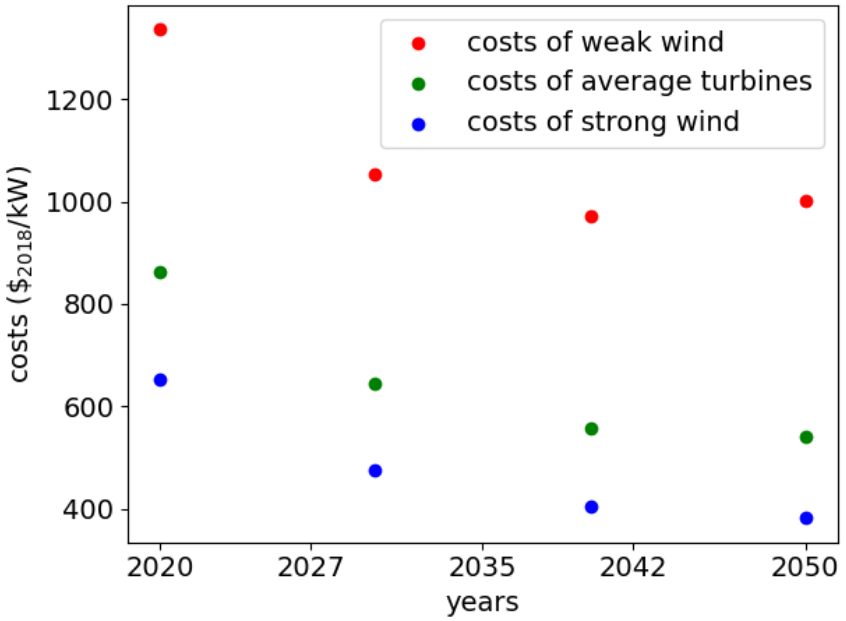


price per kW



Intermediate results of usage of resource categories

- Results for onshore
  - Very different total output
  - the use of resource categories gives the ESM more system friendly turbines to choose
  - Energy system can choose more productive wind sites without sacrificing potential

scenario	**capacity (GW)**	**energy (TWh)**	**median (GW)**	**maximal power (GW)**	**LCOE ($/kWh)**
weak wind	207	639	62	203	0.024
medium wind	304	727	64	295	0.016
strong wind	602	1092	92	580	0.015
with classes	220	665	65	215	0.022

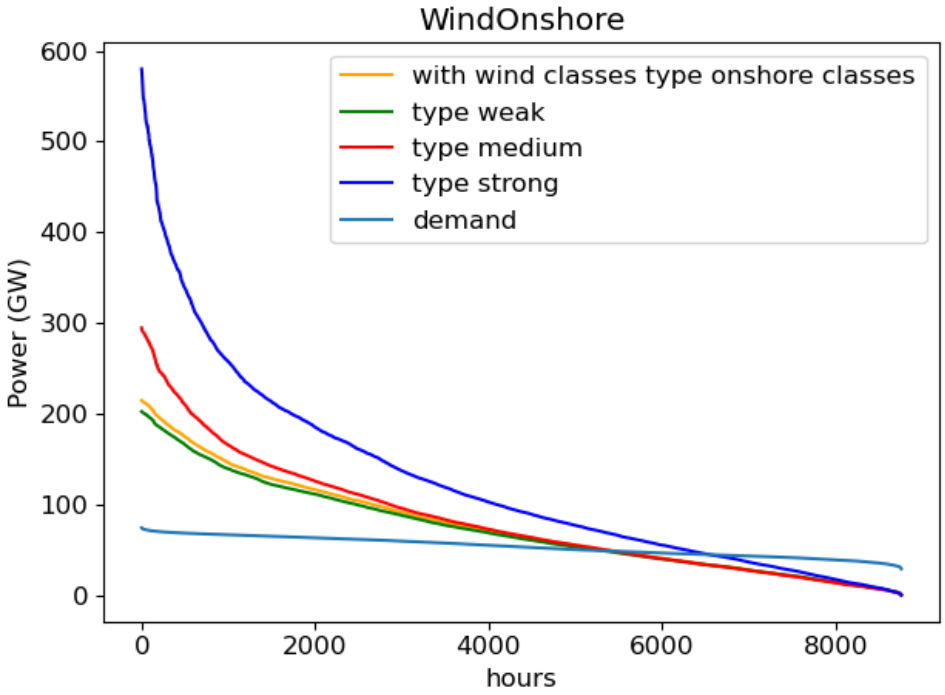
Conclusion

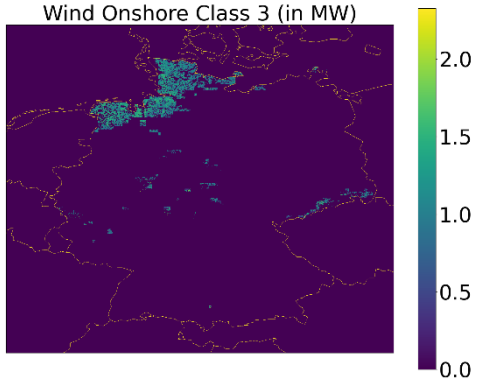
- Benefits of categories
  - the energy system can choose technologies based on system friendliness
  - more technologies can be used for the same primary energy source
- No obvious best turbine from a system perspective
- Without curtailment, wind turbines with a higher power density are producing power at a lower cost
- The median power of weak wind, medium wind, and wind classes are similar

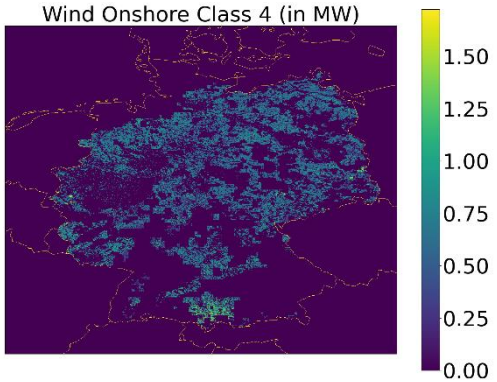
Outlook

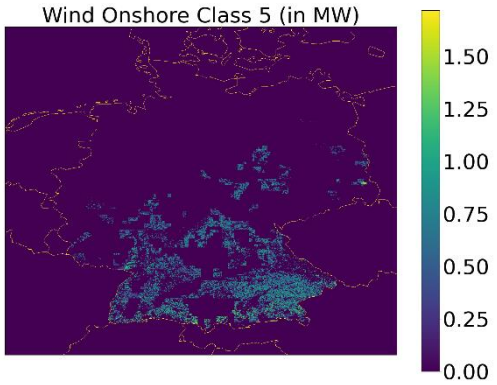
- Use higher resolved input data for the wind input
- Further benefits are being investigated
  - Apply the feed in time series in an ESM with high spatio-temporal resolution
  - Investigate the interdependency of resource classes and spatial resolution
  - Do a scaling analysis

Thank you for your time







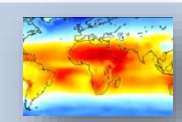


Input Data for EnDAT

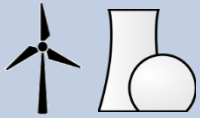
- time resolved (hourly):
  - DWD (Cosmo-EU) (~10km raster)
- Spatially resolved (~1km raster)
  - Copernicus Landcover Map
  - exclusion maps:
    - FAO-Unesco Soil map
    - Global lakes and wetlands database
    - world protected areas

REMix

Input

RE potentials 

Demand profiles (power, heat, …) 

Scenario assumptions 

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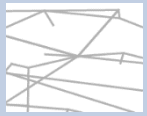
Grid data 

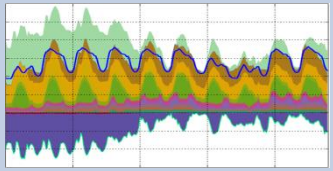
Mathematical Optimization (Linear programing)

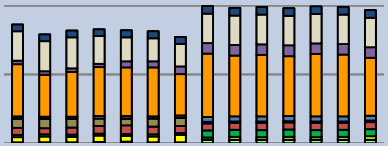
Minimization of system costs

Min/Max $\sum_{j \in n} c_j x_j$

$\sum_{j \in n} a_{ij} x_j \geq b_i \quad , \forall i \in 1 \ldots m \qquad x_j \geq 0$

Output

Dispatch (technology commitment) 

Capacity expansion (storage, transmission lines, power plants) 

DLR

Model parameterisation

For the investigation REMix[1] will be used, a linear optimising ESM

- **temporal:**
  - full year time frame; resolution up to 8760 hours
- **spatial:**
  - Germany with 345 onshore and 25 offshore regions
  - based on current high voltage transmission nodes
- **technological:**
  - limited to power sector
  - pre-set scenario capacities: power plants and grid
  - expansion options:
    - lithium ion batteries
    - transmission grid
    - gas power plants
    - VRE expansion

Gils et. al.; „Integrated modelling of variable renewable energy-based power supply in Europe“; Energy 2017