Balancing GHG mitigation and land use conflicts: Alternative Northern European energy system scenarios

Presentation of methodology and preliminary model results

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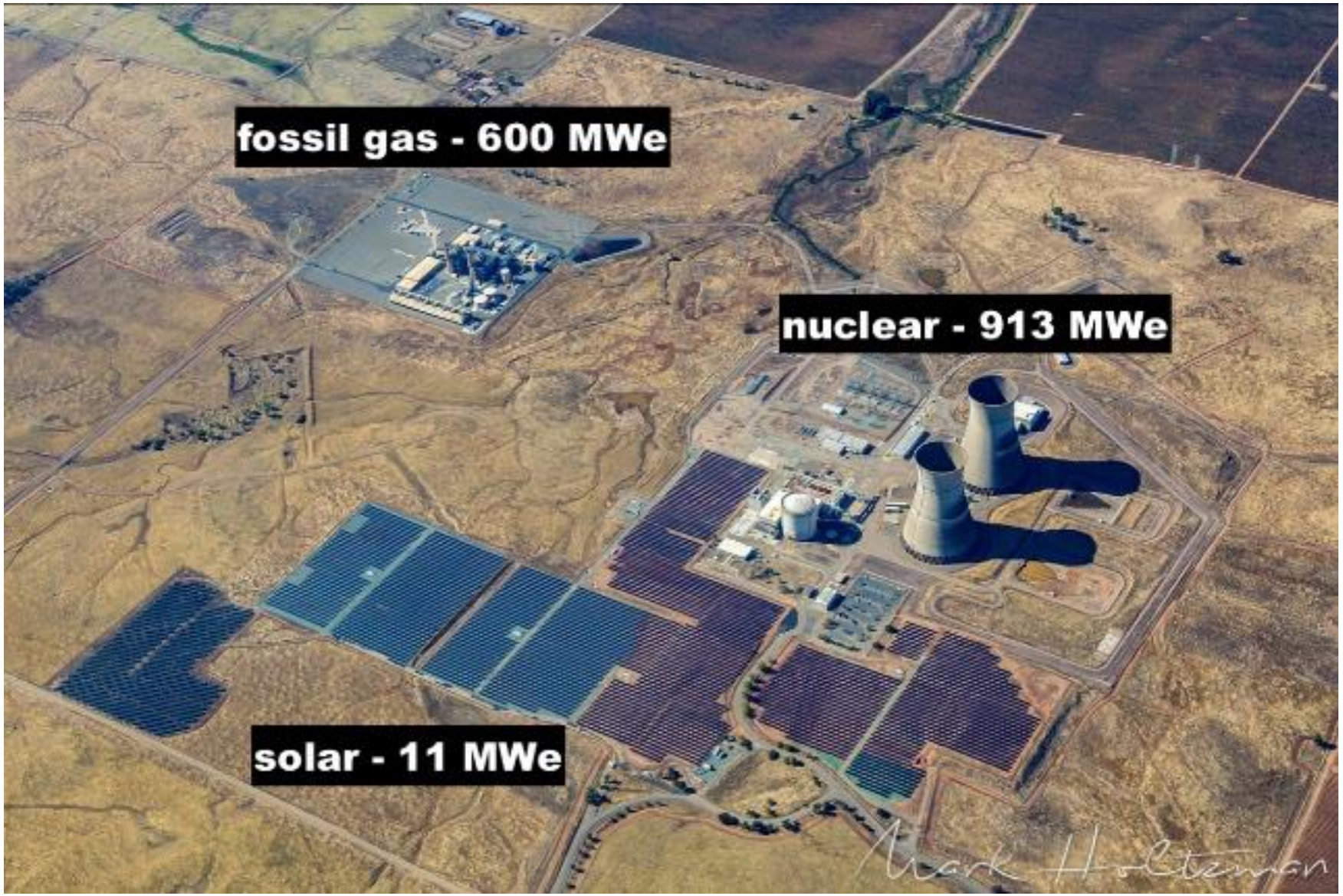
Background

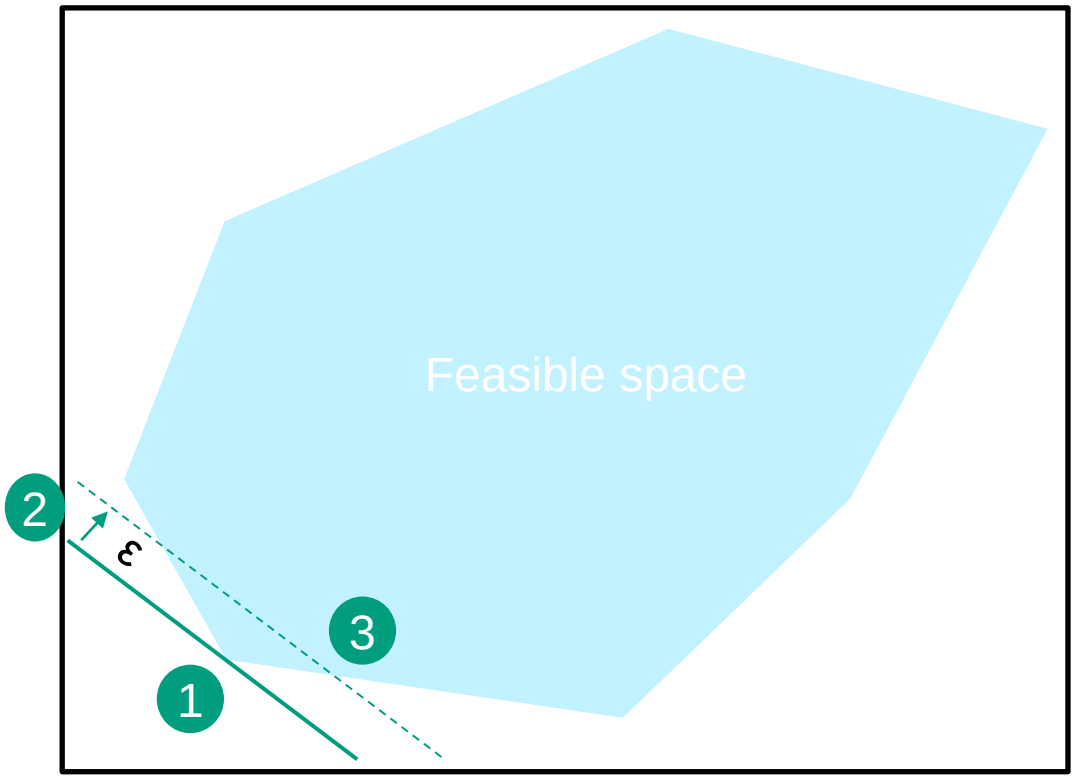
- Ambitious renewable and abatement targets are announced.
  - Increasing importance of renewables

- Renewable generation technologies typically have larger land requirement.
  - Land conflicts
  - NIMBY and NIABY

=> Assumption: compromise between system costs and total required land might be a more feasible solution.


fossil gas - 600 MWe
nuclear - 913 MWe
solar - 11 MWe

Modeling to generate alternatives (MGA)



- Step 1: find the anchor of the lowest system costs.
- Step 2: assign a slack ε to allow the system costs increasing by ε%.
- Step 3: define the MGA objectives and find the compromised systems.

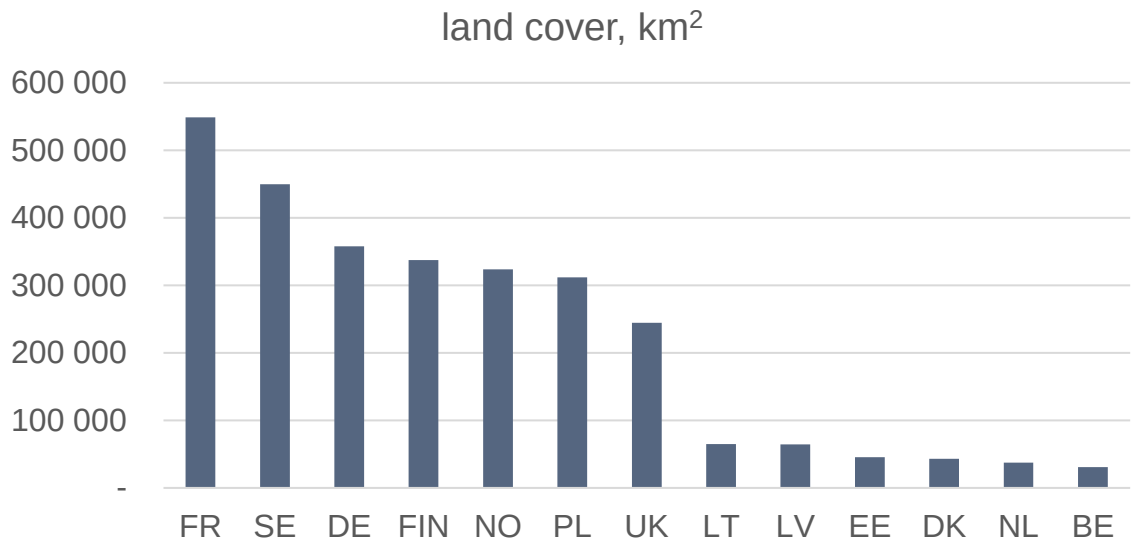
Main assumptions

- Year 2040, 8 weeks, 24 hours
- Electricity demand +20% from current level
  - More refined projections in pipeline
- Zero fossil emissions, except for the industrial areas in the Western European countries
- Given transmission capacities as in the TYNDP (expected and planned)
- Generation capacities determined by the model
- Step-wise price for wood pellets (the land requirement for wood pellets is not counted since it is regarded as residues from timber harvesting)

Land area and land requirement

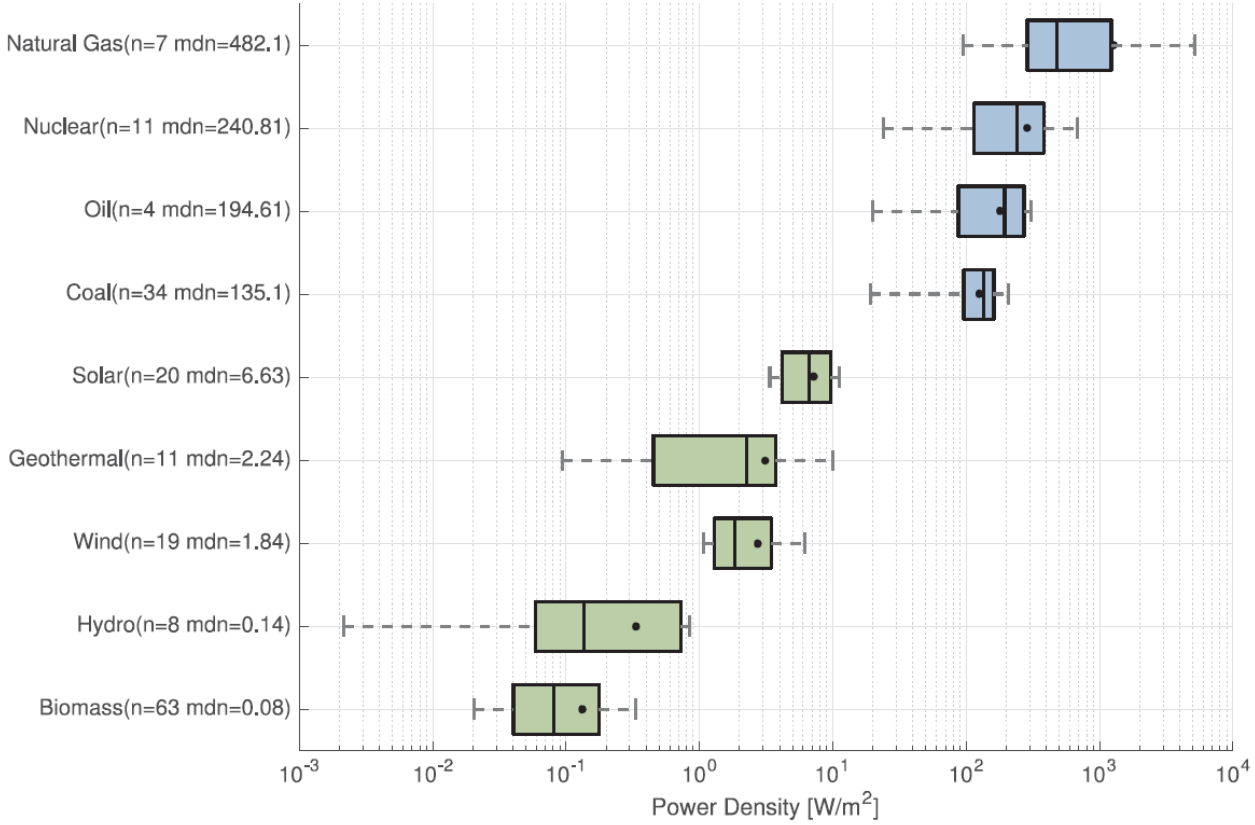
(not accounted for now)

NUCLEAR	3 461
COAL	7 899
LIGNITE	10 406
FUELOIL	5 571
NATGAS	779



	m²/MW	
Solar PV	18 000	Space required for the utility-scale PV module
Onshore wind	50 505	Estimation from operating wind farms
	m²/MWh	
Biofuel (excl. wood pellets**)	12.65	Direct land use in the entire lifecycle
Long-term heat storage	1.56	Volume / height
Short-term heat storage	0.50	Volume / height

There is no one answer for the land requirement (or power density).



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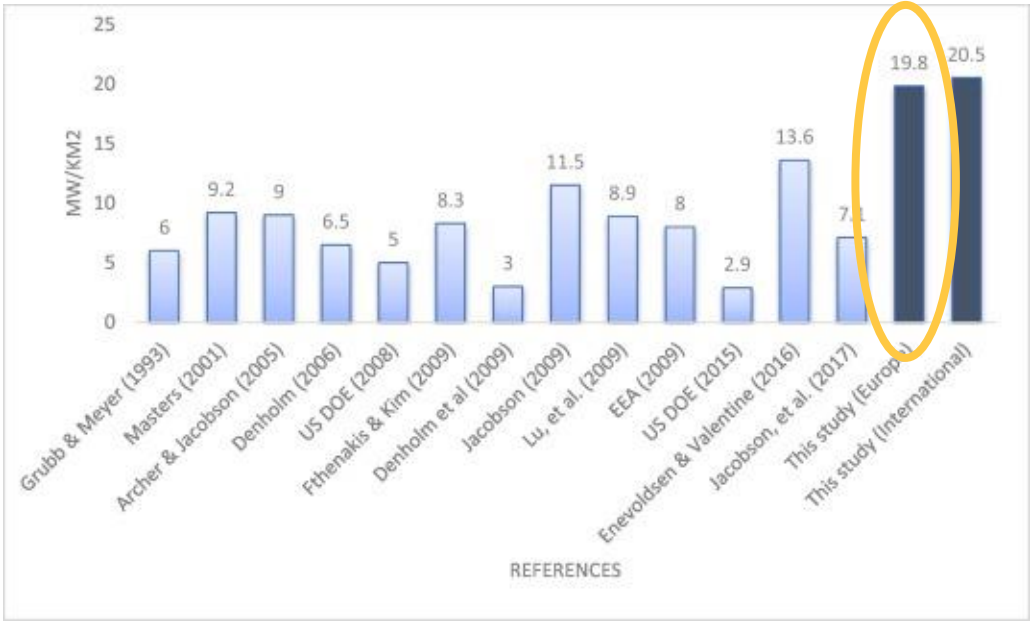
The spatial extent of renewable and non-renewable power generation: A review and meta-analysis of power densities and their application in the U.S.

John van Zalk[a], Paul Behrens[a,b,*]

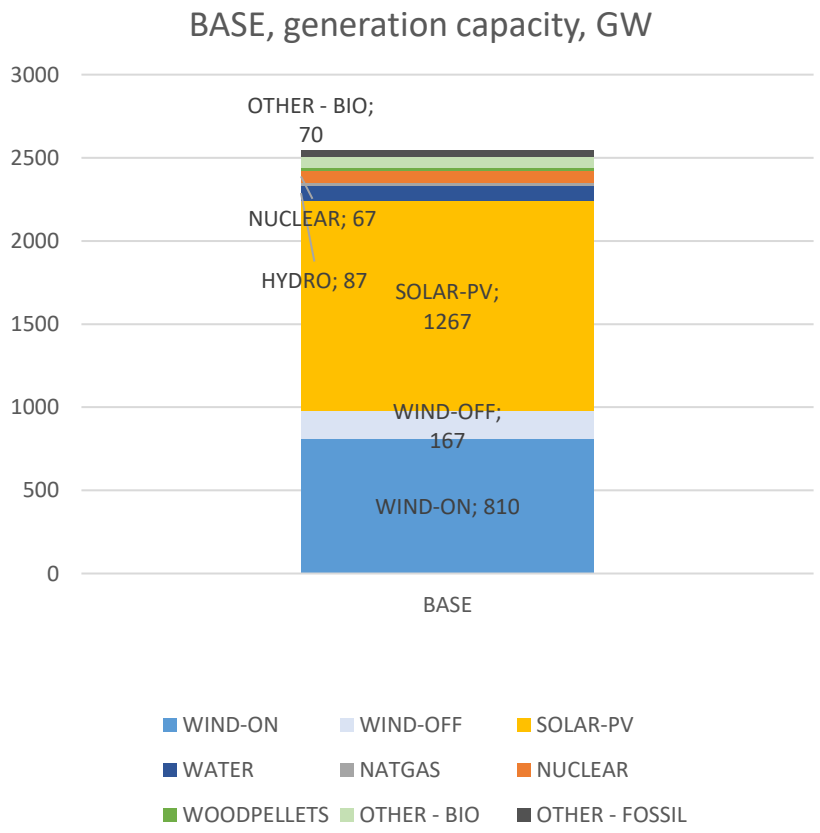
Onshore wind power density

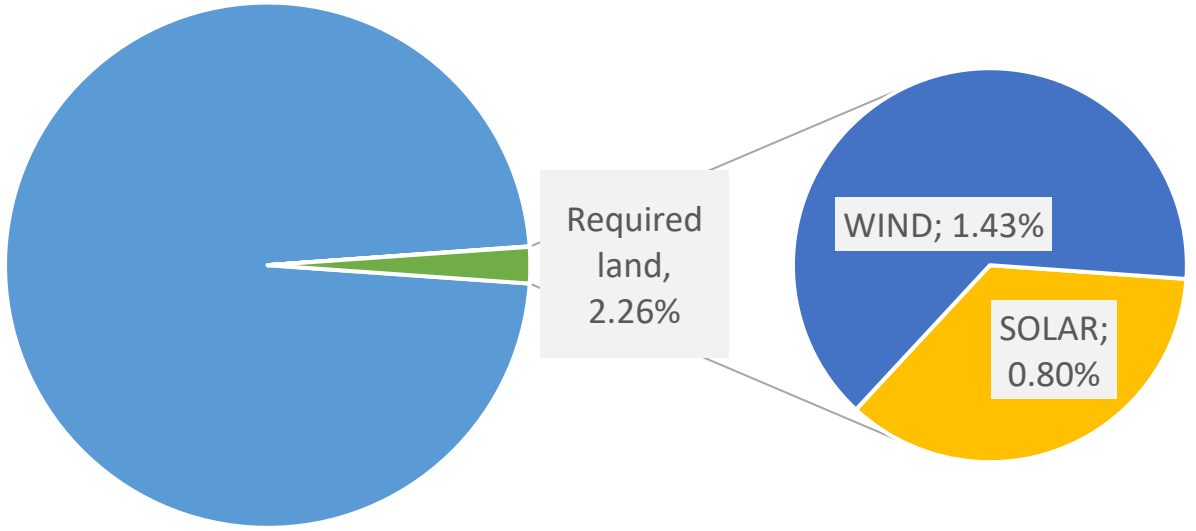


Enevoldsen, P., & Jacobson, M. Z. (2021). Data investigation of installed and output power densities of onshore and offshore wind turbines worldwide. *Energy for Sustainable Development*, *60*, 40-51.

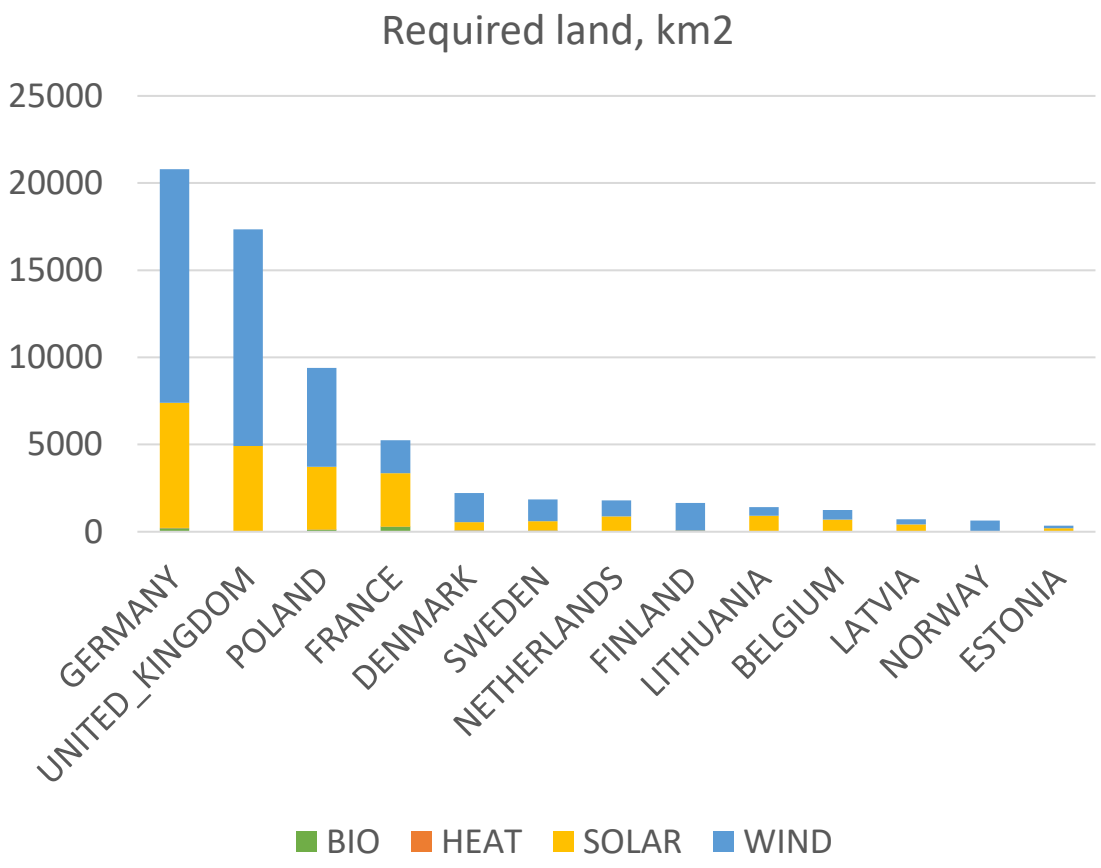
Preliminary results – BASE

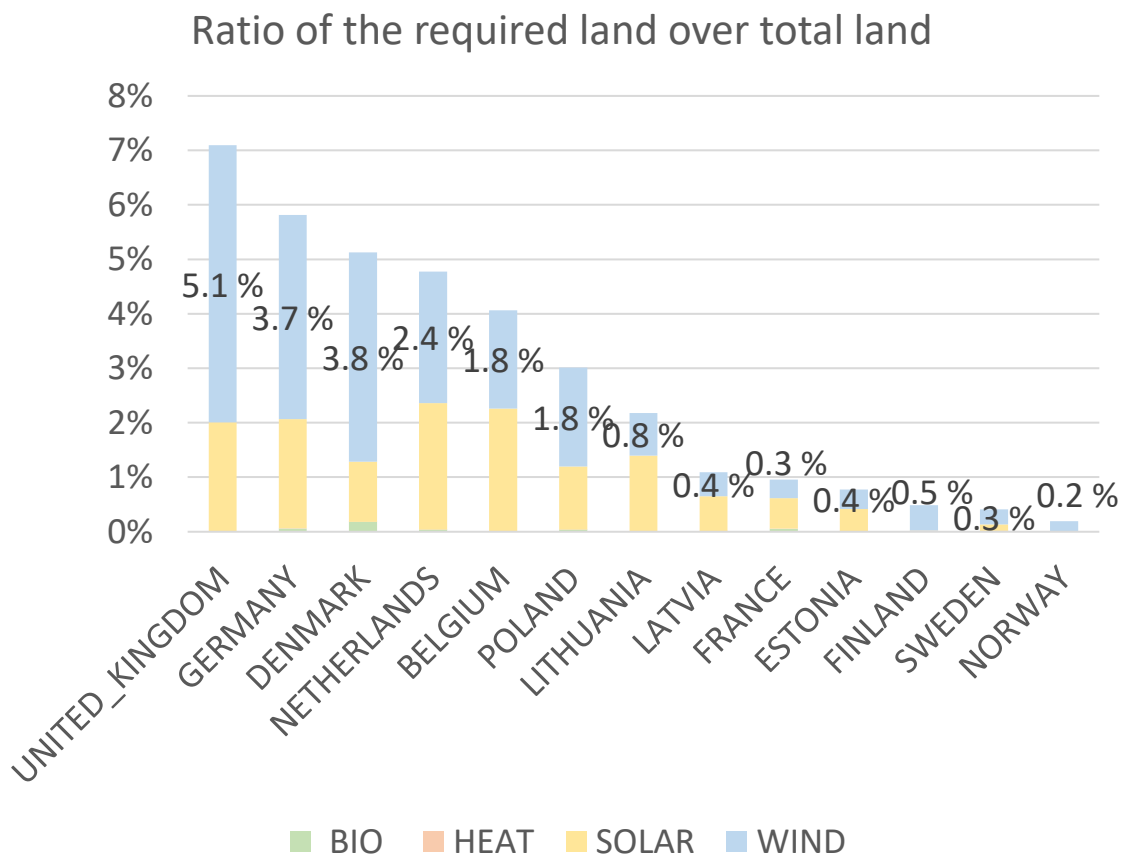
A fossil free North European energy system





Required land by the renewables, and the share of the required land over the total land area





MGA objectives

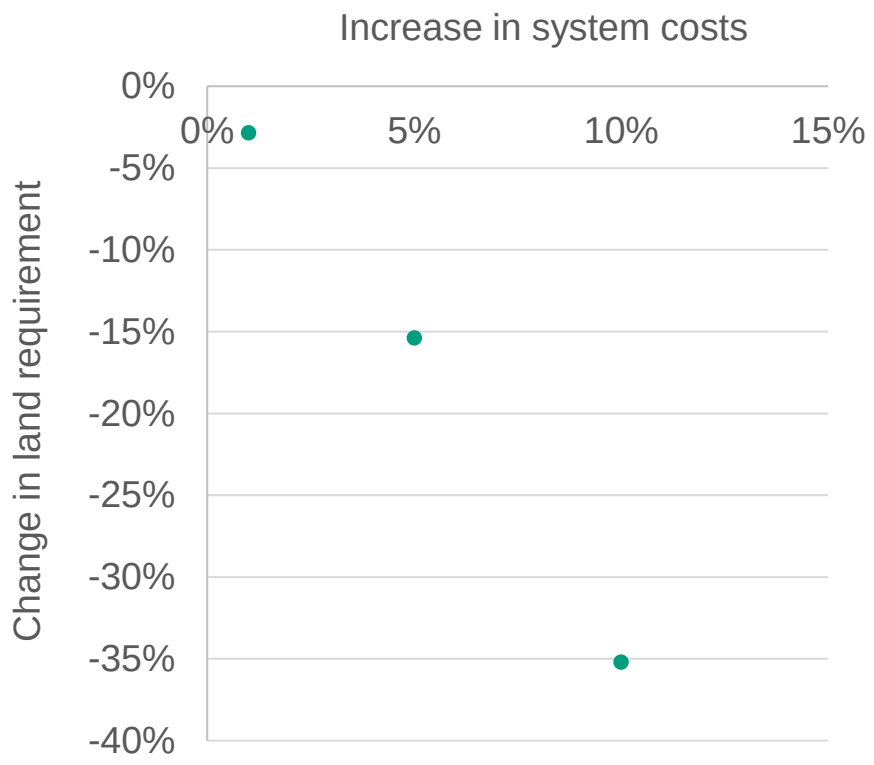
- minimize the sum of the share of the required land in each region

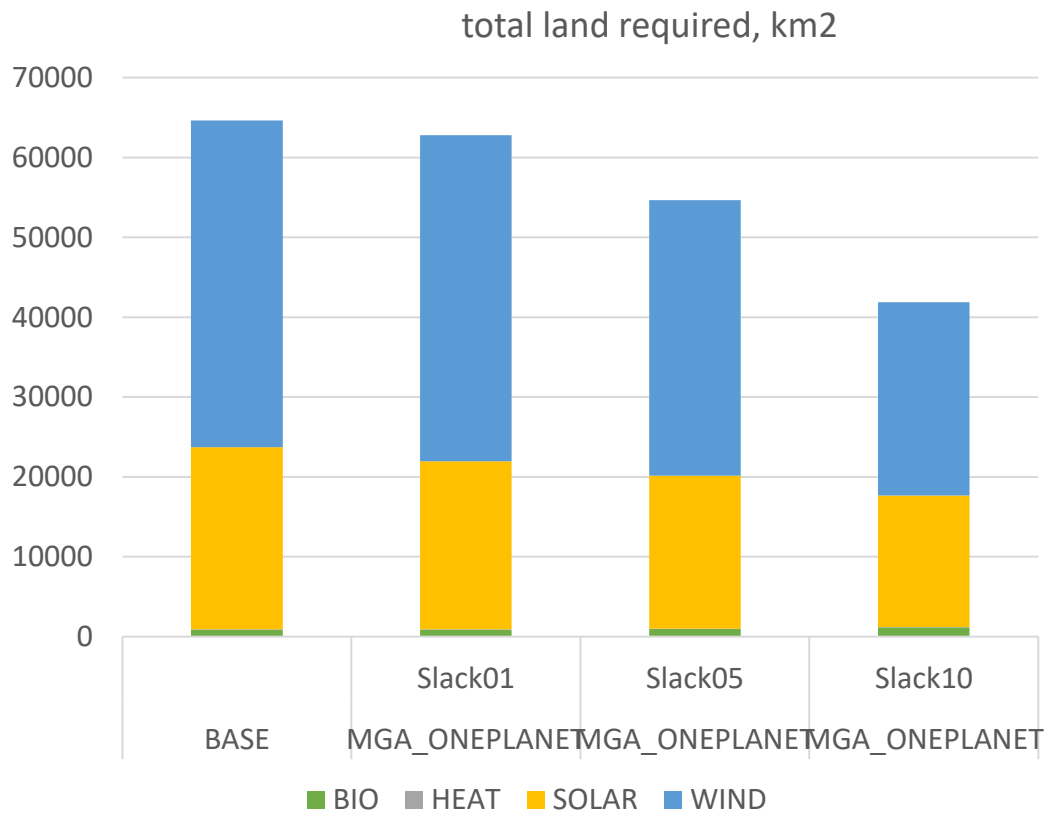
$$\text{Min. } \sum_{region} \frac{\begin{array}{c} land\ requirement_{wind}(region) + land\ requirement_{solar}(region) \\ + land\ requirement_{bio}(region) + land\ requirement_{heat\ storage}(region) \end{array}}{total\ land\ area\ (region)}$$

S.t. Total costs ≤ minimum system costs * (1 + slack)

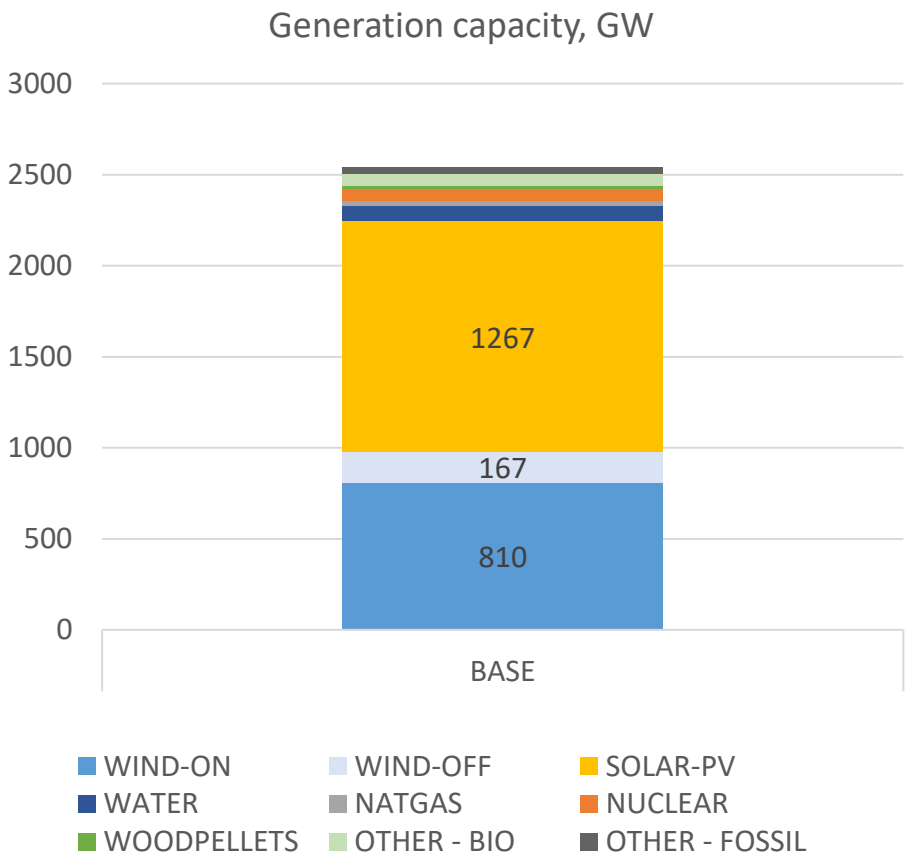
Preliminary results – MGAs

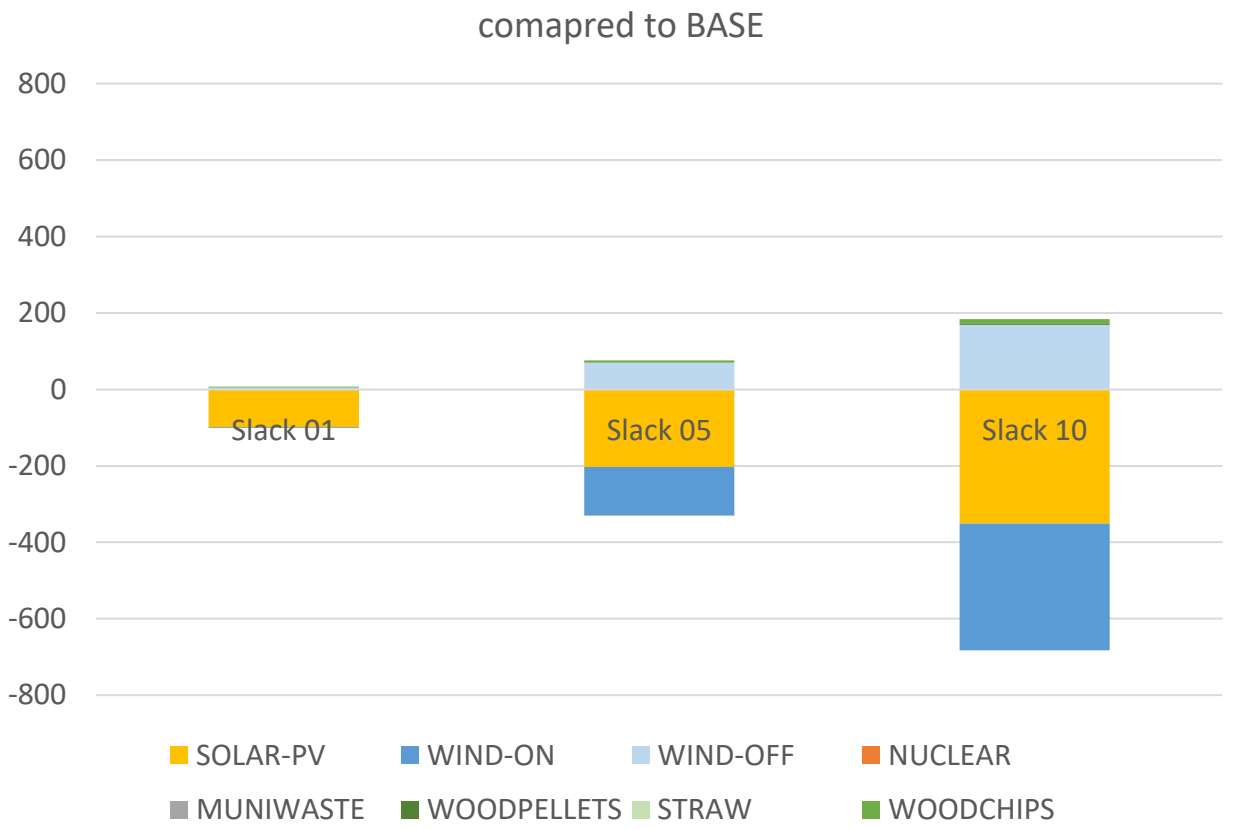
Saved land by higher system costs



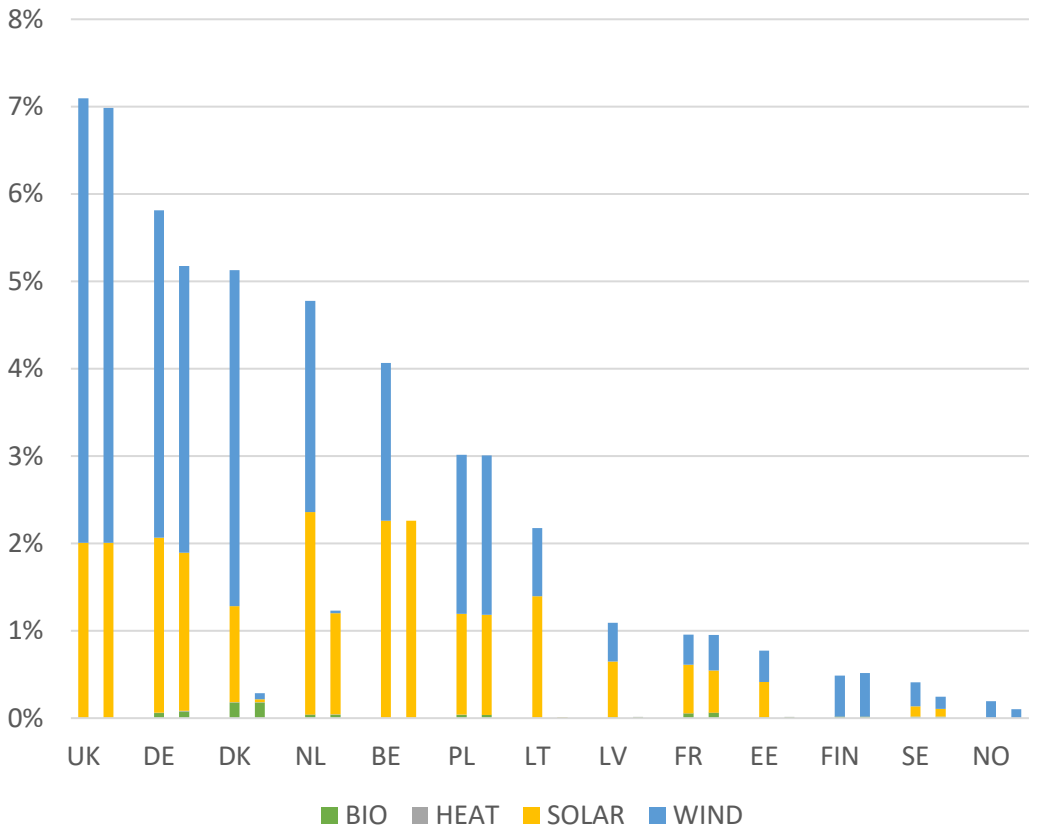


Change in generation investments





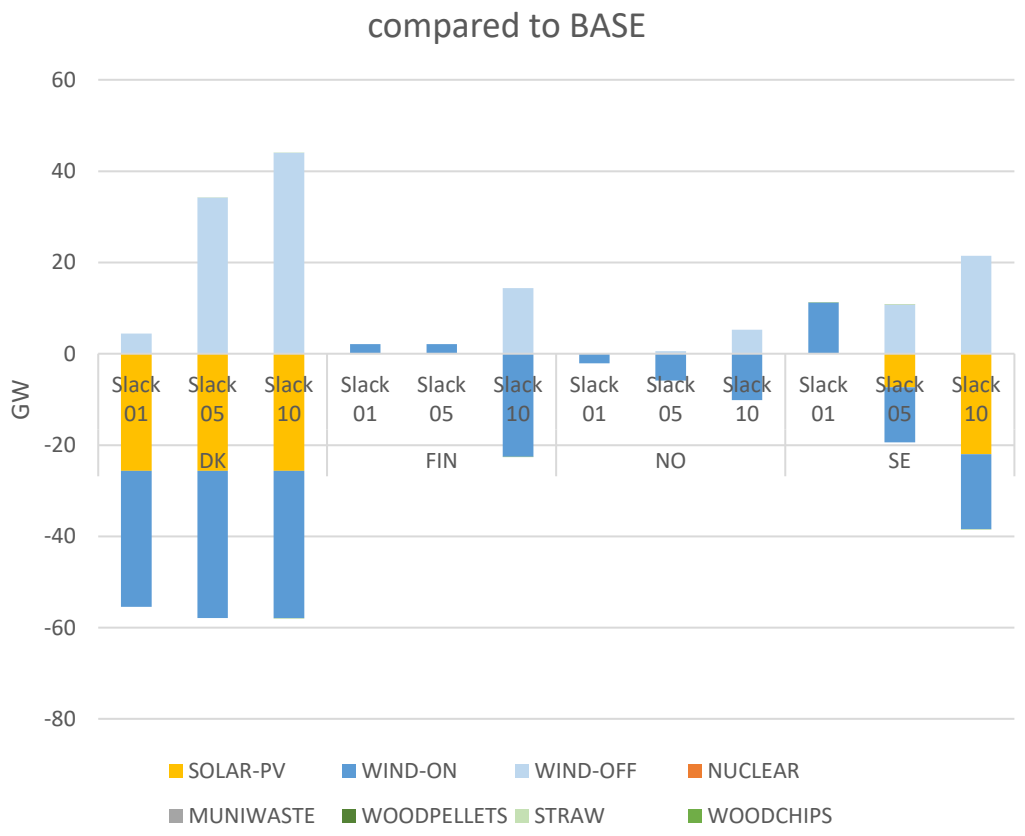
Share of the required land over the total land area, BASE and MGA.

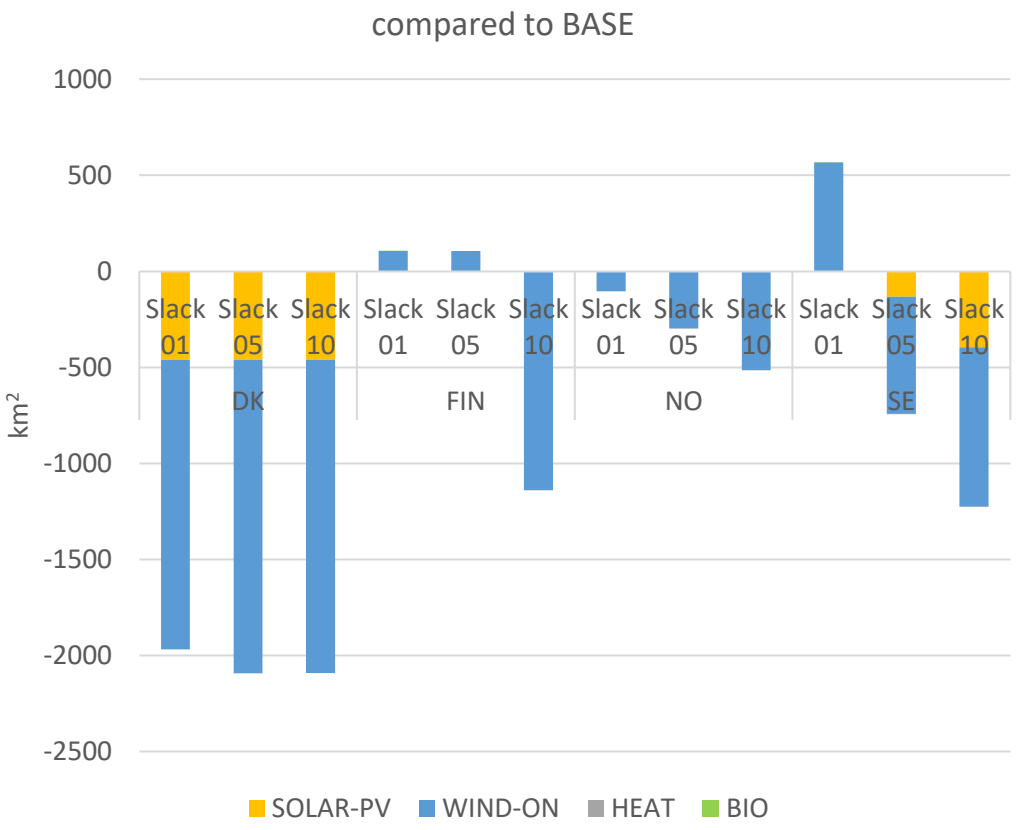


- First bar: BASE
- Second bar: MGA with 5% slack

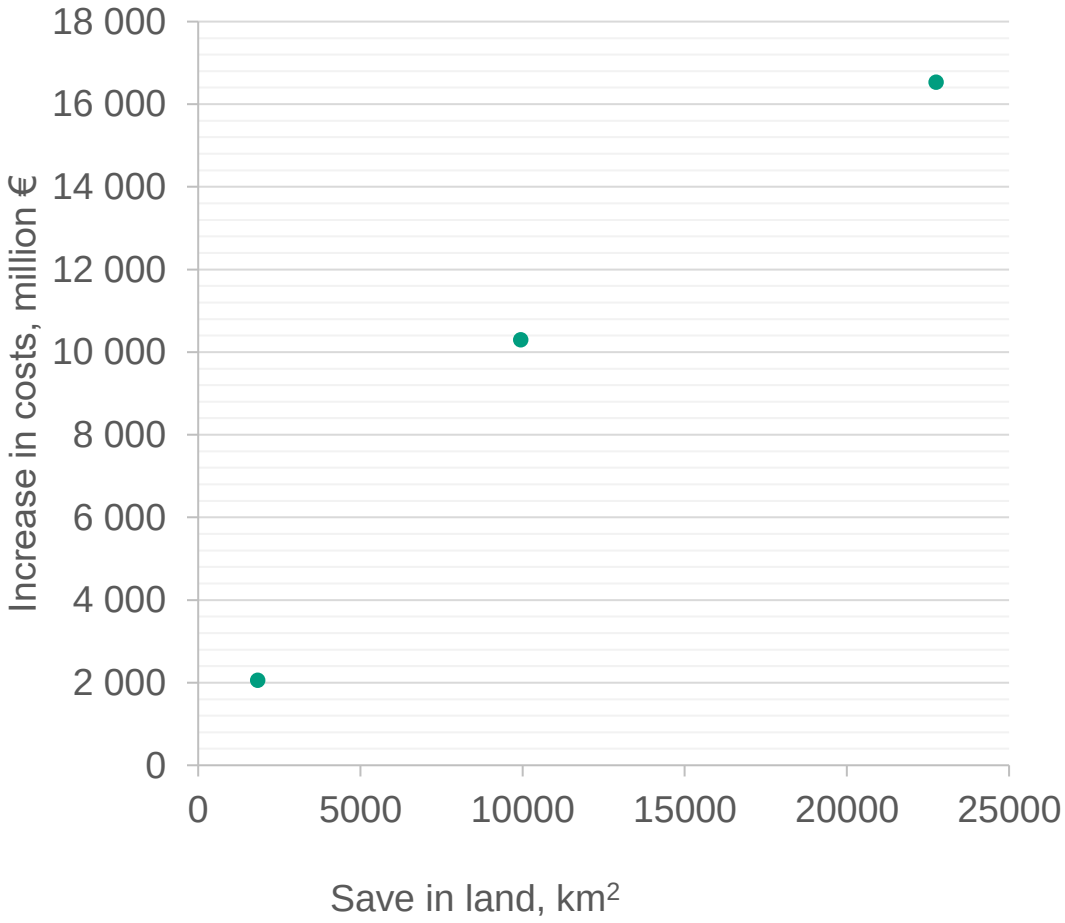
Notable save of the land share in the Nordic and Baltic countries.

Zoom in to the Nordic countries

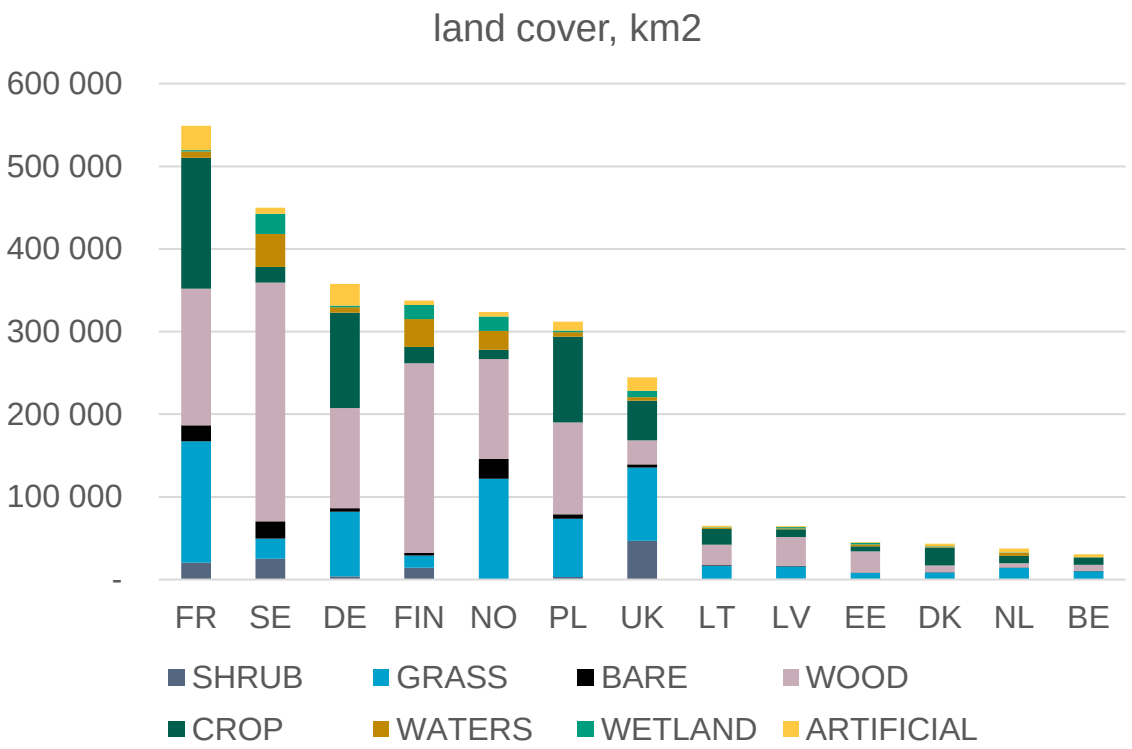




- Slack 5%
  - 1.12 million Euro per km2 land saved
    - 11200 kr/daa
    - 11,2 kr/kvm
- Slack 10%
  - 0.73 million Euro per km2 land saved



Remark 1: Land cover type



- We can assume only certain types of land can be counted.

	Onshore wind	PV farm	Bio	Heat storage
Shrubland	v	v	v	v
Grassland	v	v	v	v
Bare land	v	v		v
Cropland	v	(v)	(v)	
Woodland	(v)		(v)	
Built-up area				
Artificial, non built-up area				
Other artificial areas				
Water				
Wetland				

MGA objectives

- One planet: min land requirement/ total land by region

$$\sum_{region} \frac{land\ requirement_{wind}(region)+land\ requirement_{solar}(region)+land\ requirement_{bio}(region)}{total\ land\ area\ (region)}$$

- All potential land: min land requirement/ potential land by regio

$$\sum_{region} \frac{land\ requirement_{wind}(region)}{\begin{array}{c}cropland\ area\ (region)+woodland\ area\ (region)+shrubland\ area\ (region)\\ +grassland\ area(region)+bareland\ area\ (region)\end{array}} + \frac{land\ requirement_{solar}(region)}{\begin{array}{c}cropland\ area\ (region)+shrubland\ area\ (region)\\ +grassland\ area(region)+bareland\ area\ (region)\end{array}} + \frac{land\ requirement_{bio}(region)}{\begin{array}{c}cropland\ area\ (region)+woodland\ area\ (region)\\ +shrubland\ area(region)+grassland\ area(region)\end{array}}$$

Remark 2: the MGA objective can be customized.

- For example:
  - To min. total land (in km^2)
  - To min. material demand
  - To max. employment

Discussion points

- Comments on the methodology?
- Comments on the assumptions?
  - Land requirement
  - Grid investments
  - Electricity demand
- What kind of land use objectives are you interested in?
  - For example: minimizing land use only in the Nordics
- Which results are you interested in?