Renewable energy deployment in the UK: spatial analysis of opportunities and threats

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Motivation

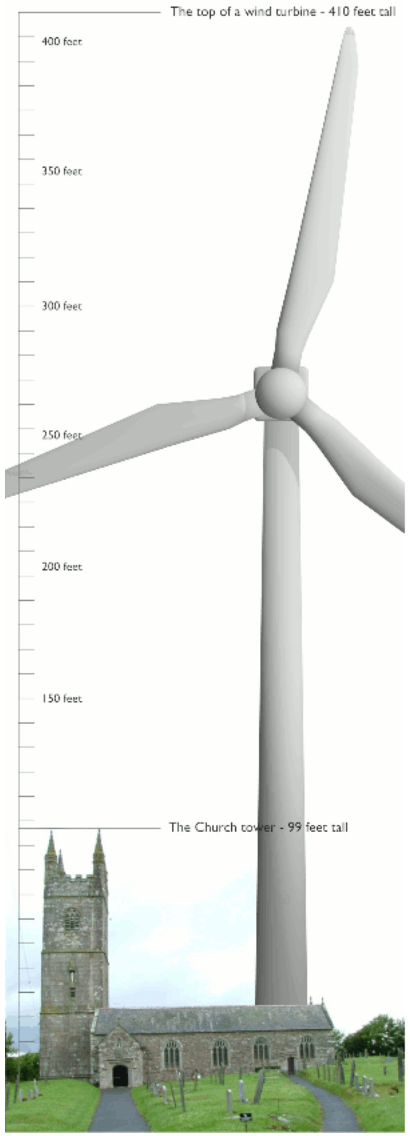
- Decarbonisation of power sector is key to reaching UNFCCC Paris agreement goal
- Variable renewable energy (VRE) technologies, such as wind and solar can be an essential component
- The location of VRE determines
  - total output and timing of production
  - technical feasibility
  - the impact on the environment and the communities they are sited

→ Support for renewable energy has been consistently high during the Energy and Climate Change Public Attitudes tracker at around 75- 80%

→ Perceived negative impacts affect the local population who is often not compensated (Bassi et al., 2012)

→ Opposition towards wind farms has been growing in the UK with local opposition being particularly strong (Damian Carrington, 2012; Haggett, 2011).

→ For wind energy the majority of projects is developed and owned by commercial companies and not the communities compared to other countries (Bassi et al., 2012)



Motivation

- Lack of studies that carry out an assessment of the potential for deployment of several VREs including limiting factors affecting this deployment and resulting costs

- Quantifying the costs associated with excluding certain areas can help finding politically and publicly feasible decarbonisation strategies and discuss compensation and better involvement of communities affected by VRE deployment

Motivation and research questions

To close the gap in research:

1. We develop a framework of scenarios that combine different levels of technical, social and environmental criteria of exclusion areas in order to scope out the feasible potential and location of VRE deployment

2. We use a spatially and temporally explicit electricity system model to quantify the system costs resulting from the difference in land and sea availability for VRE deployment

→How do social, environmental and technical constraints influence high renewable energy scenarios in GB?

→ How do energy scenario costs with high social, technical and environmental restrictions compare to scenarios with low restrictions?

→ If costs are substantially different could this be used to potentially subsidize communities that approve new renewable sources?

Methodology

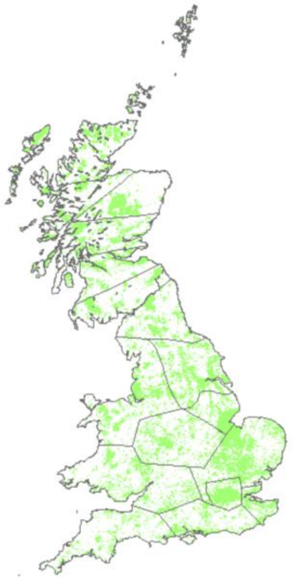
1. GIS analysis to develop 27 scenarios with low, medium and high social, environmental and technical constraints for VRE development

2. Scenarios are used as input to the high spatial and temporal resolution electricity system model highRES for 2050

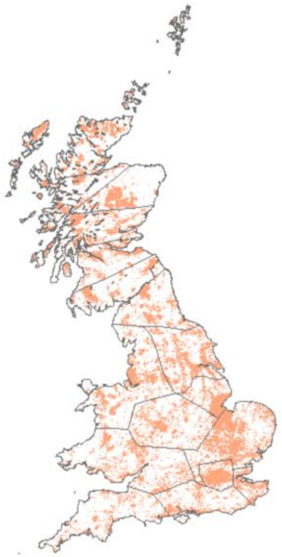
3. Costs and investments into VRE integration options are compared across scenarios using high and low constraints

GIS analysis: Solar

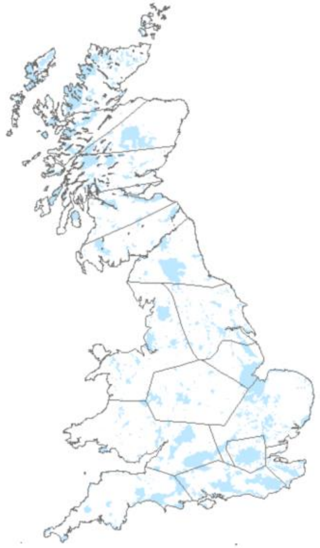
Env
low



Soc
low



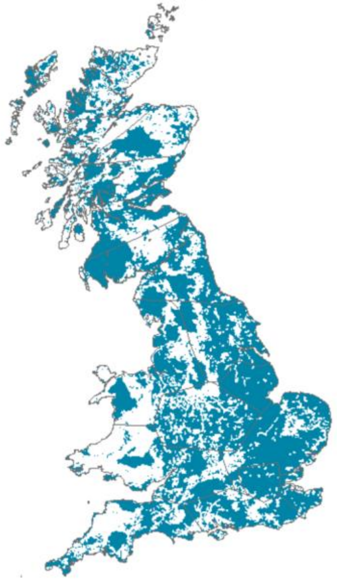
Tech
low



Env
high

Soc
high

Tech
high



GIS analysis: Onshore wind

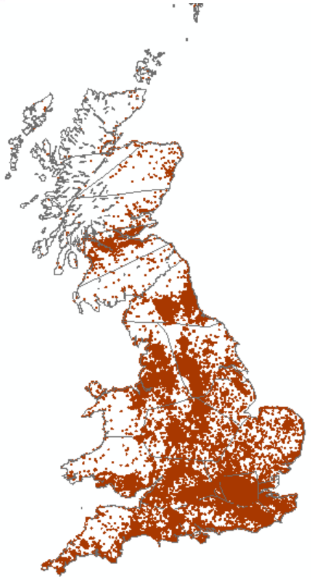
Env
low

Soc
low

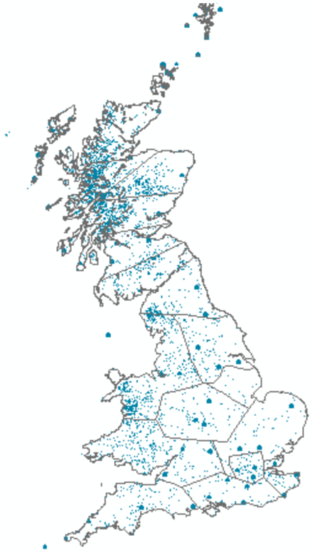
Tech
low

Env
high

Soc
high

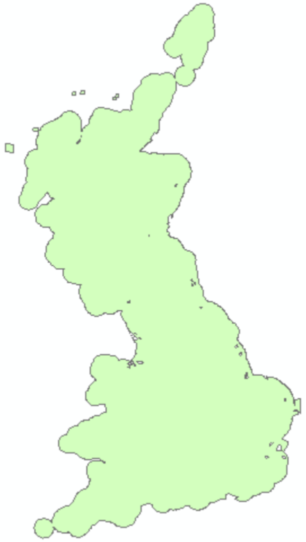


Tech
high



GIS analysis: Offshore wind

Env
low

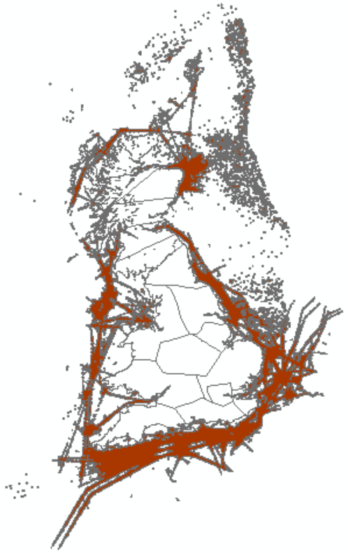


Soc
low

Tech
low

Env
high

Soc
high



Tech
high

High spatial and temporal resolution electricity system model highRES

- Objective: minimise power system costs to meet hourly demand subject to constraints
  → Technical constraints: ramping, minimum & maximum generation
  → Storage constraints
  → Transmission constraints

- Integration options are network reinforcement, interconnection, storage, flexible generation

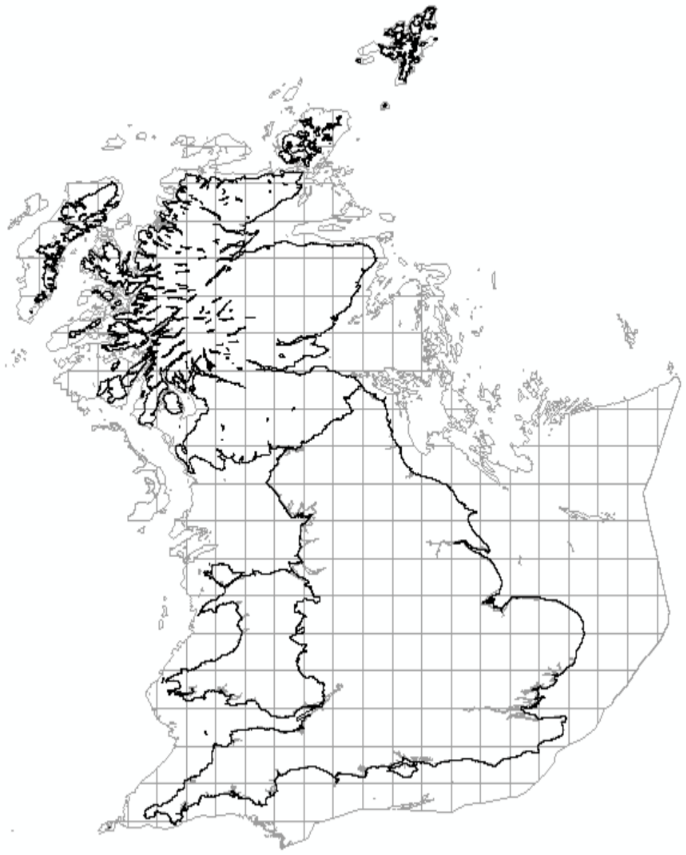
- Output: Location of generation and integration options, total system costs, electricity price, power plants usage rates, emissions, renewable curtailment

Weather data: Wind and Solar

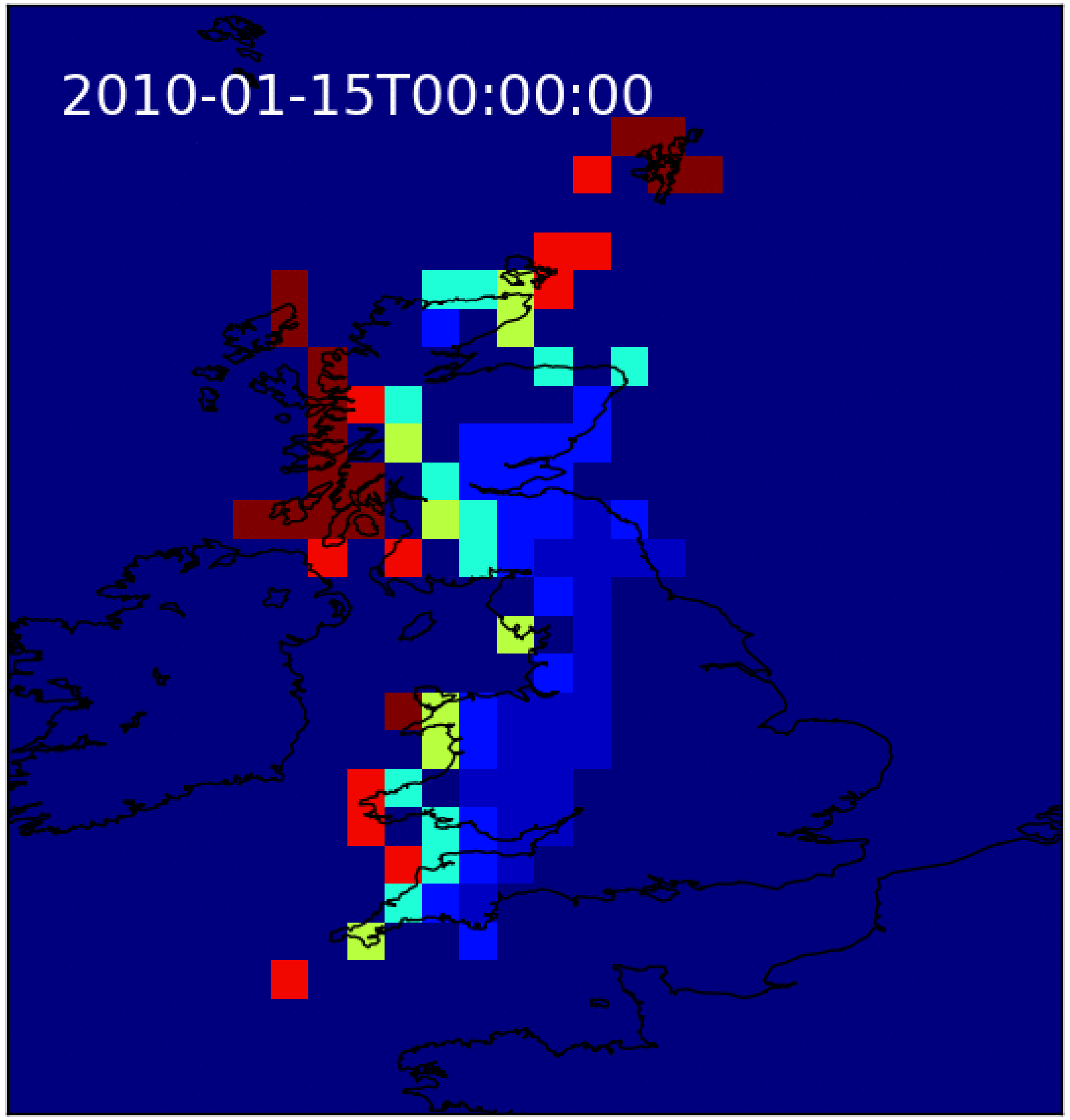
Core focus of highRES is a good representation of VRE:

- Where can we built VRE? :
  - Resource assessment: Exclude areas from development for technical, social and environmental reasons

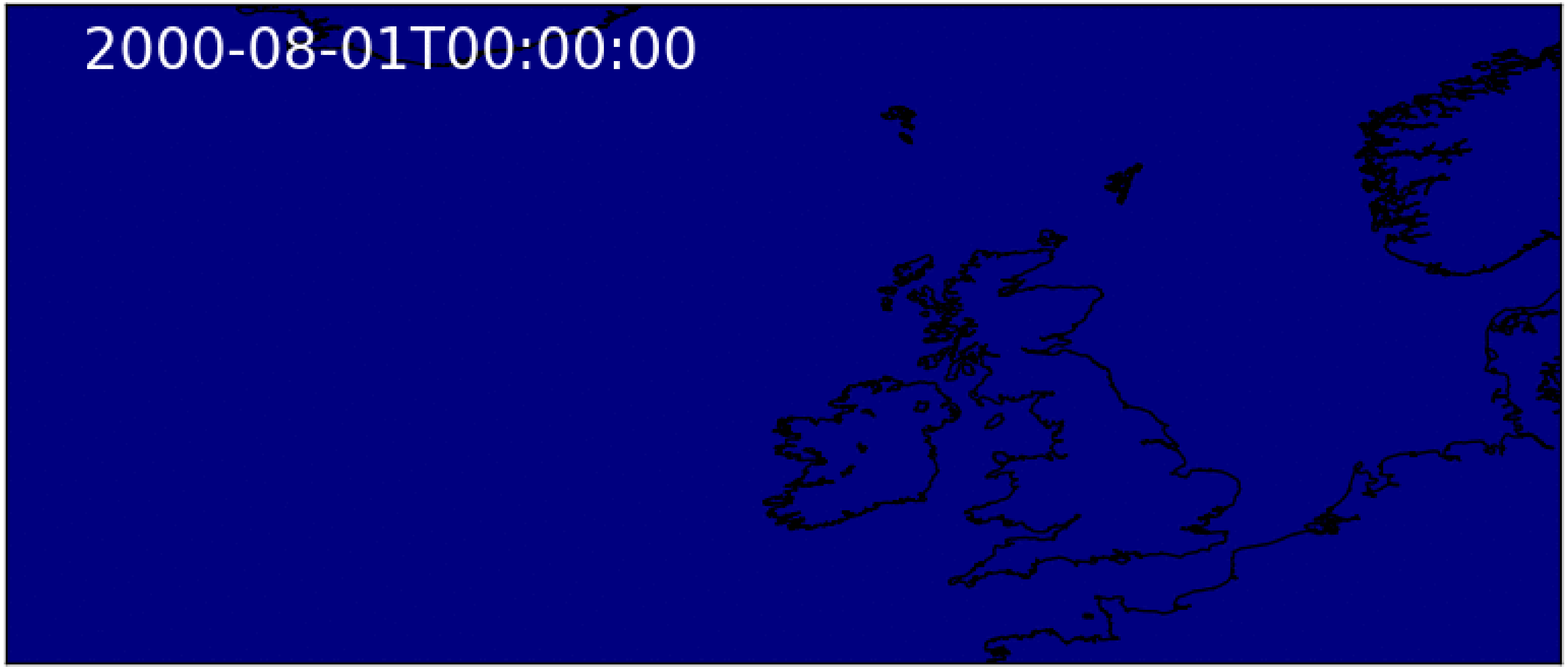
- How much can we generate?
  - Wind onshore and offshore: NCEP Climate Forecast System Reanalysis (CSFR)
  - Solar rooftop and ground mounted: Satellite Application Facility on Climate Monitoring (CMSAF)
  - Temporal resolution: hourly
  - Spatial resolution: 0.5°x0.5° (35km x 50km)
  - Currently have 2000-2010 data processed
  - Fed into the model as hourly capacity factors, i.e. the model decides how much capacity is built in a grid cell and that capacity is multiplied by CF to get generation



Weather data – On shore wind



Weather data – Solar PV



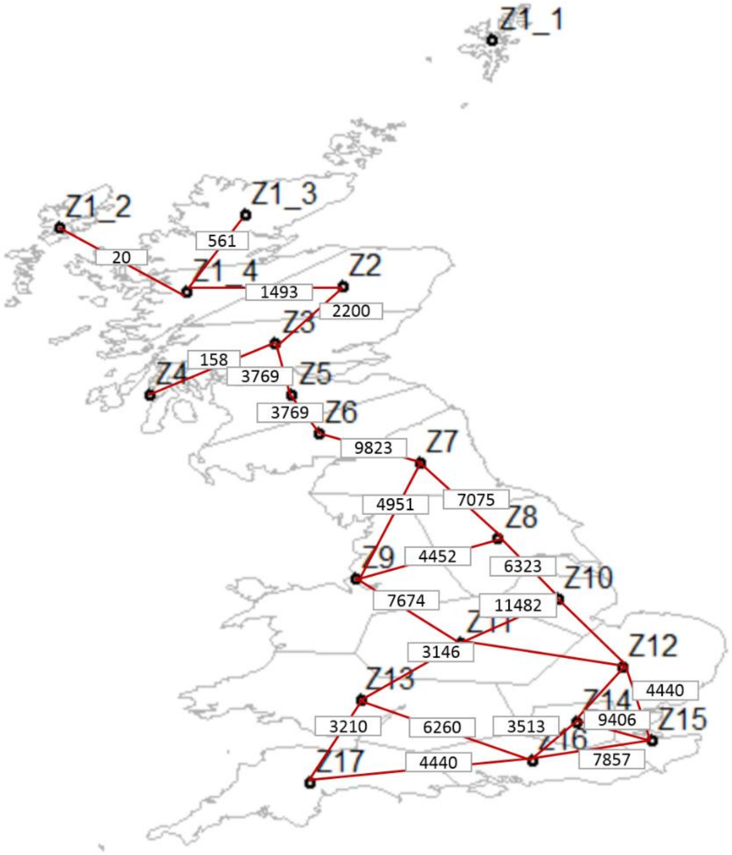
Demand- Supply Balancing

Renewable generation at grid cell level

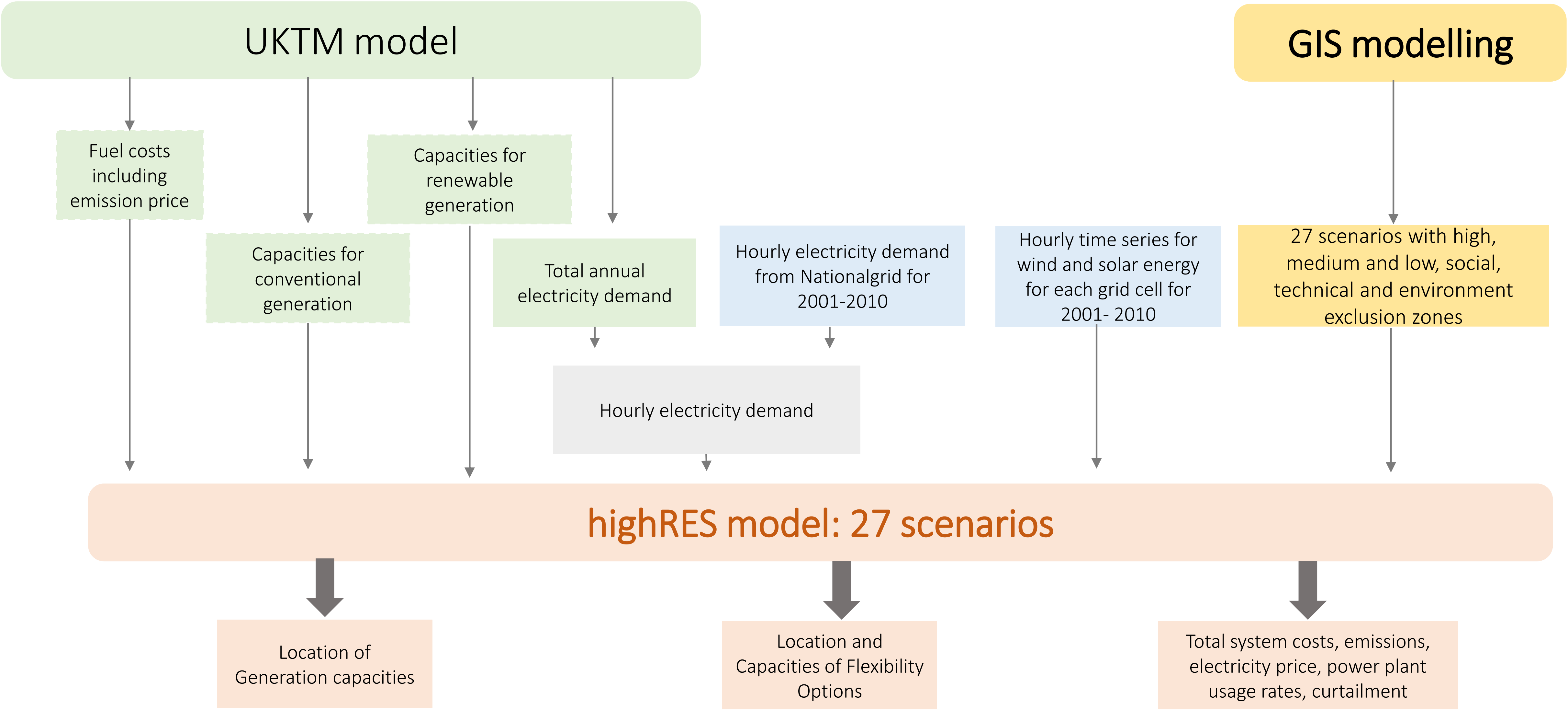
Demand Supply Matching at Zonal Level

- Zones and demand shares based on National Grid

- Simplified grid connecting the zones and enabling demand-supply balancing between zones



Methodology: Model linkage



UKTM- highRES linkage

GIS modelling:

27 scenarios

PV	3600GW (all low) 2200GW (all high)
Onshore wind	1100GW (all low) 550 GW (all high)
Offshore wind	500 GW (all low) 160 GW (all high)

UKTM run:

which meets 80% GHG reduction target by 2050

Solar 44.45 GW
Wind offshore 38.83 GW
Wind onshore 32.48 GW
Nuclear 34.2
Biomass 6.8 GW
Geothermal 0.5 GW
Hydro 1.64 GW

Electricity demand: 503TWh

Fuel prices

highRES runs:

2 scenarios:

1. All high
2. All low

For 10 weather years

Costs

Location of VRE

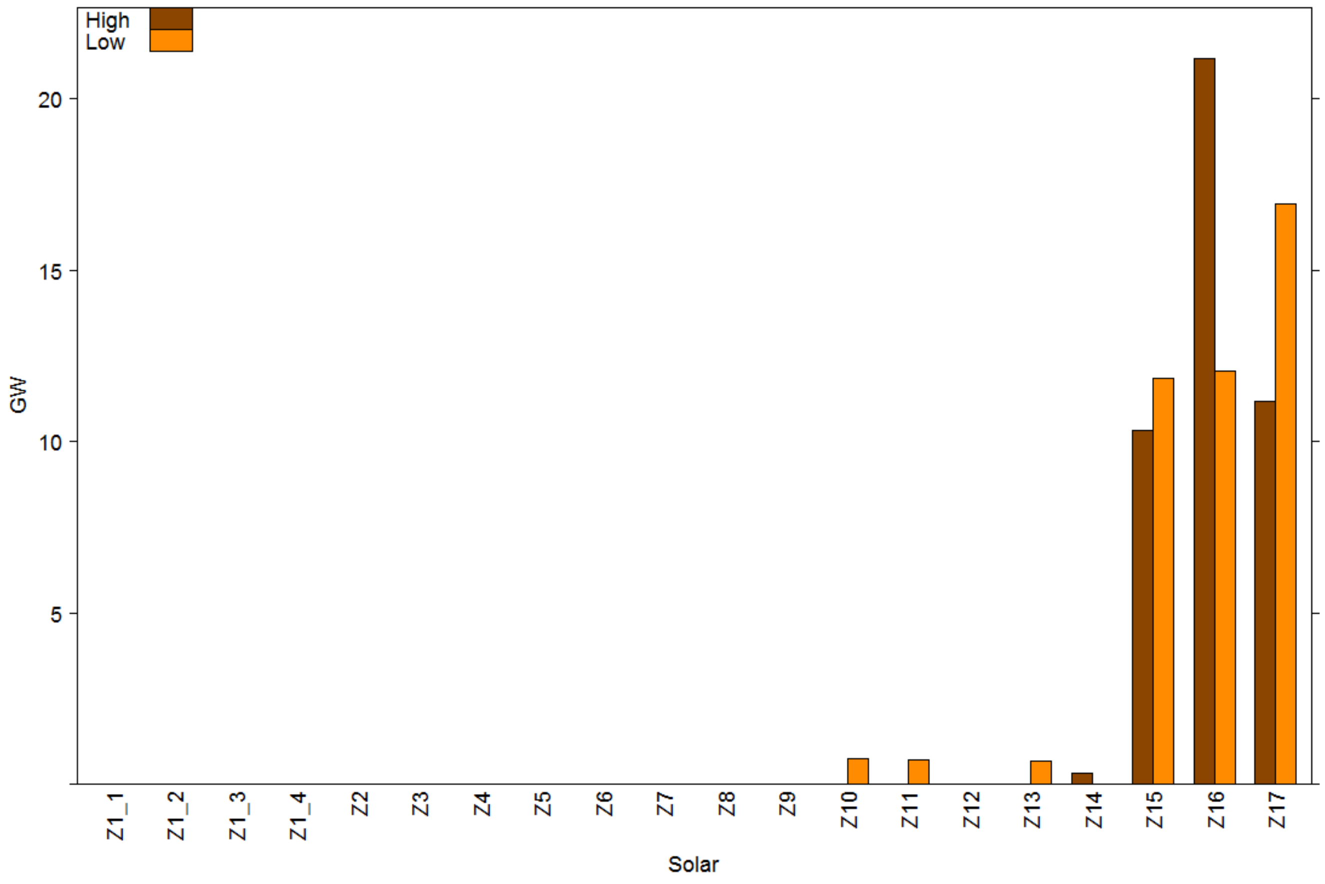
Location and capacities of integration options

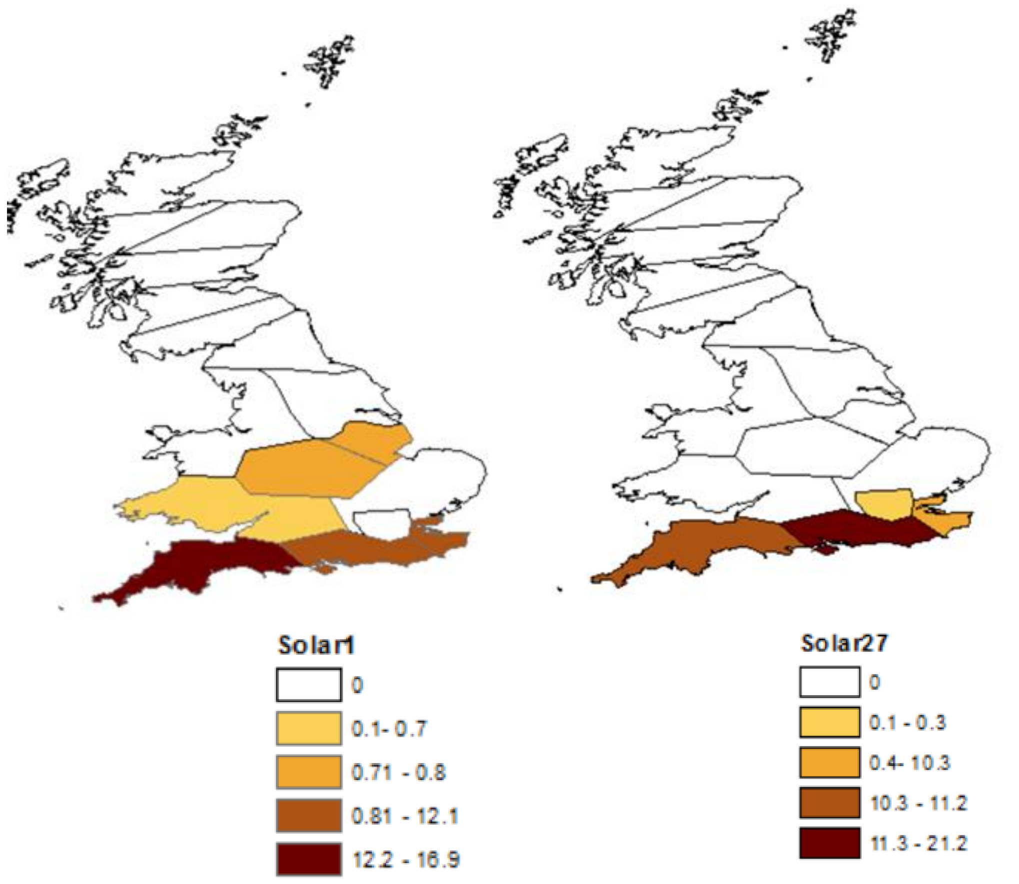
Emissions, VRE Generation, prices…

Results

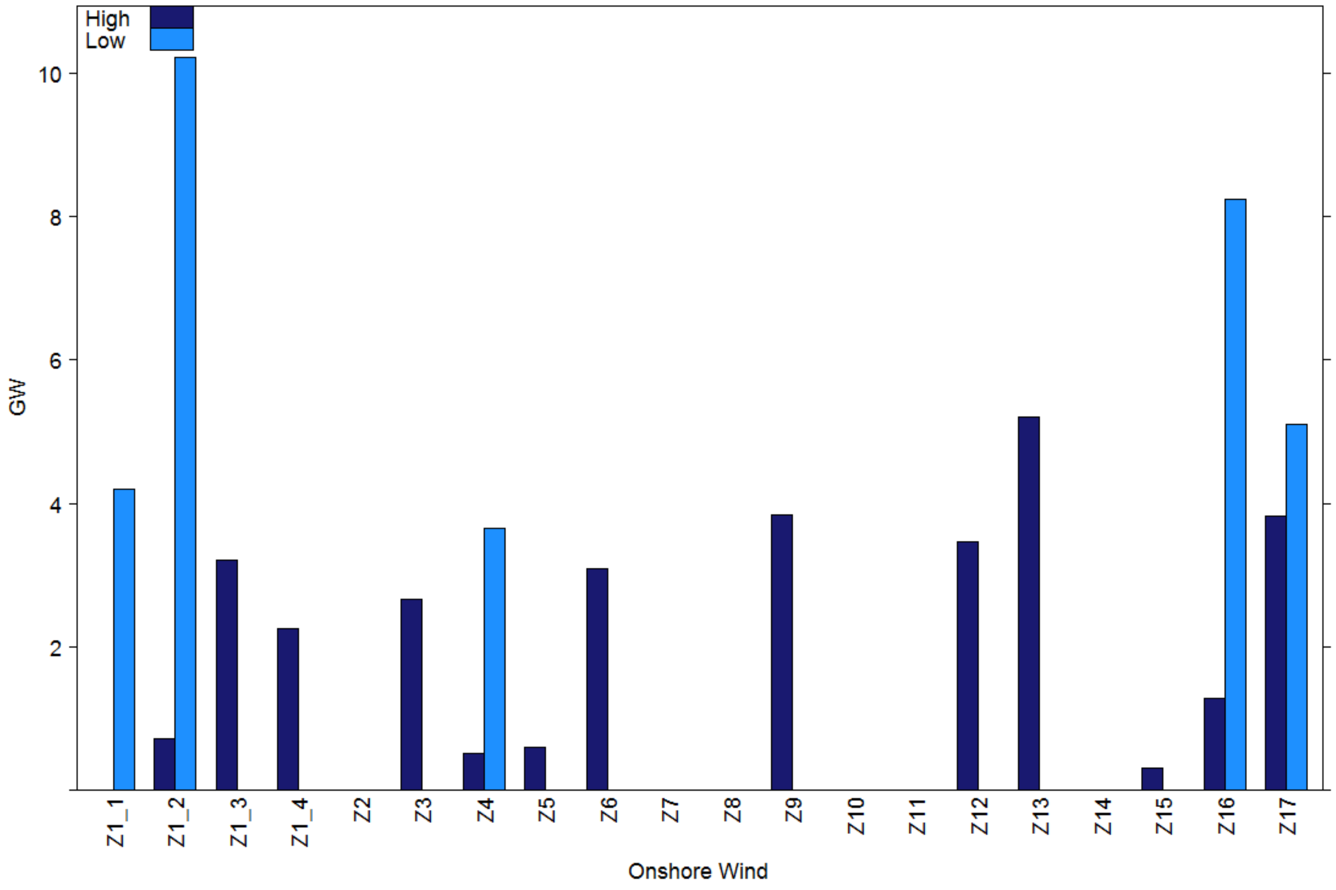
	Low restrictions	High Restrictions
LCOE (£/MWh)	72	77
Emissions (g/CO_2/kWh)	0.08	0.24
VRE Generation (% of demand)	81%	75%
Integration options (GW)	Flexible Generation: 9 Storage: 32 Transmission: 288	Flexible generation: 12 Storage: 47 Transmission: 211

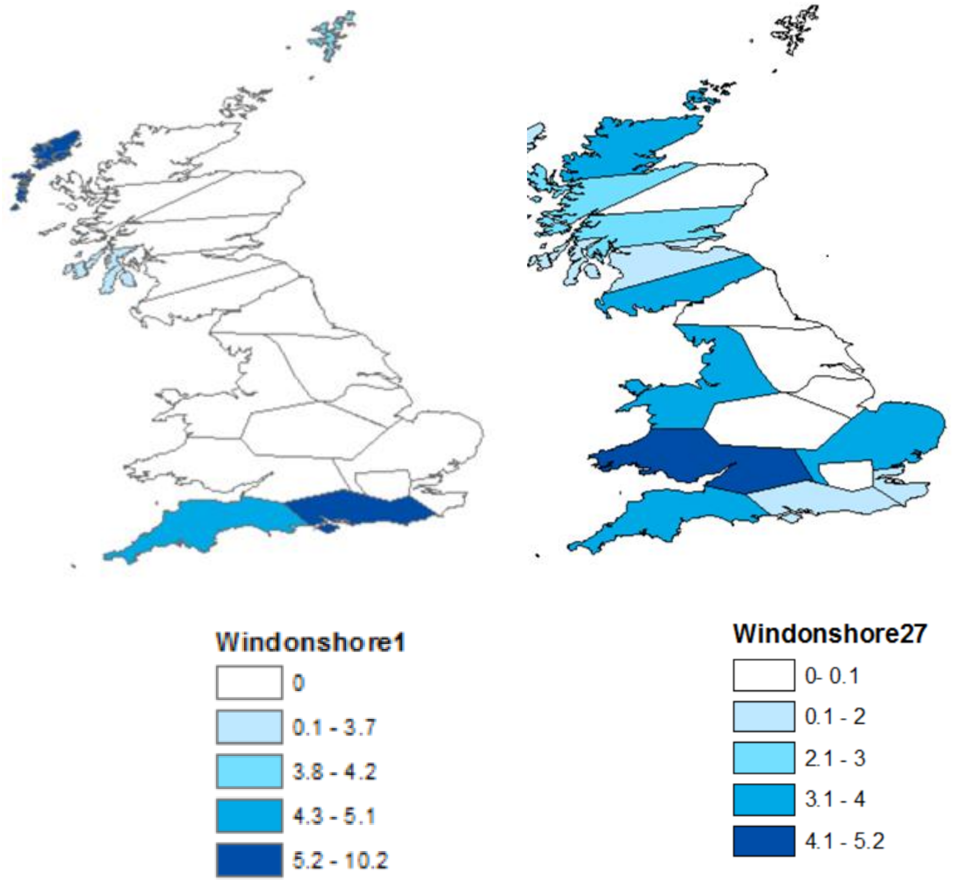
Results: Where is Solar energy located?



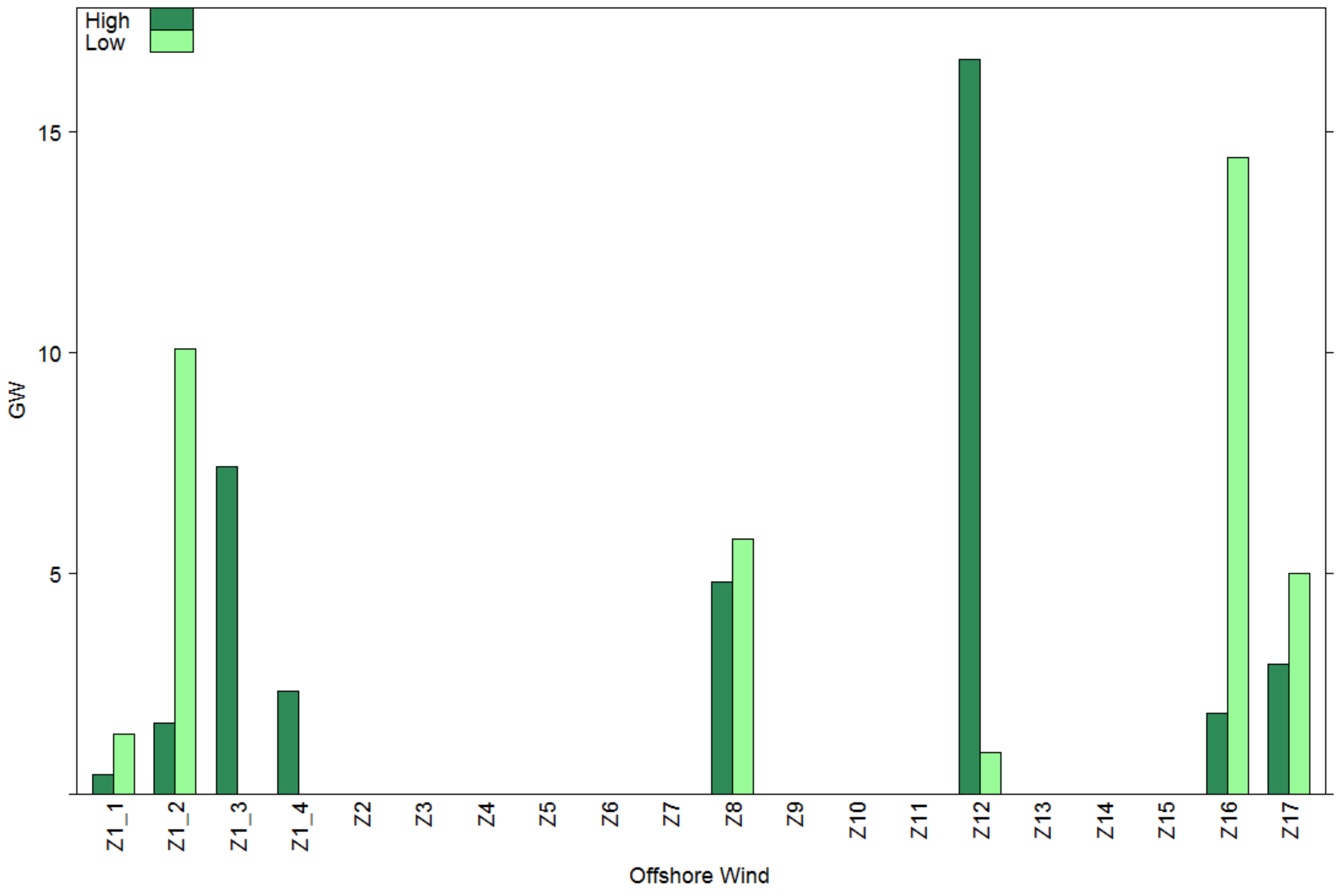


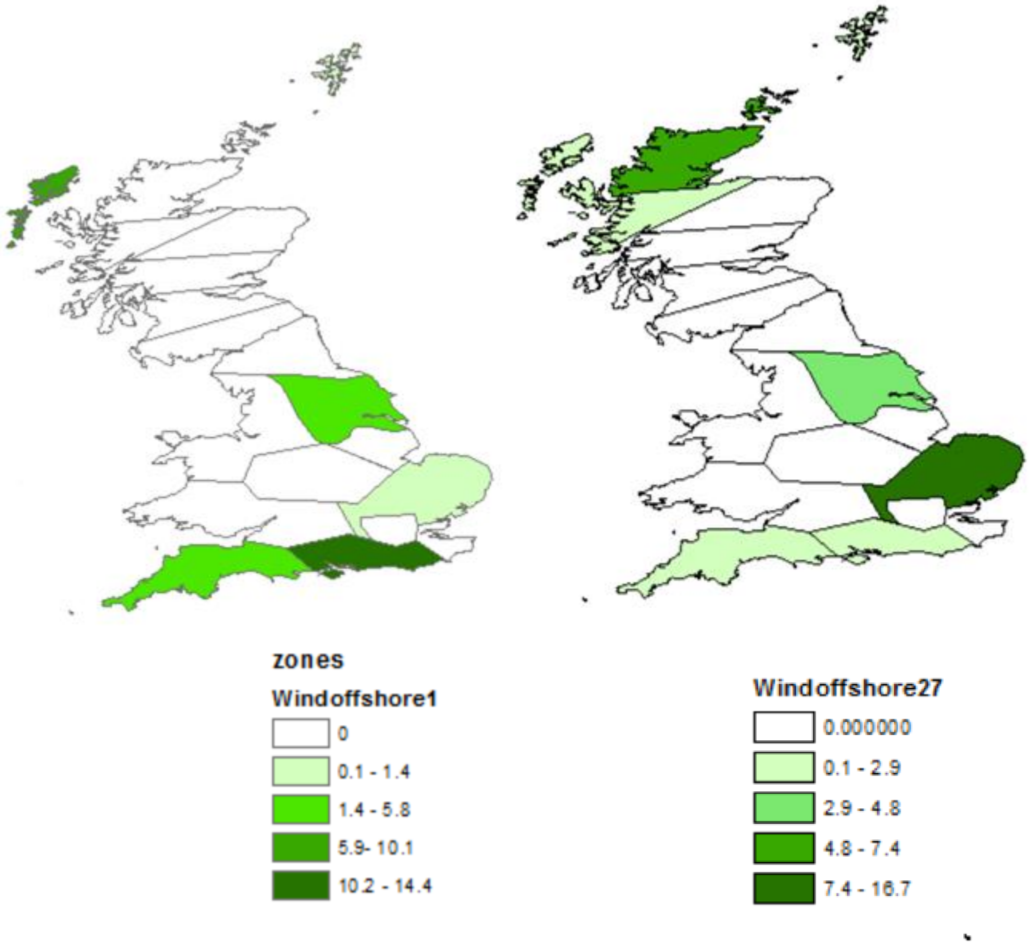
Results: Where is Onshore Wind located?



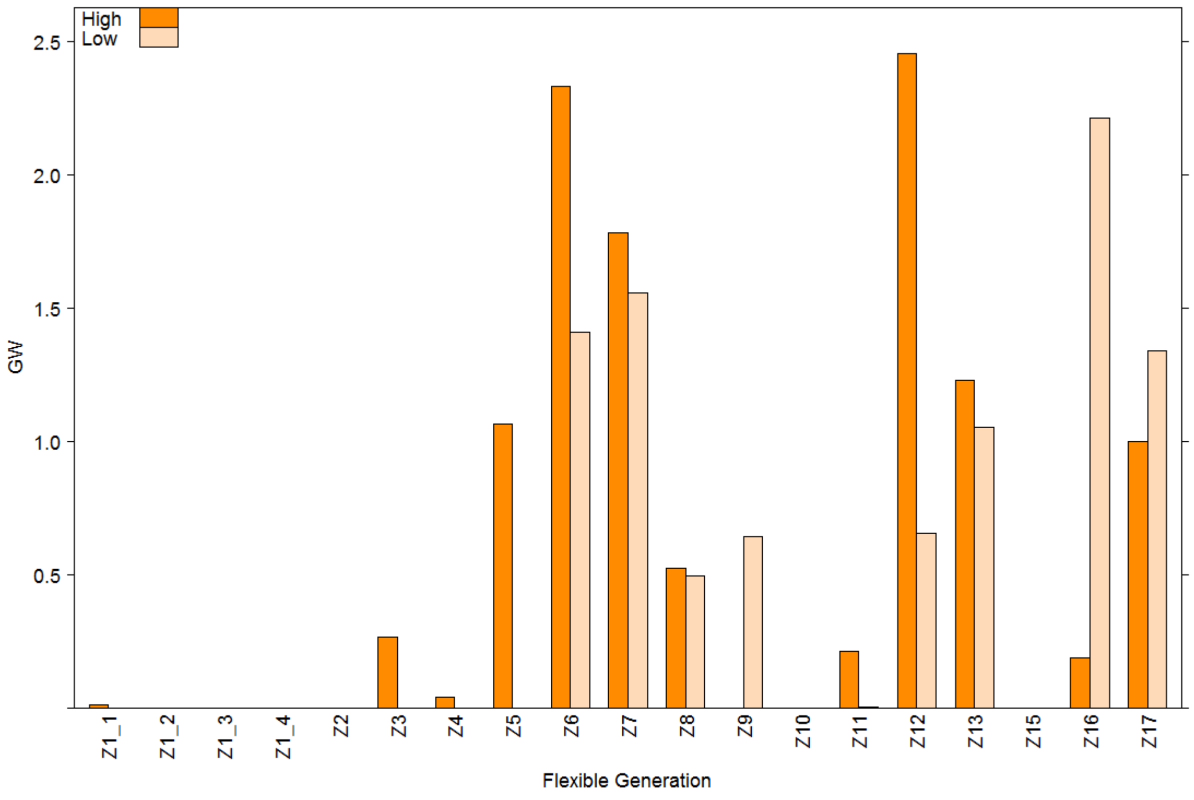


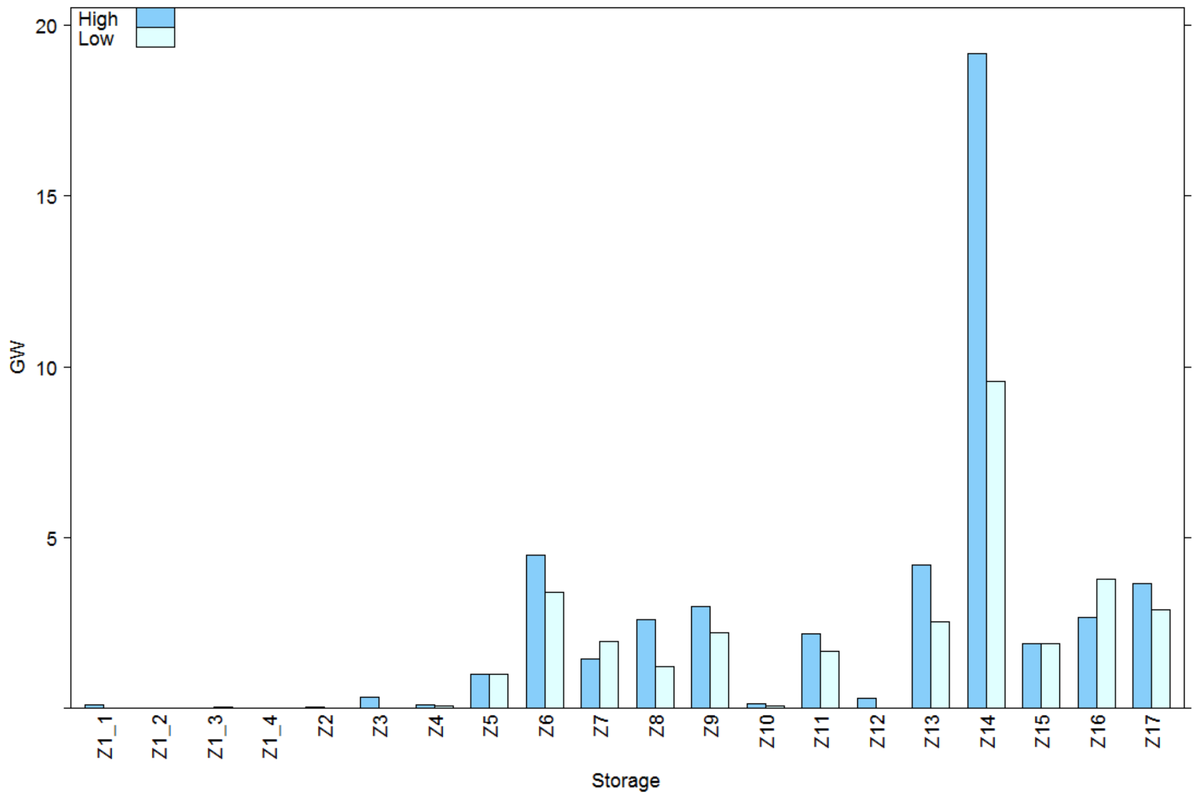
Results: Where is Offshore Wind located?



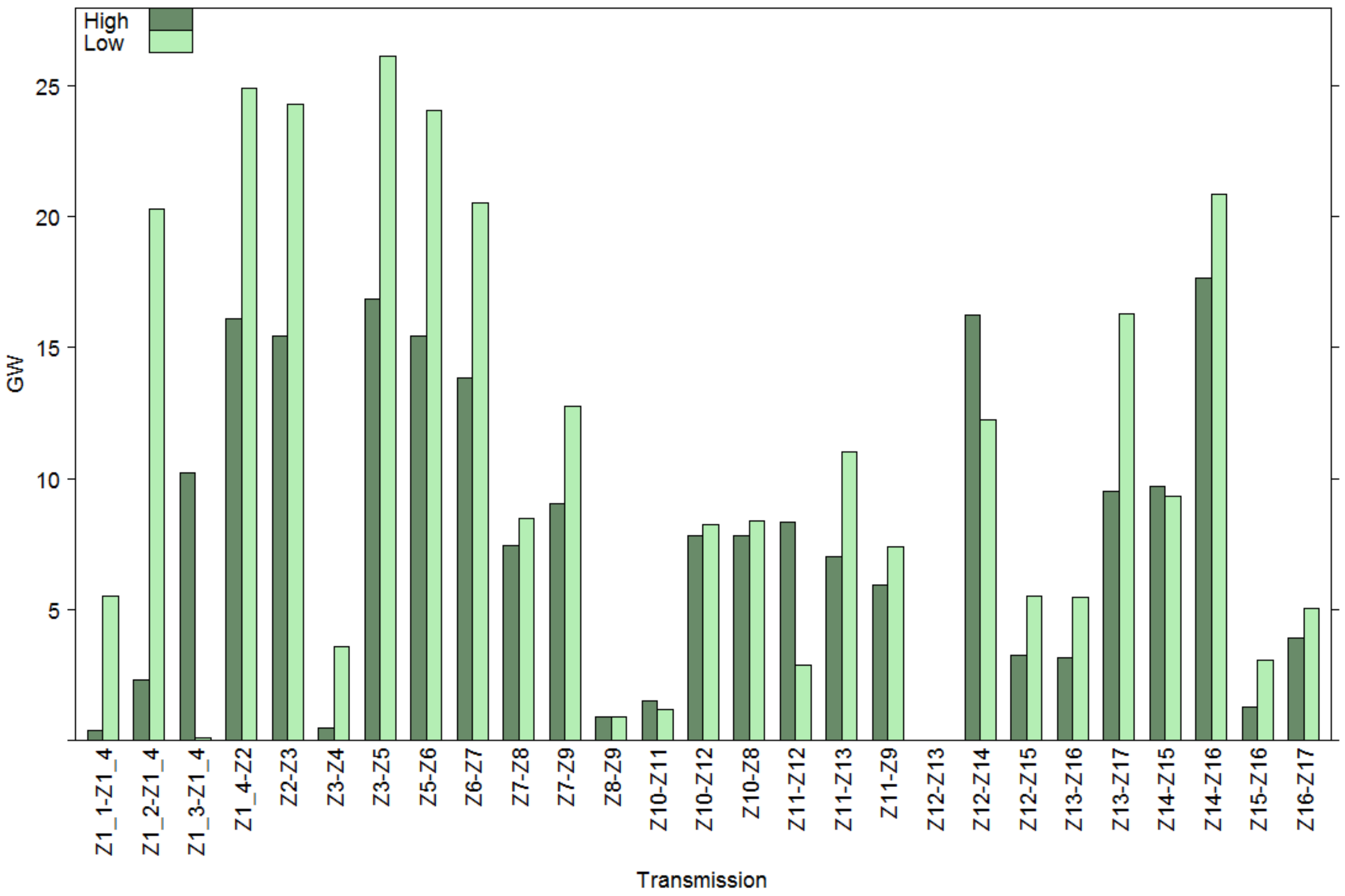


Results: Where are storage and flexible generation located?





Results: Where is the transmission system extended?



Conclusions

- Restrictions determine
  - Costs, VRE generation and Emissions
  - Location of VRE
  - Location and capacities of integration options

- Difference in costs, system configuration as well as emissions show the need to develop projects in cooperation with affected groups

Future work

- Analyse all 27 scenarios
- Include restrictions on transmission line extension
- Participatory research involving stakeholders
- Policy instruments to engage communities
- Demand side response as additional integration option

Thank you!

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