Spatial Optimization of Energy Infrastructure
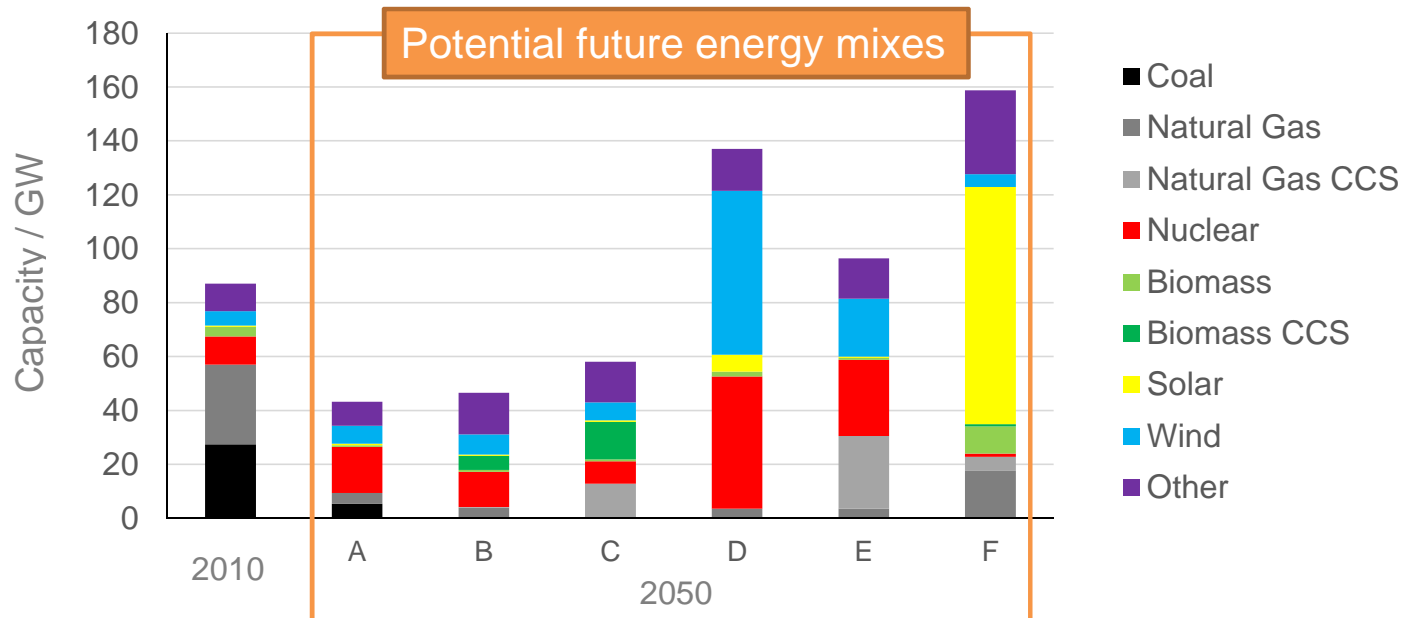
Gemma Delafield

Dr Greg Smith, Prof Brett Day & Prof Ian Bateman, University of Exeter

Energy models

- Energy models tell us **how much** energy we need

- But **NOT where** energy should be located
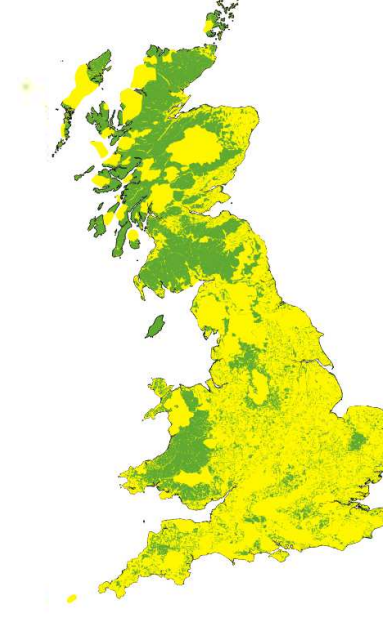
Land use conflicts

Excluding areas of land

High grade
agricultural land

National Parks
& AONB

High quality ag land
NP & AONB

My research objectives

1) Develop a spatial cost minimization model to identify where the **optimal locations for new energy infrastructure** across the UK

2) Apply the model to determine the cost to the energy system **when areas of land are excluded** from energy development **to protect food security / biodiversity**
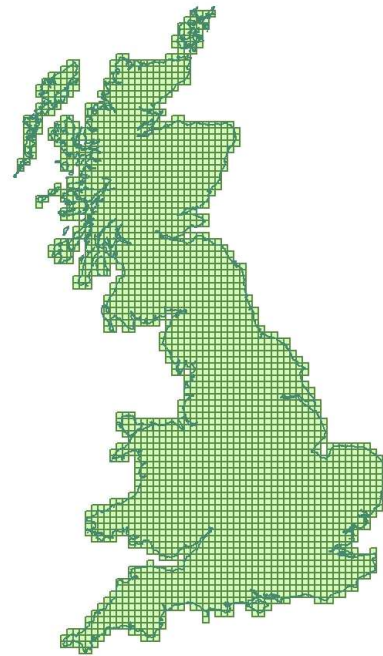
Model development
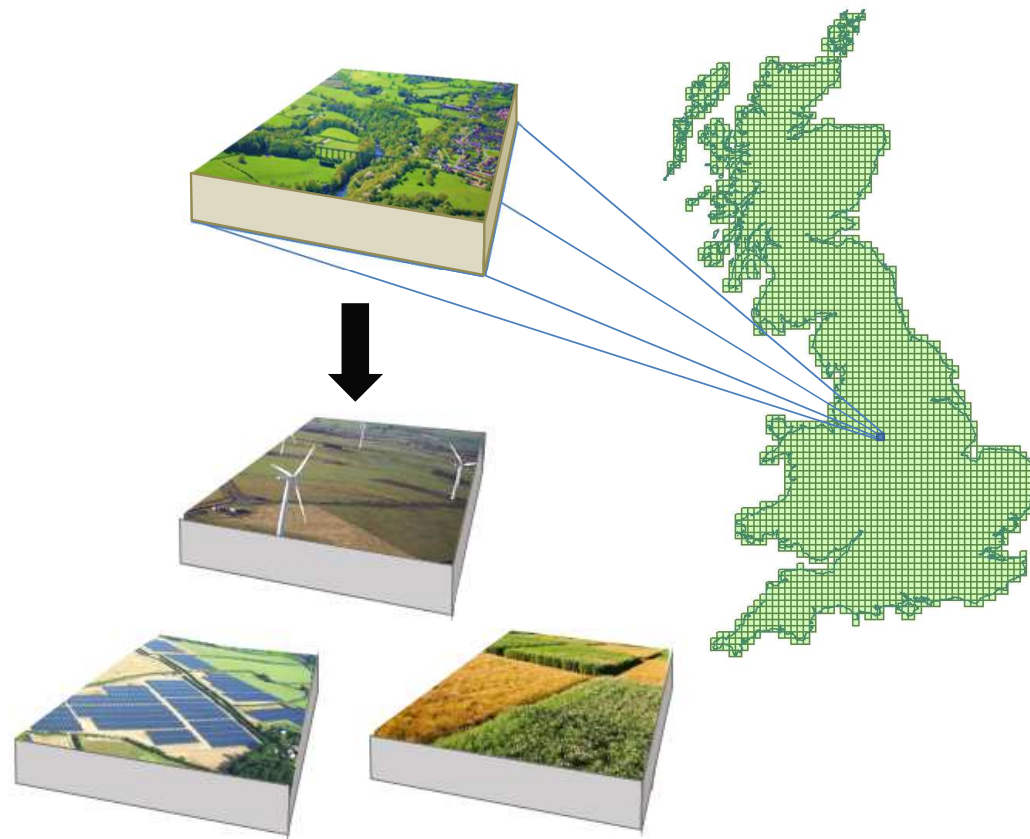
How do we spatialize UKTM output?
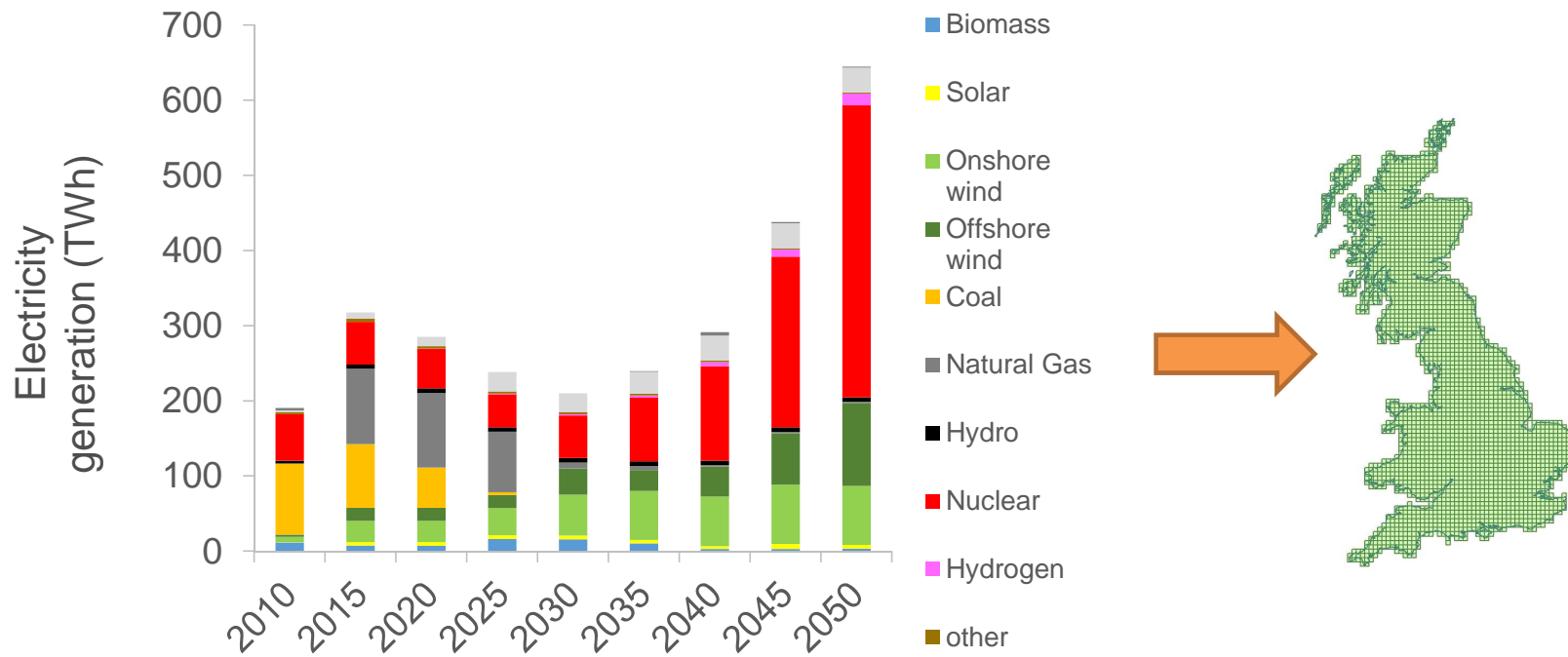
Gridded model

Which combination of cells deliver the energy system at the least cost?

>250,000 1km^2 cells

Spatial optimization model

Spatial optimization techniques

- Connecting to transmission network
  - Dijkstra's algorithm

- Solar-Wind
  - Greedy algorithm or Hungarian algorithm

- Bioenergy
  - Mixed integer linear programming
  - Greedy algorithm

- Solar-Wind-Bioenergy
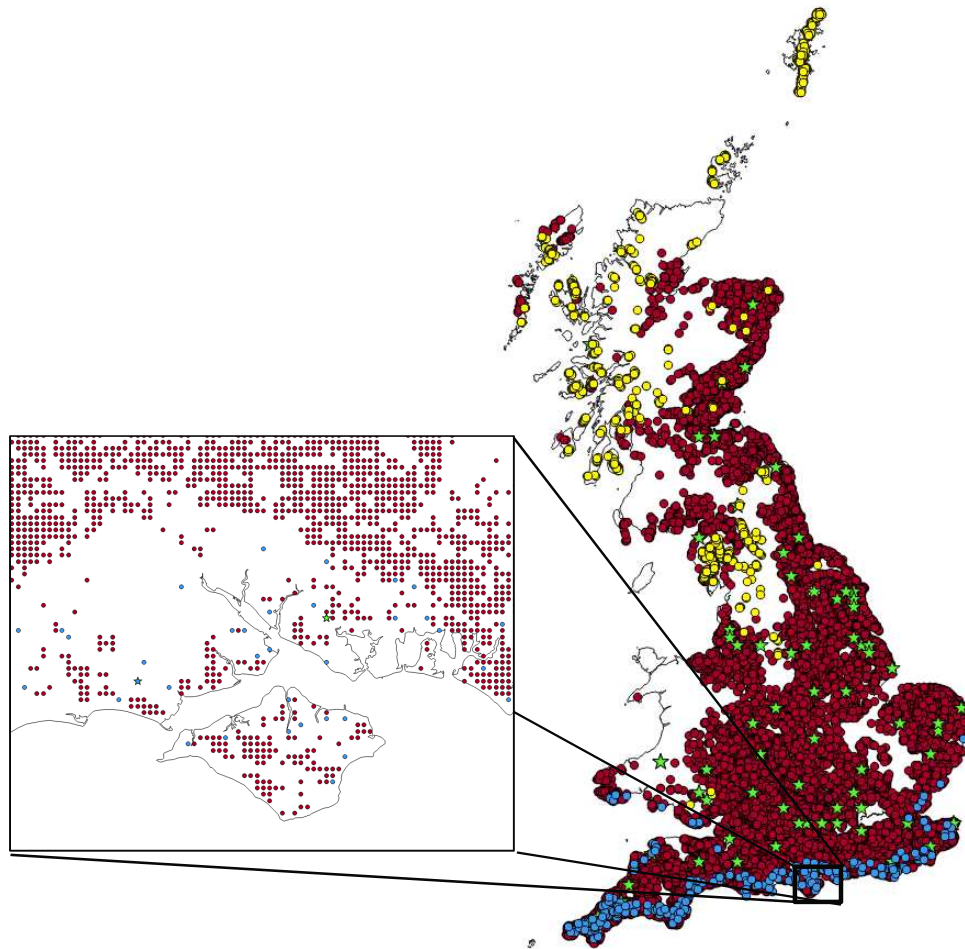 - Iterative Hungarian and Greedy algorithm

Spatial optimization: Bioenergy

Low yield ☐

High yield ▉
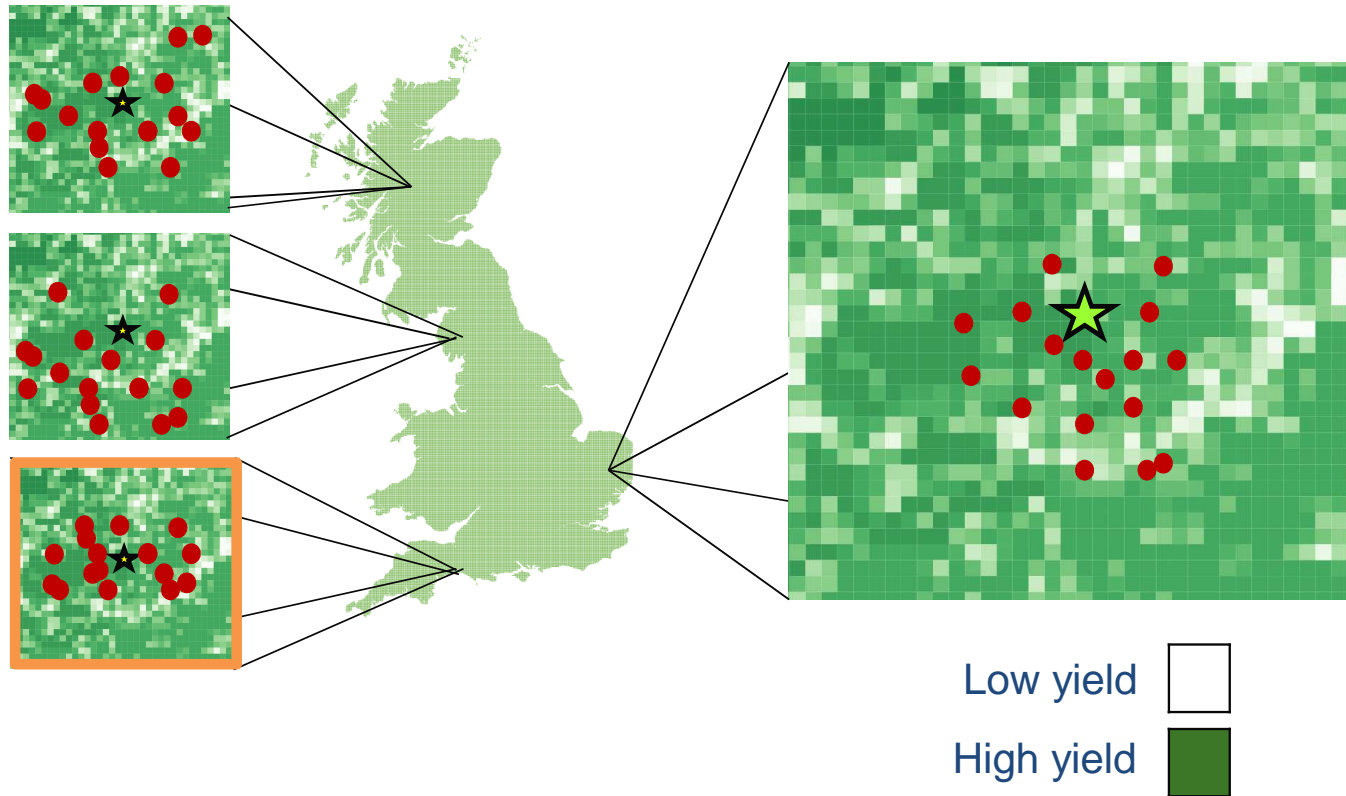
Application of model
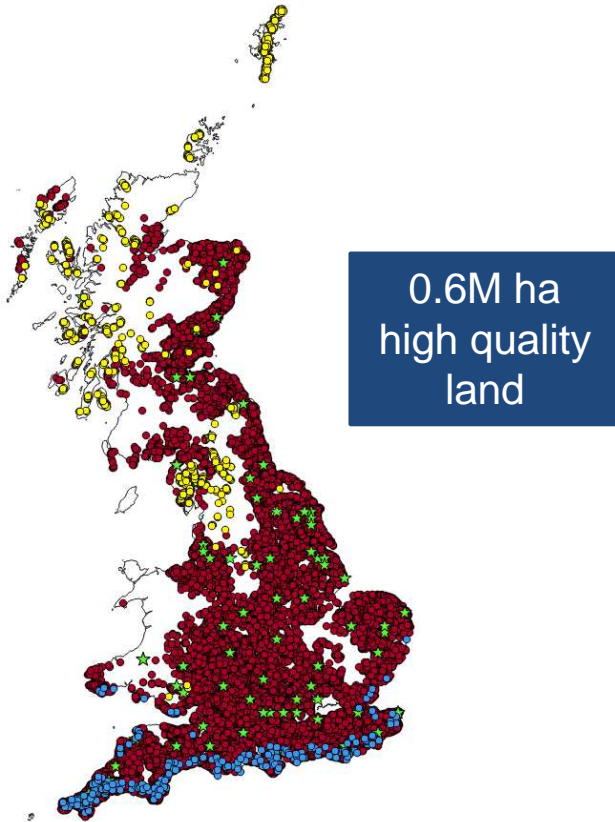## Preliminary findings

Energy-Energy Conflicts

1 in 5 of the good locations for solar farms were also good for growing the bioenergy crop *Miscanthus*
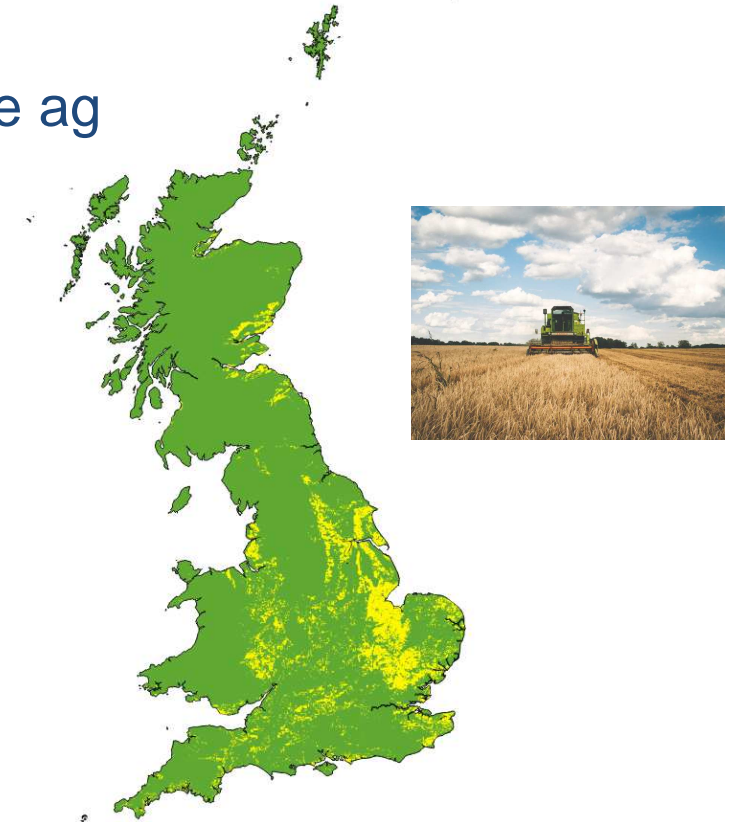
Solar 🔵
Wind 🟡
Bioenergy power plant ⭐
Bioenergy crop 🔴

Energy-Food Conflicts

Exclude:
- Nothing

0.6M ha high quality land

Spatial footprint	2.25M ha
Annualised cost	£1.81 billion

Exclude:
- High grade ag

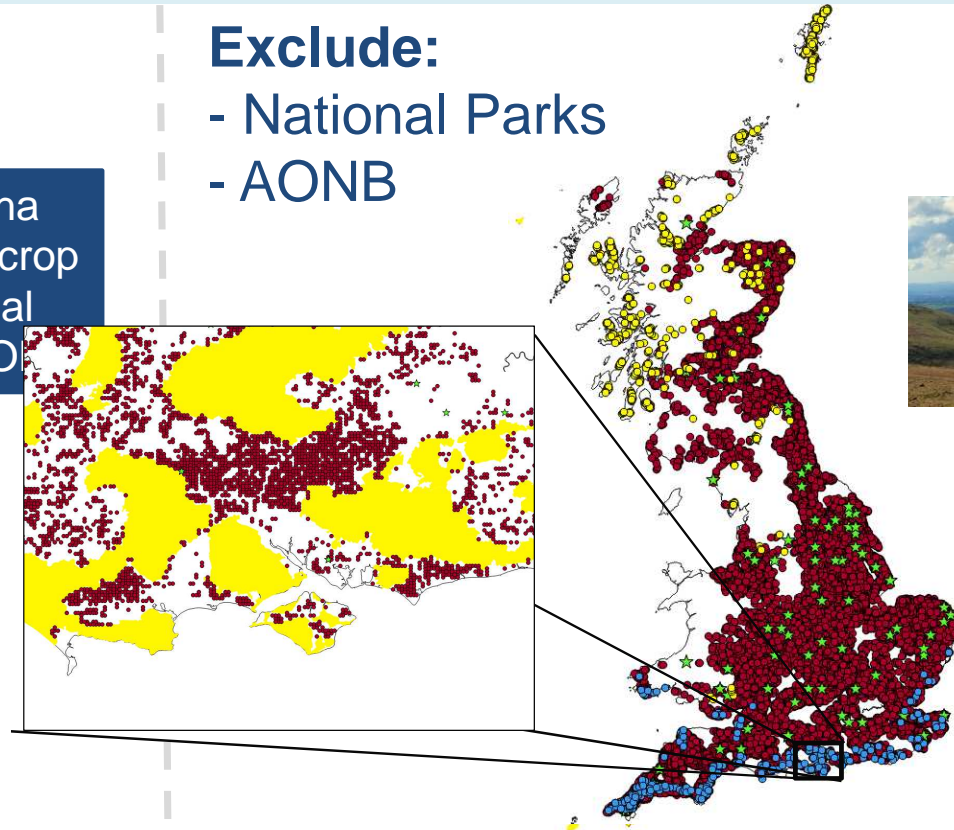| Spatial footprint	2.32M ha (+3%)
Annualised cost	£1.84 billion (+23M)

Energy-Environment Conflicts

Exclude:
- Nothing
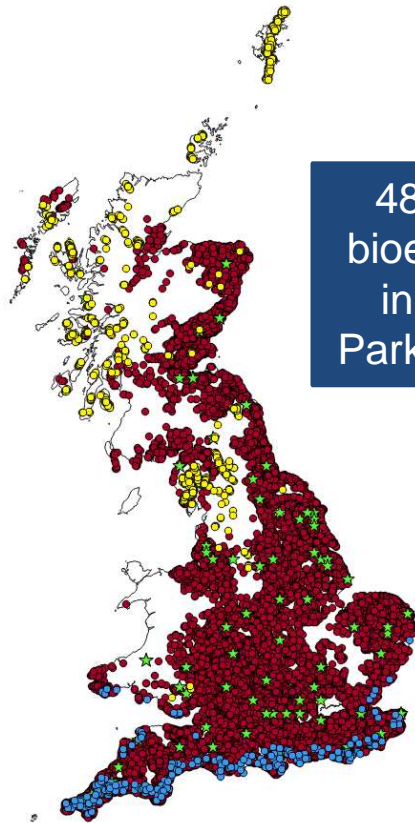
487,000 ha bioenergy crop in National Parks or AO[...]
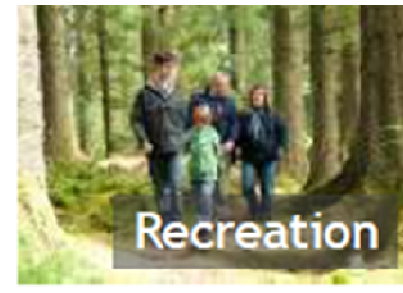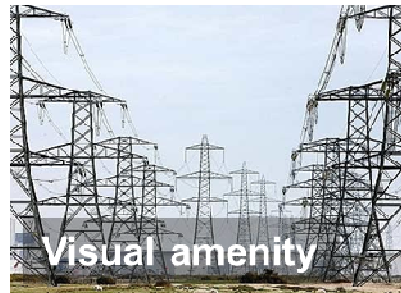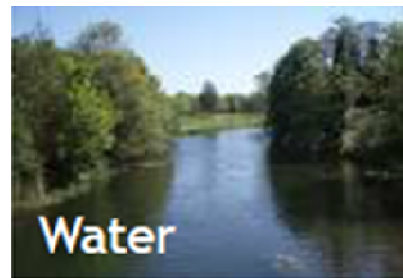
Exclude:
- National Parks
- AONB

Spatial footprint	2.25M ha
Annualised cost	£1.81 billion

Spatial footprint	2.46M ha (+9%)
Annualised cost	£1.96 billion (+143M)

Future focus: Externalities

Biodiversity

Water

Visual amenity

Recreation

CH_4 N_2O CO_2 Soil   GHG

Use environmental economics literature to value the **externalities**.

Include these values alongside the financial costs when choosing energy generation locations

Thank you for listening!

Key messages:

1. Spatial optimization allows us to improve our understanding of how energy futures might impact the UK's landscape.

2. Determining the implied costs of excluding land from energy development can help inform decision-making.

@G_Delafield

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