Projecting the location of energy crops in the UK using an agent-based model

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- UK policy background
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What are perennial energy crops?

- Source of biomass
  - Electricity, heat or potentially biofuels
- Lower inputs and GHG emissions compared to annual crops
- Short rotation coppice (SRC)
  - Typically willow or poplar
  - 20-30 year productive life
  - Harvested every 3-4 years
- Miscanthus
  - Type of grass
  - Grows to ~3.6m high
  - 16+ year productive life
  - Harvested annually


SRC willow


Miscanthus

UK policy background

- Farmer subsidies
  - Grants of 50% establishment costs, under Energy Crop Scheme
  - Scheme closed for new applications in August 2013
- Energy industry subsidies
  - Electricity generation: Renewable Obligation Certificates
  - Changes under Electricity Market Reform
    - Feed-in-tariff using Contract for difference
    - Carbon price floor. Planned increases stopped in 2014 budget
  - Heat used: Renewable Heat Incentive

Areas established to date

- Uptake lower than anticipated
- No current target, but 2007 Biomass Strategy was 350,000 ha by 2020, equivalent to 6.5% of arable land.
- Total areas in England under both energy crop schemes (ECS1 & 2) from 2001-2013
  - 15,000 ha Miscanthus
  - 3,100 ha short-rotation coppice
  - < 1000 ha / year since 2009
- ECS2 significantly under-spent, just 5.5%
  - In 2007, budget of £47 million allocated to support establishment of 60,000 ha
  - £2.61 million spent till 2013 to establish 3,600 ha

Research background

- Existing research conducted on:
  - Biophysical behaviour
  - Environmental impact
  - Land use constraints
  - Modelling of supply with exogenous demand (or demand given supply)
- Work required to include:
  - Contingent interaction of supply and demand
  - Economic case for all market participants
  - Endogenous market price movements
  - Behavioural aspects of farmer adoption

Research Aims

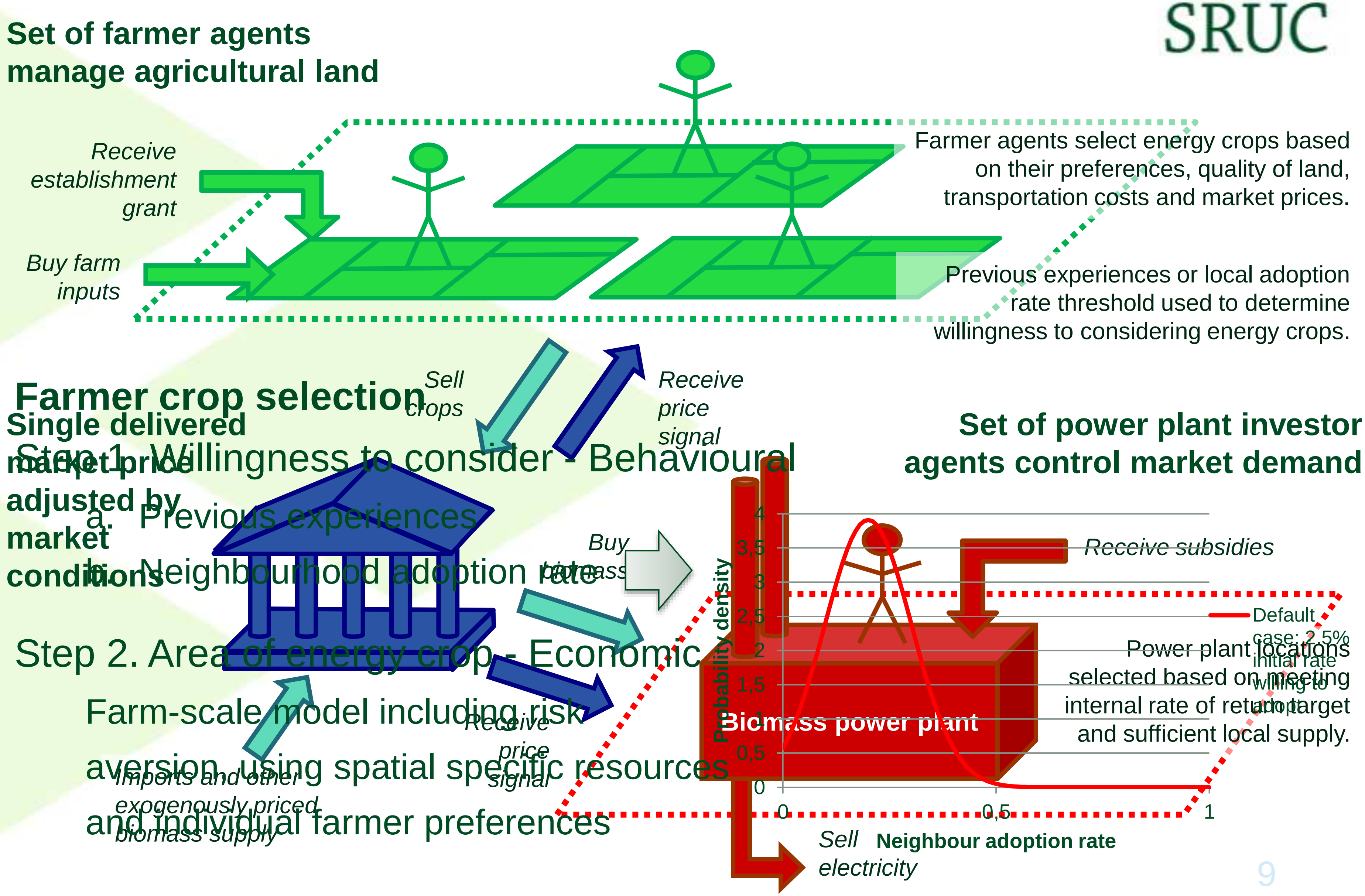
- To investigate:
  - Reasons for the low levels of uptake to-date
  - Potential UK perennial energy crops supply
  - Costs and potential of greenhouse gas emissions abatement from the market
  - Cost-effectiveness of alternative policy measures

- Agent-based modelling approach selected

What are agent-based models?

- Dynamic representation of decision makers (the agents) and their interactions, often within a spatial framework
- System behaviour emerges, based on the decisions of the agents and their interactions with their environment and one another
- Supports the two-way interaction of behaviour between micro and macro scales

Agent-based model construction



Farmer crop selection

Step 1. Willingness to consider - Behavioural

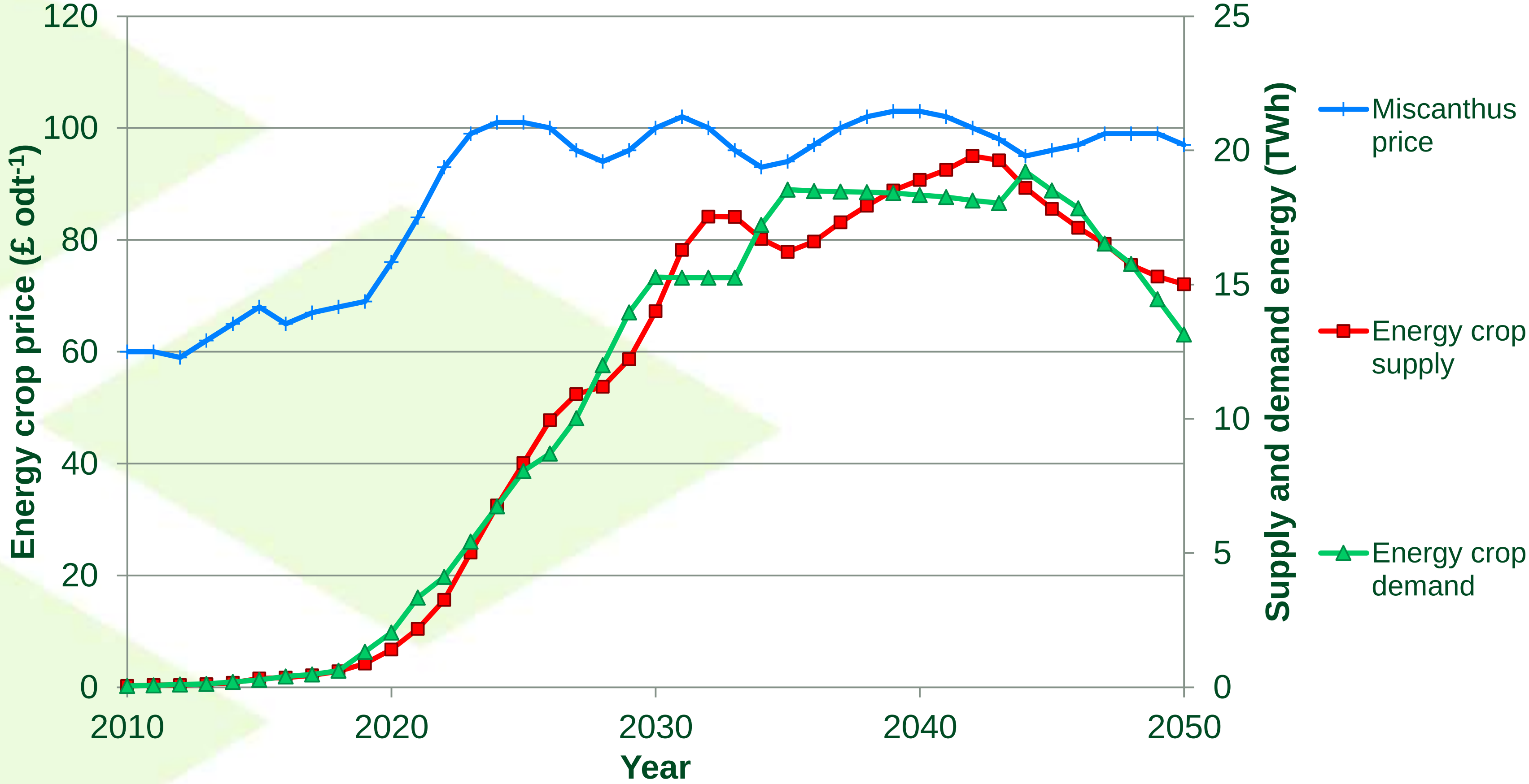
a. Previous experiences

b. Neighbourhood adoption rate

Step 2. Area of energy crop - Economic

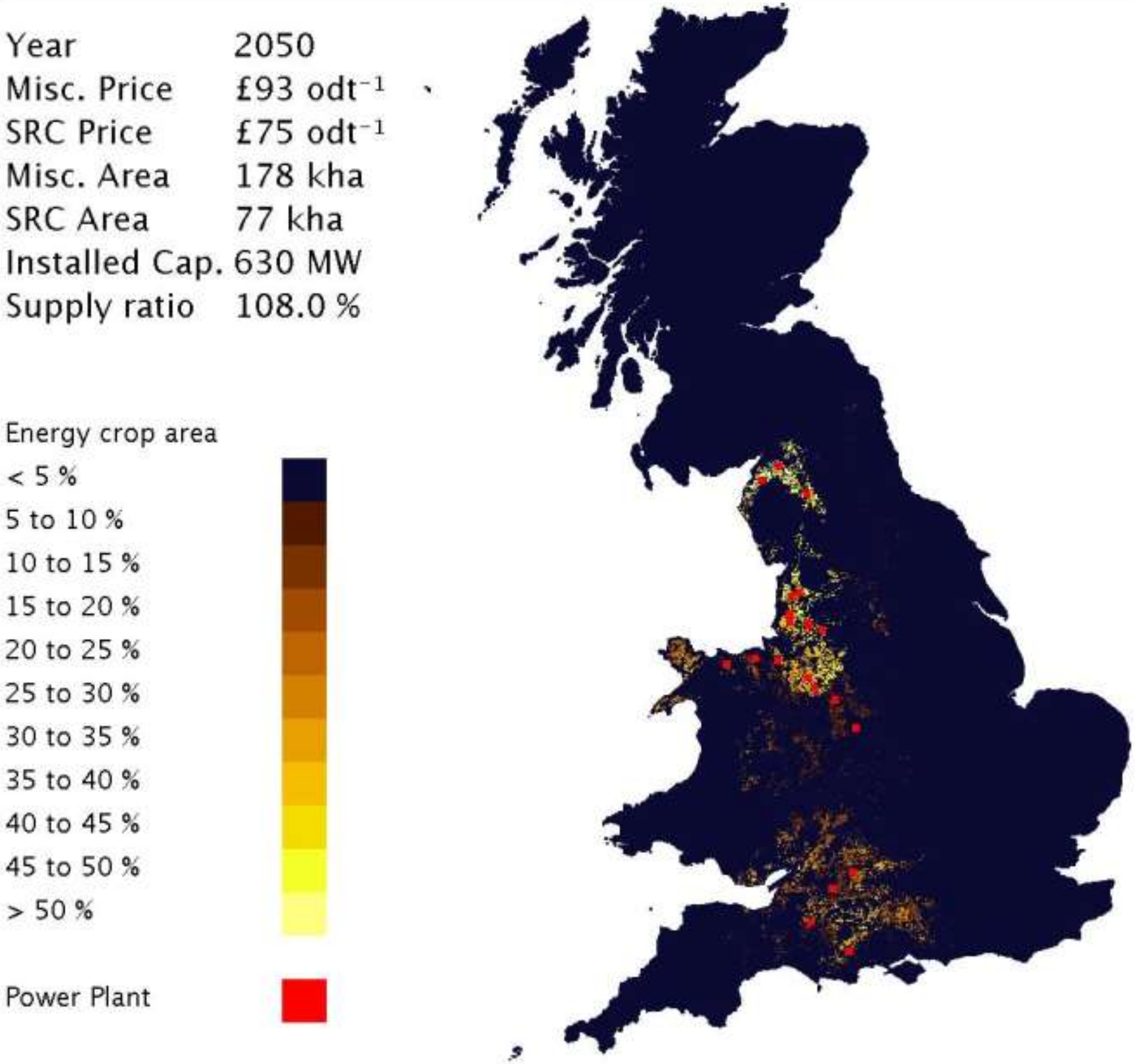
Farm-scale model including risk aversion, using spatial specific resources and individual farmer preferences

Results: Supply/demand and prices



Energy crop prices and biomass supply and demand over time from one model run.

Spatial diffusion pattern



Sample output maps of energy crop selection and power plant locations between 2010 and 2050.

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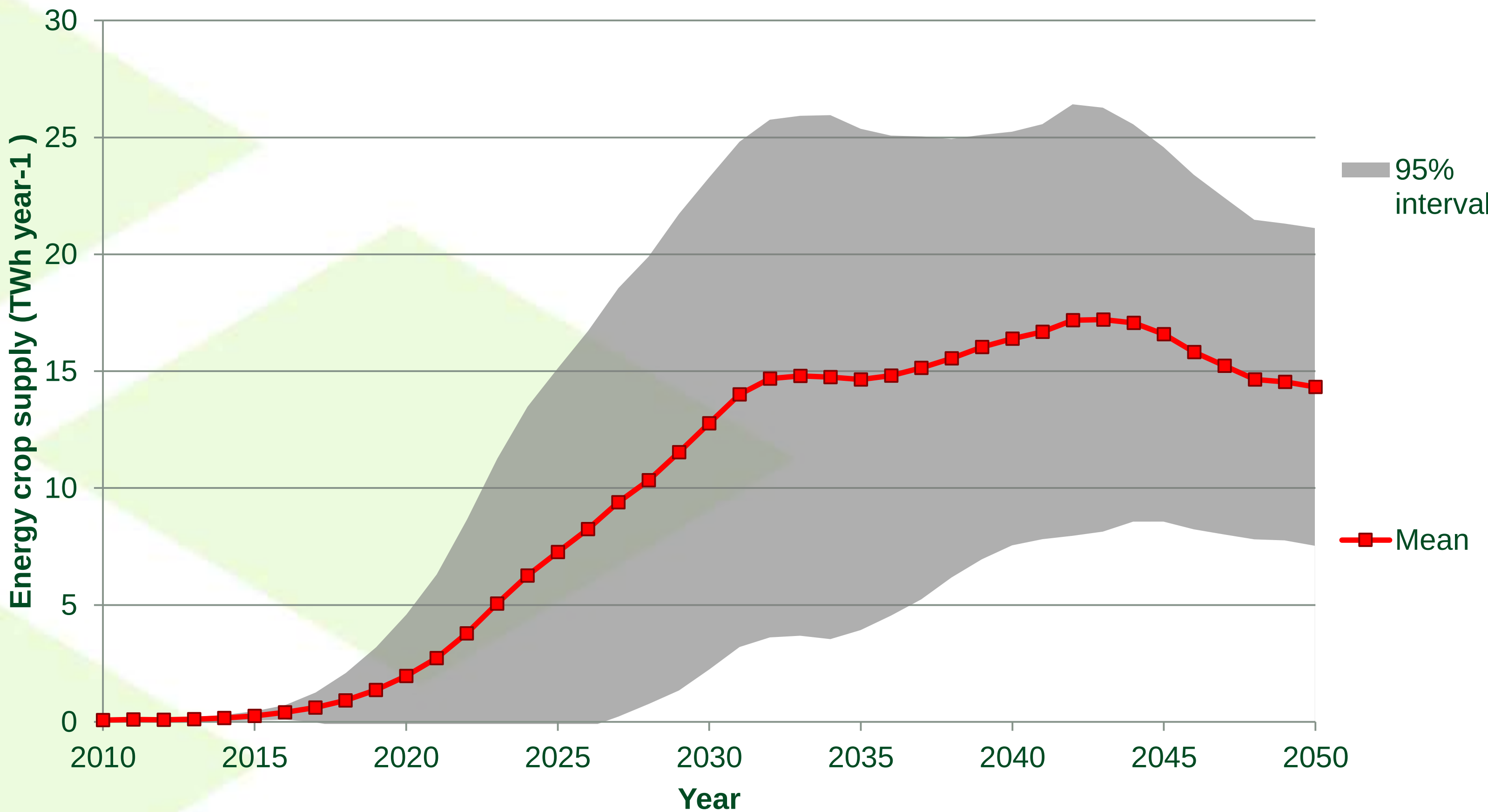
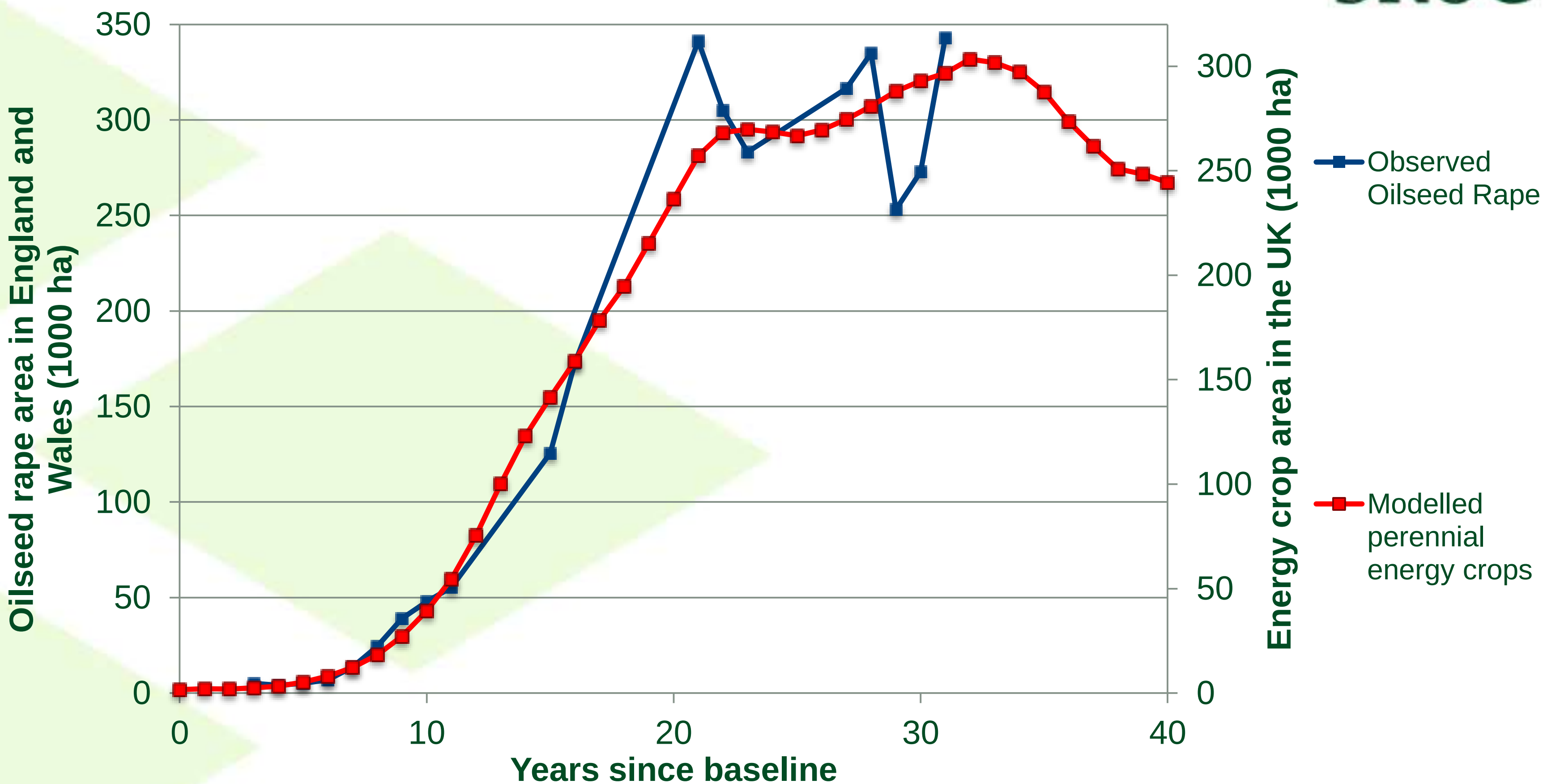
Energy crop supply result distribution



Energy crop supply in biomass energy terms over time for 12 model runs

Comparison with oilseed rape adoption



Historic oilseed rape data for England and Wales, against a baseline year of 1966, and mean (12 runs) modelled perennial energy crop areas, using a baseline year of 2010.

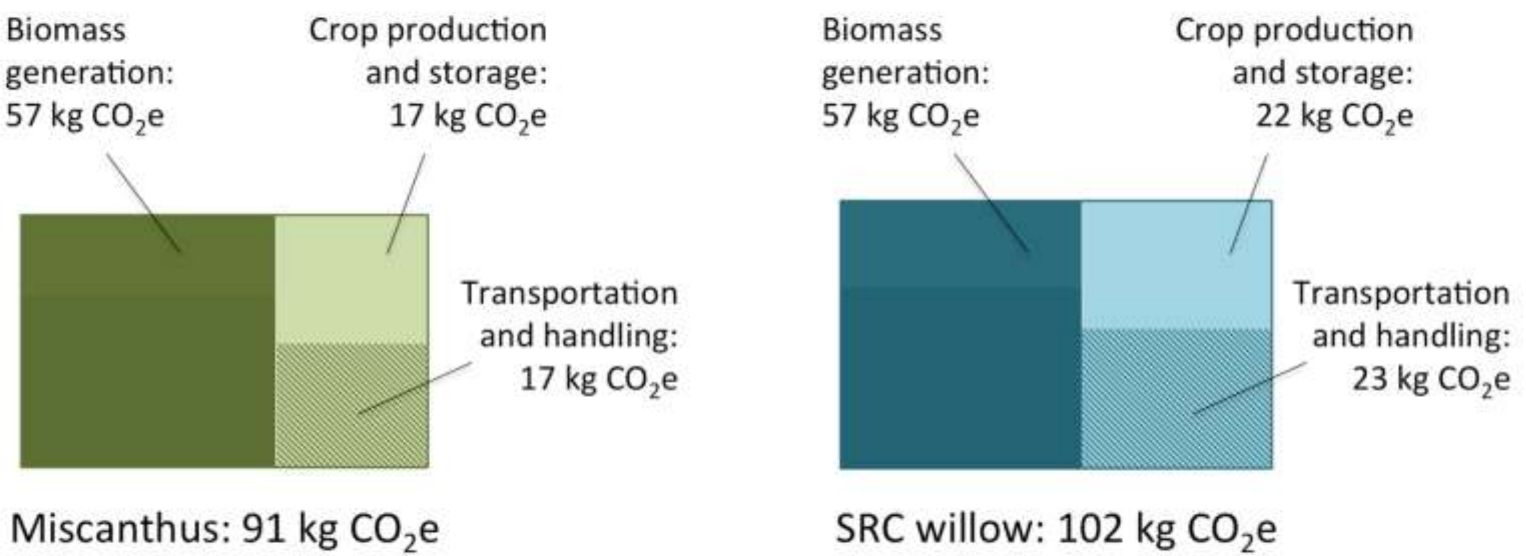
Comparison to previous studies

- Adoption lower and slower than previous studies
  - 39,000 ha in 2020
    - Between 9 and 25 times lower than previous figures[7,8]
  - 236,000 ha in 2030
    - Between 6 and 9 times lower than previous figures[9,10]
- Evidence behaviour arises from spatial diffusion
  - High initial farmer adoption rate bring results broadly into line with these previous results.

[7] DEFRA (2007) Biomass Strategy. *Department for Environment Food and Rural Affairs*.
[8] Gill B, MacLeod N, Clayton D, Cowburn R, Roberts J, Hartley N (2005) Biomass Task Force. *Report to government. London, UK*.
[9] Bauen AW, Dunnett AJ, Richter GM, Dailey AG, Aylott MJ, Casella E, Taylor G (2010) Modelling supply and demand of bioenergy from short rotation coppice and Miscanthus in the UK. *Bioresource Technology*, **101**, 8132–43.
[10] E4tech (2009) Biomass supply curves for the UK.

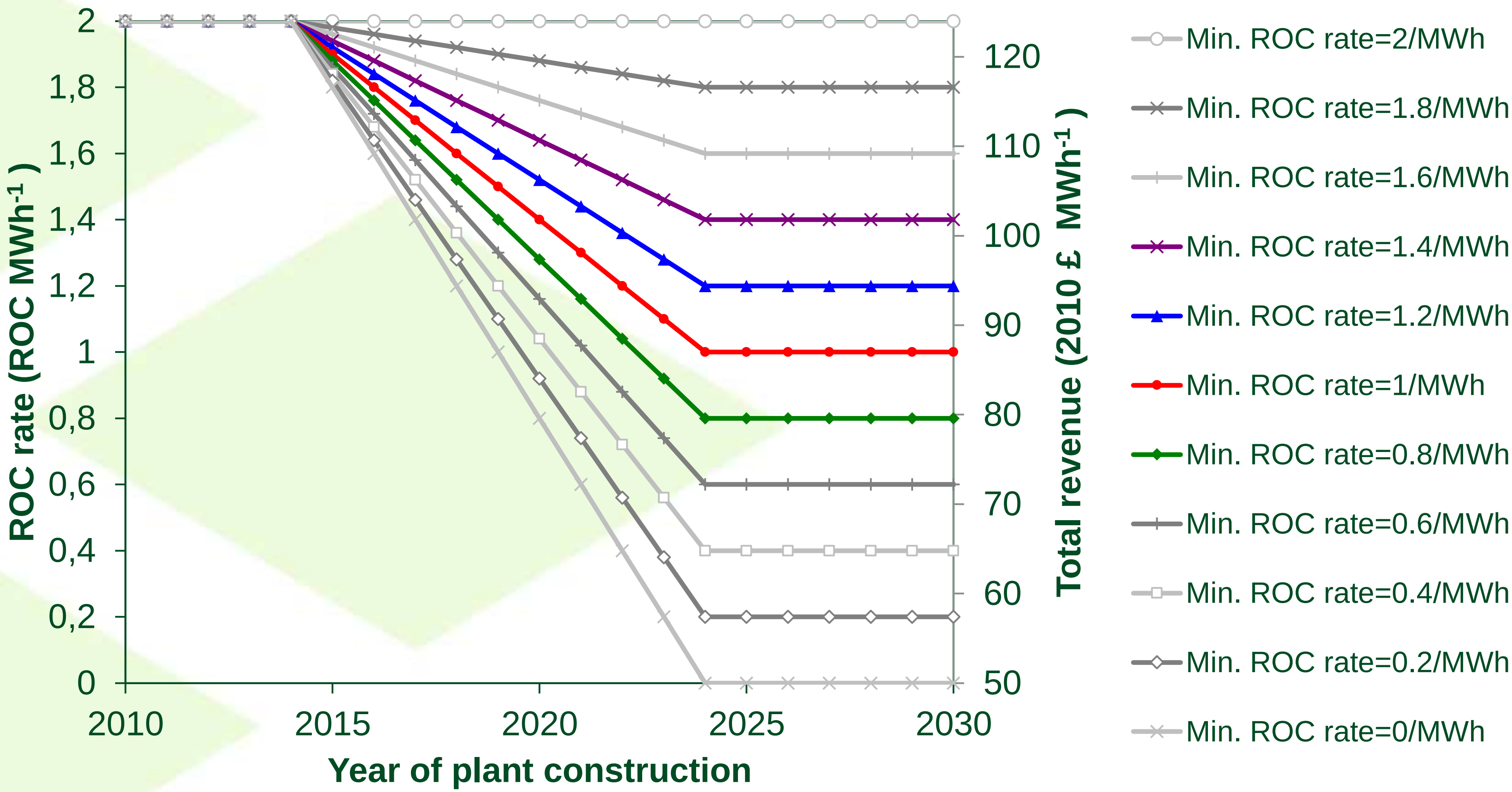
Assessing the GHG impact

- GHG emissions balance include in model
  - spatial yields, transport distances and plant efficiencies used for each crop, plant and time period
- Example energy crop electricity emissions



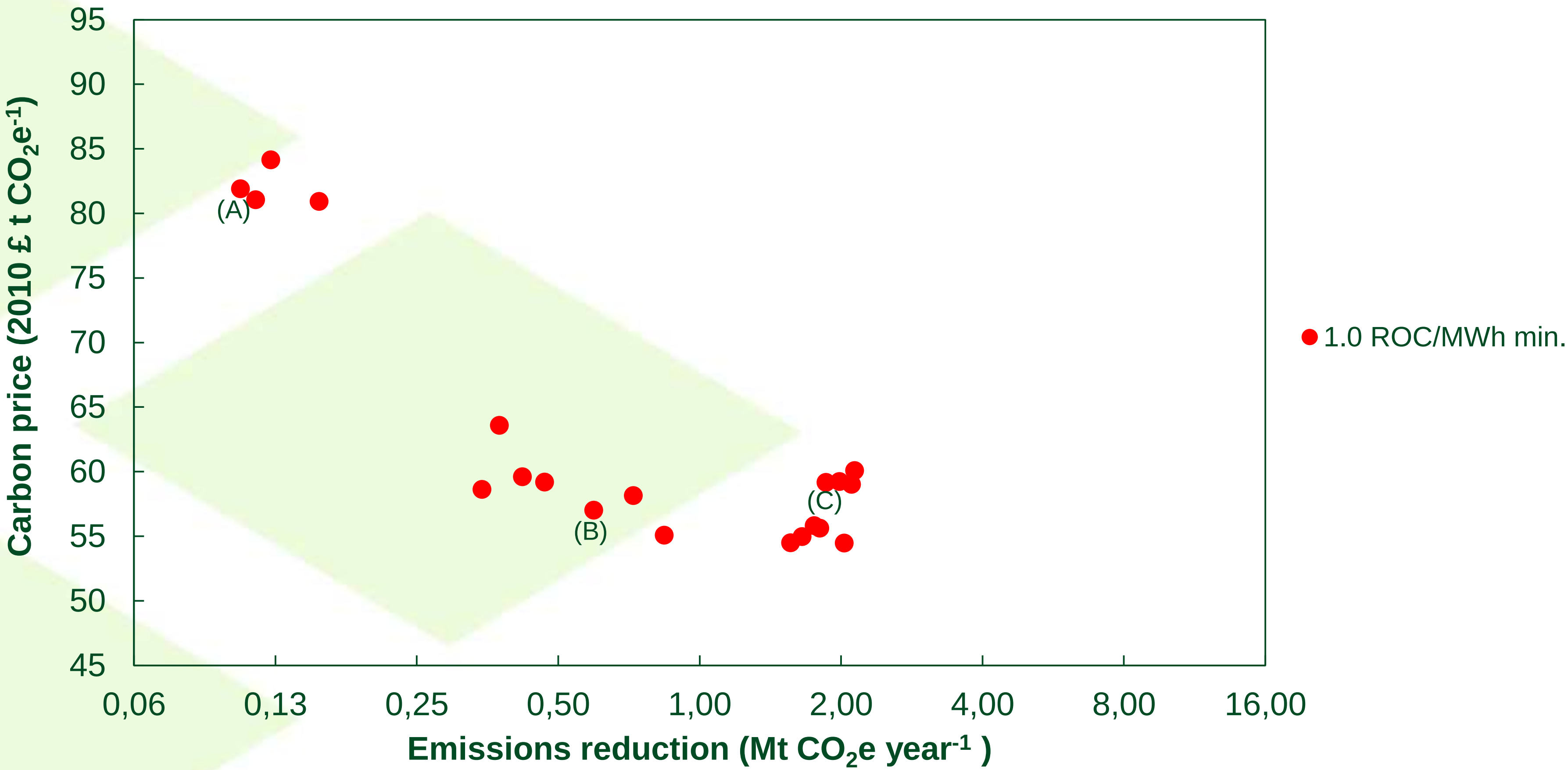
CO_2 equivalent emissions for 1MWh of electricity generated from Miscanthus and SRC willow, assuming a yield of 12 odt ha^{-1} and a 50 km transportation distance.

Electricity generation policy scenarios



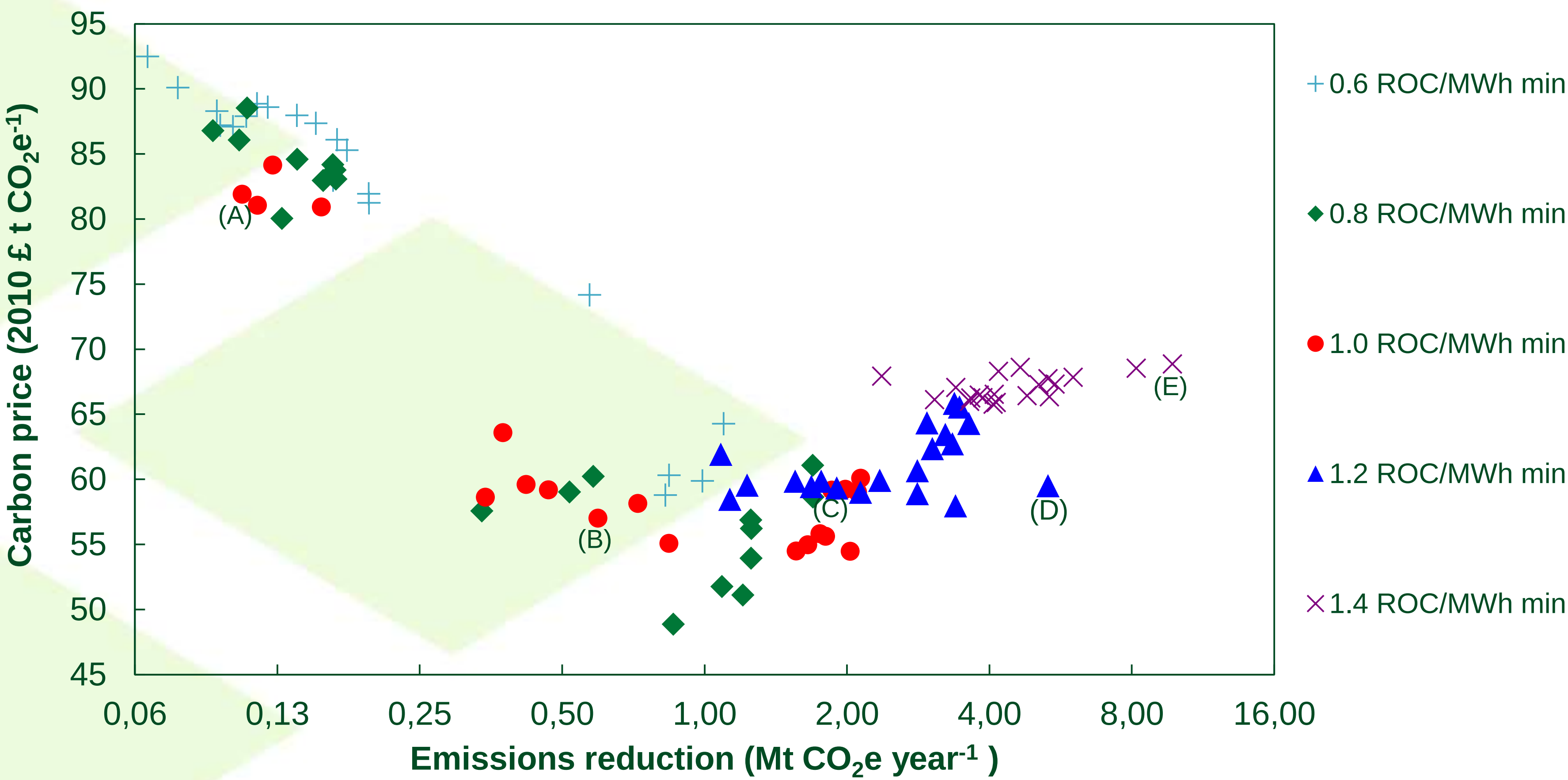
Renewable Obligation Certificate (ROC) rates scenarios by year of plant construction

Carbon price and abatement for runs



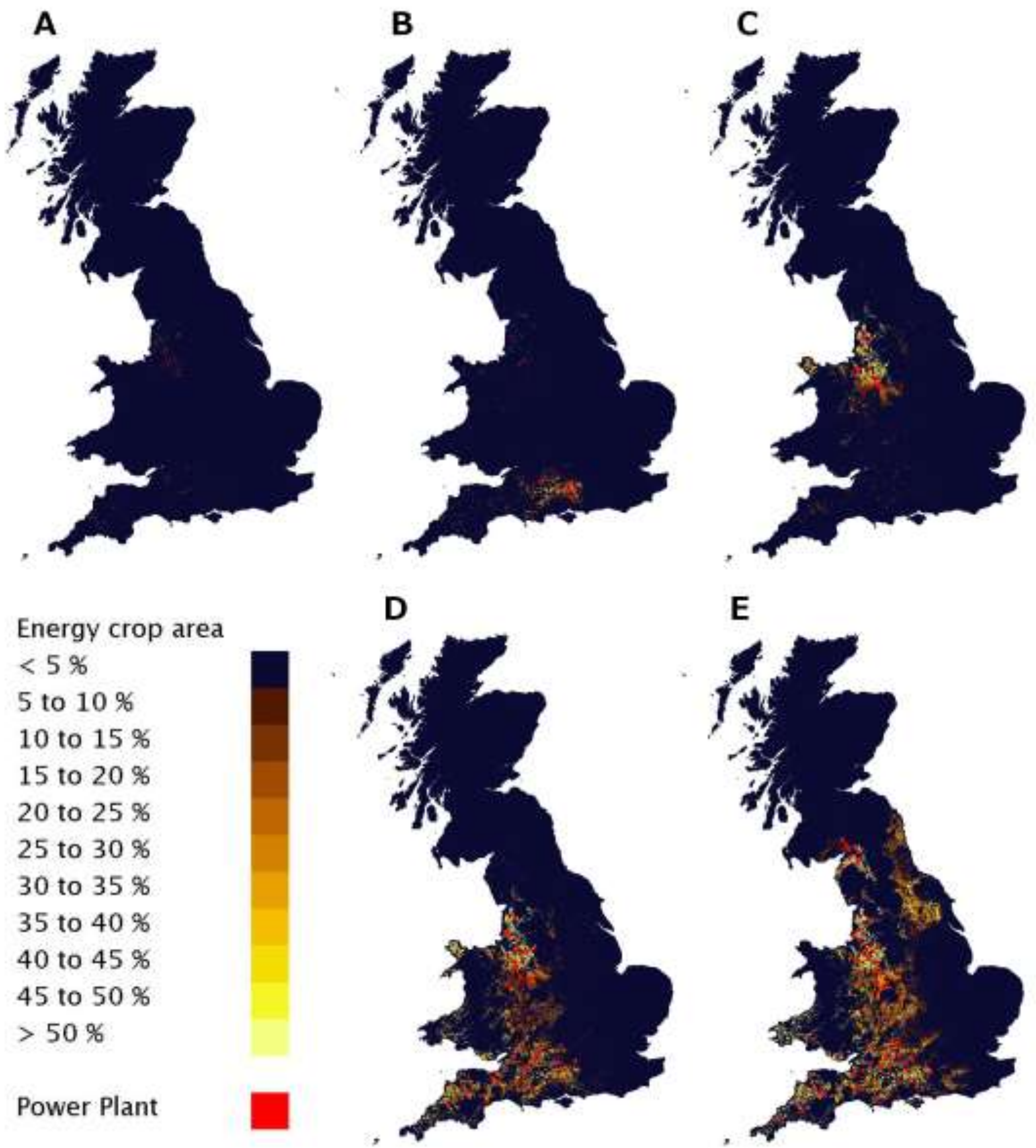
Scatter plot of individual runs with various ROC rates and 50% establishment grant showing cost of carbon abatement against emission reduction, with displacement of coal generation

Carbon price and abatement for runs



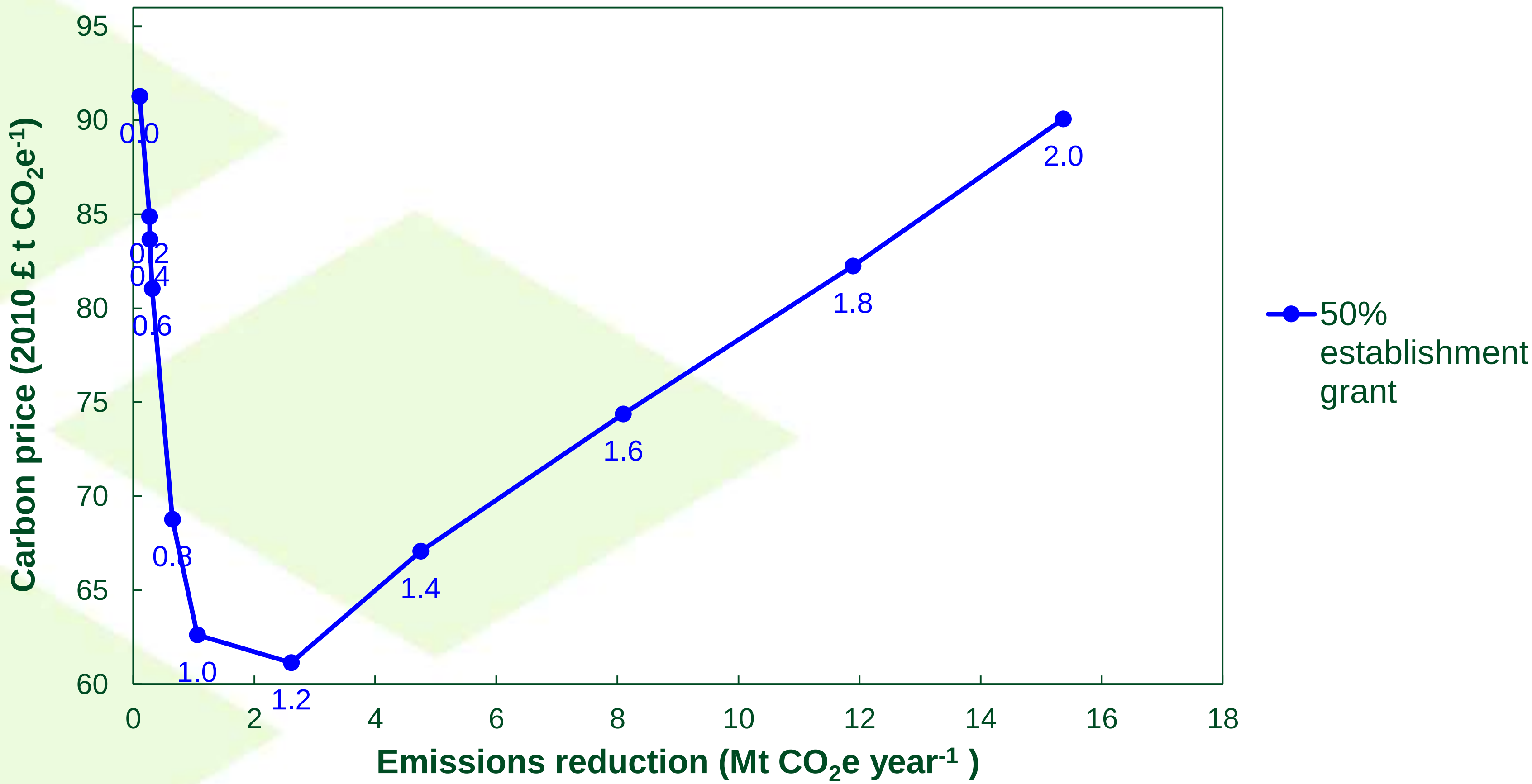
Scatter plot of individual runs with various ROC rates and 50% establishment grant showing cost of carbon abatement against emission reduction, with displacement of coal generation

Example spatial distributions



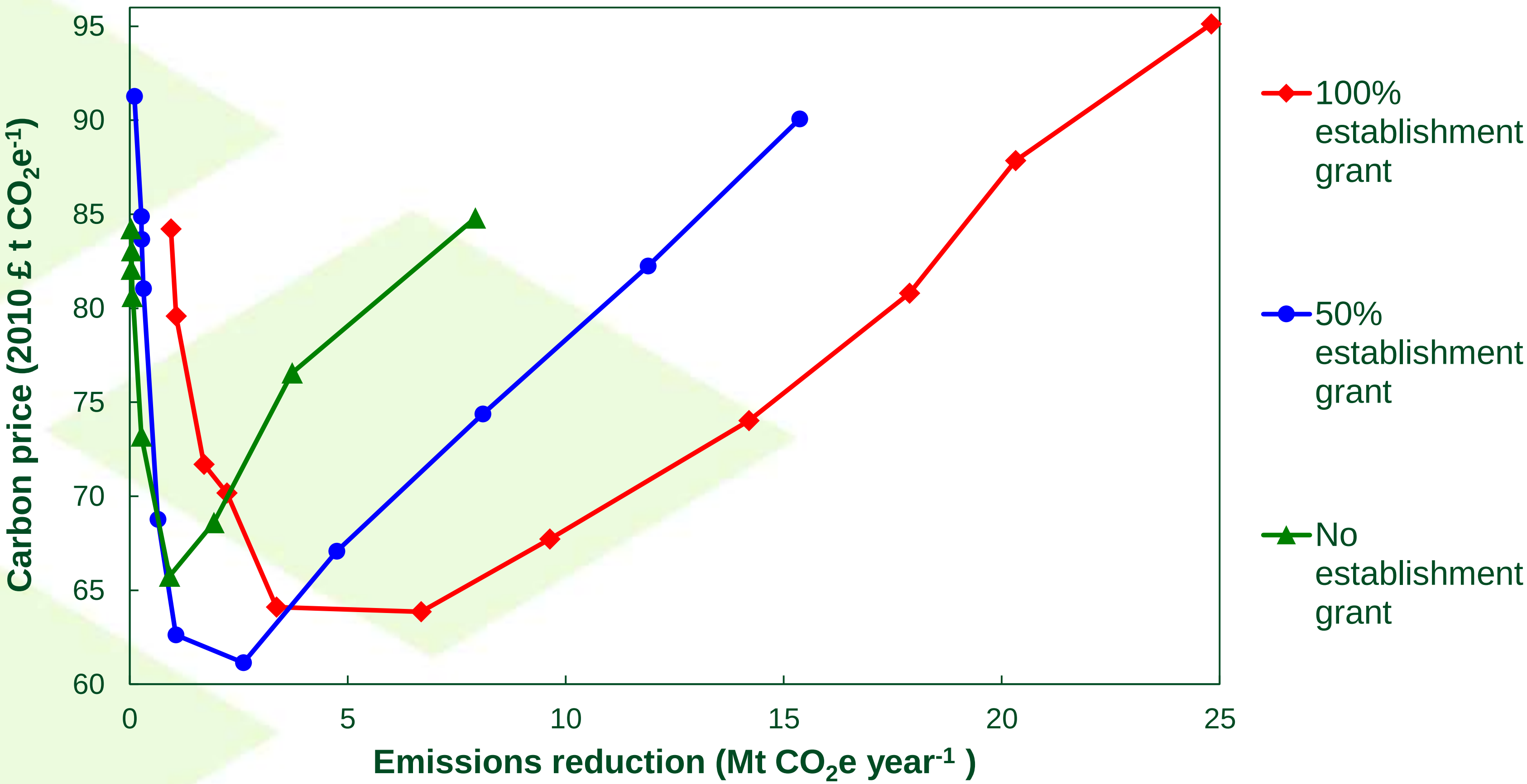
Example distributions of energy crop selection and power plant locations at 2040, A,B & C from examples 1.0 ROC MWh^{-1} minimum ROC rate scenario, D & E showing highest CO_2 equivalent abatement from 1.2 & 1.4 ROC MWh^{-1} minimum ROC rates runs runs

Carbon abatement and cost



Cost of carbon abatement against annual emission reduction for various subsidy policies, assuming displacement of coal generation. Values below points show the minimum ROC rates (ROC MWh^{-1}) used in that scenario

Carbon abatement and cost



Cost of carbon abatement against annual emission reduction for various subsidy policies, assuming displacement of coal generation.

Conclusions

- Area of UK perennial energy crops may be substantially less than previously suggested due to time lags in farmer adoption[1]
- Farm support fulfils an important role in stimulating market development and increasing the cost-effectiveness of carbon abatement [2]
- Minimum subsidy cost of carbon abatement seen at an intermediate level of energy generation subsidy[2]

[1] Alexander P, Moran D, Rounsevell M, Hillier J, Smith P (2014) Cost and potential of carbon abatement from the UK perennial energy crop market. *GCB Bioenergy*, **6**, 156–168.
[2] Alexander P, Moran D, Rounsevell M, Smith P (2013) Modelling the perennial energy crop market: the role of spatial diffusion. *Journal of the Royal Society Interface*, **10**.

Thank you

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Miscanthus
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SRC
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