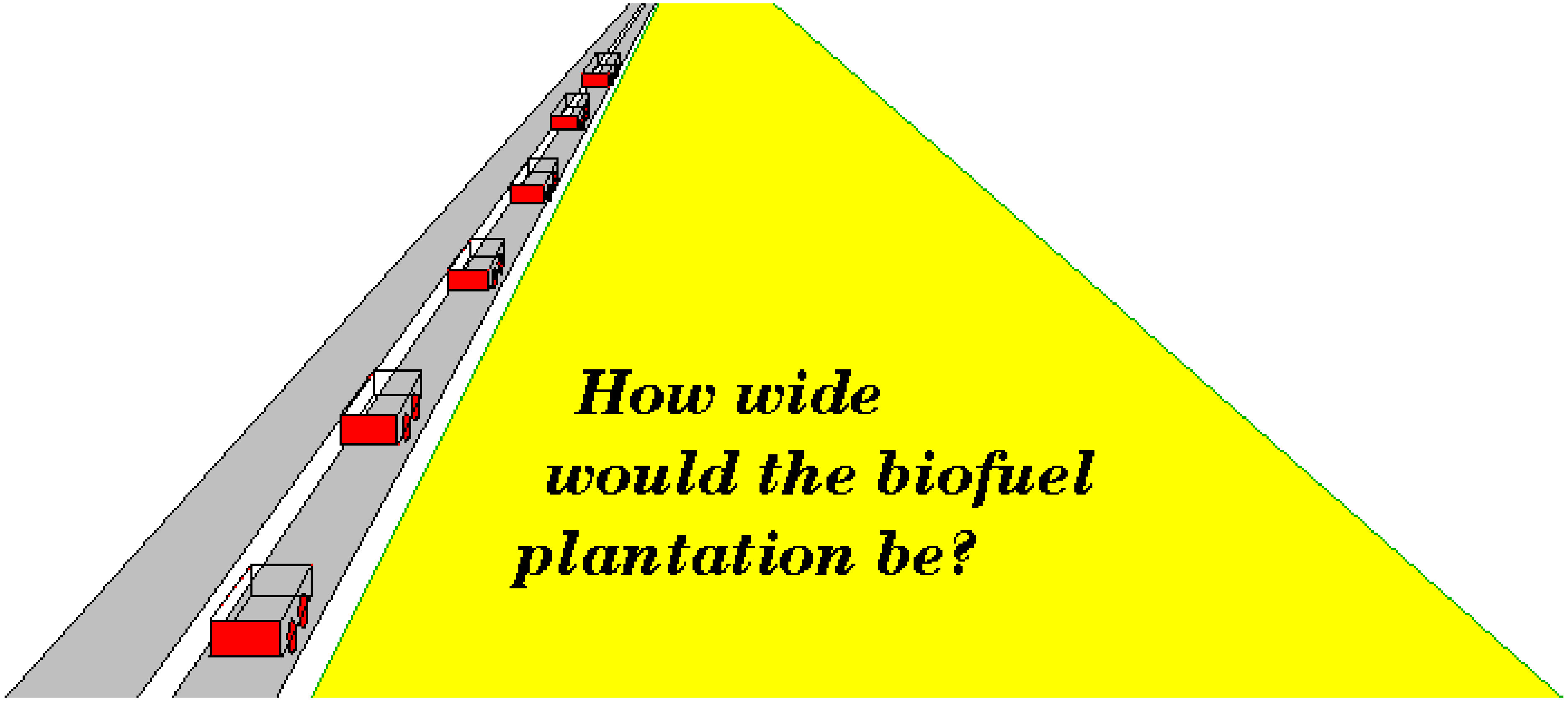
Ups and Downs of the 2050 Calculator

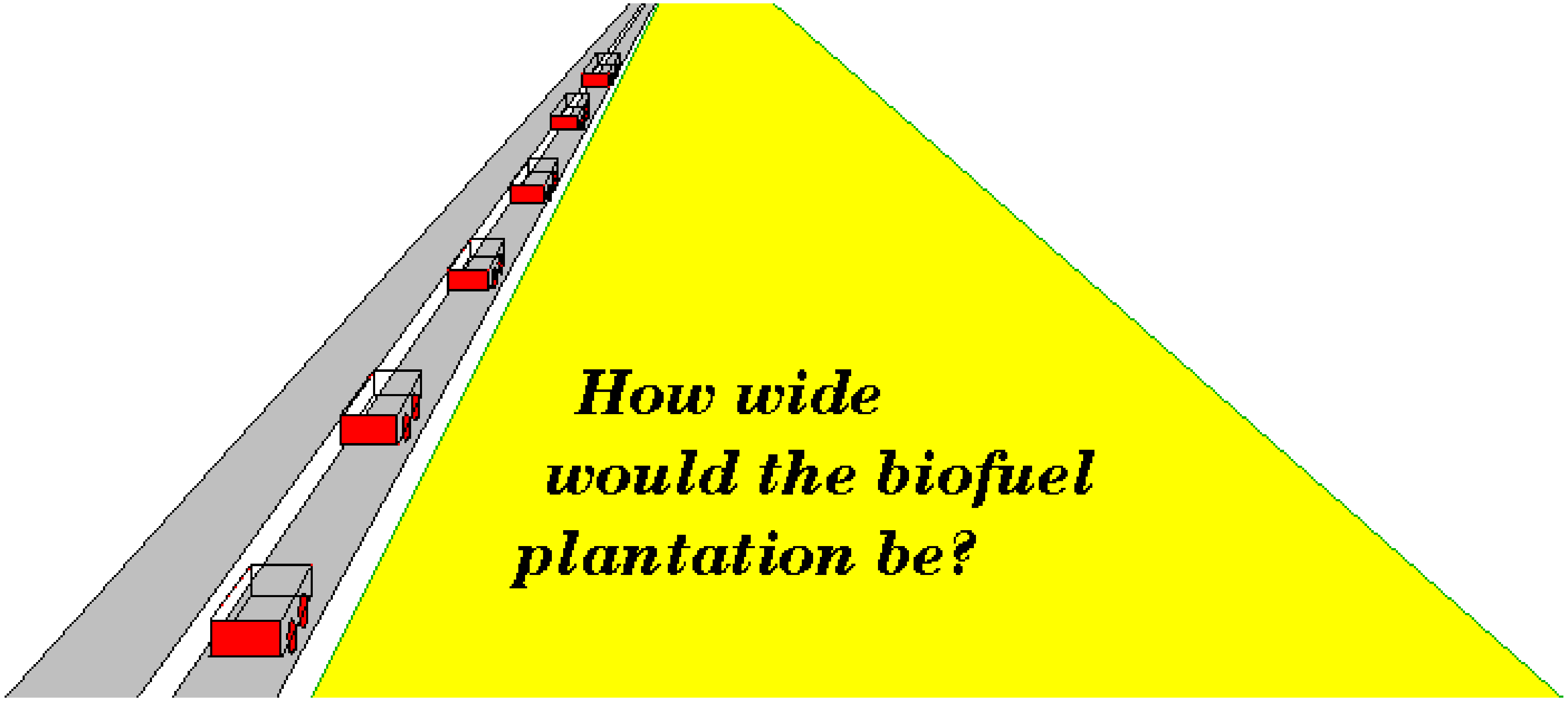
2050 Community Conference   Taipei February 2015

David MacKay FRS

Department of Engineering, University of Cambridge
Former Chief Scientific Advisor, Department of Energy and Climate Change, UK Government



How wide would the biofuel plantation be?



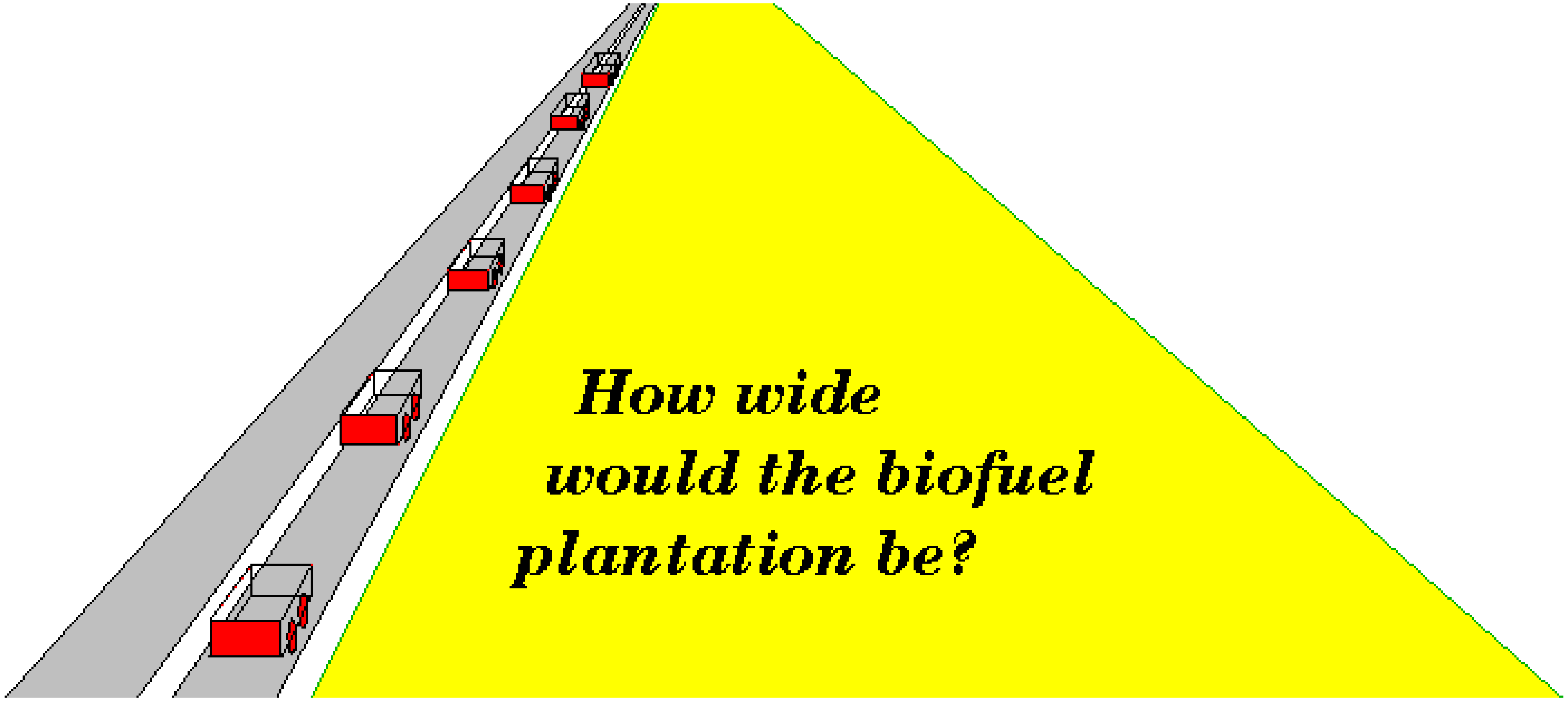
One lane of cars

60 miles per hour

30 miles per gallon

1200 litres of biofuel per hectare per year

80 metres car-spacing



One lane of cars

60 miles per hour

---

30 miles per gallon

1200 litres of biofuel per hectare per year

80 metres car-spacing

= 8 kilometres wide

wishful thinking ⟶ poorly-designed policies

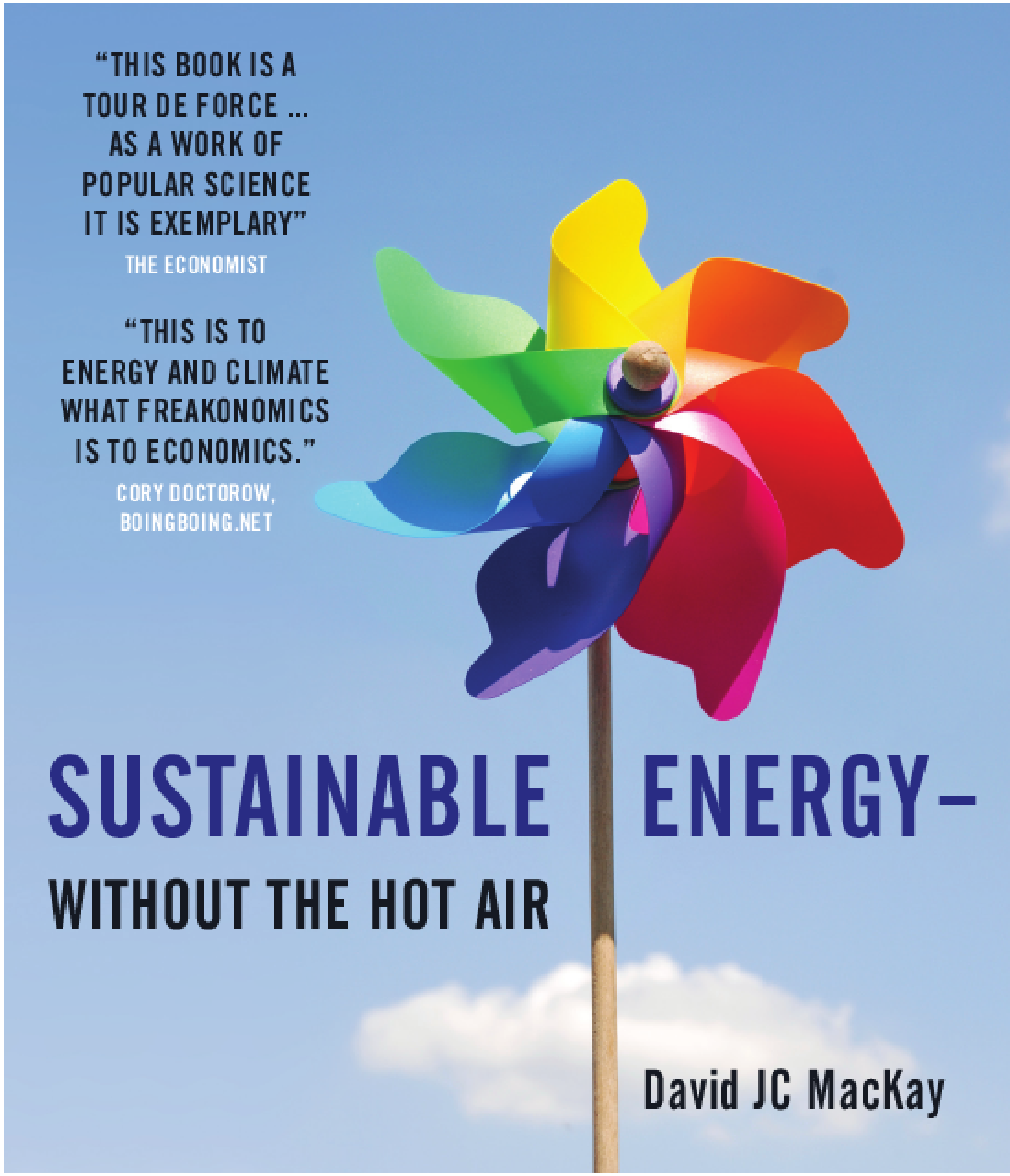
In 2005, the Greater London Authority had a planning requirement that
10% of a building's energy demand is met from on-site renewable energy sources

The designers predicted that the 3 x 19kW wind turbines would produce ~ 8% of the building's energy consumption.

If they worked as predicted, the true cost of the wind turbine's electricity would be 1200 pounds per MWh (10x off-site low-carbon electricity!)

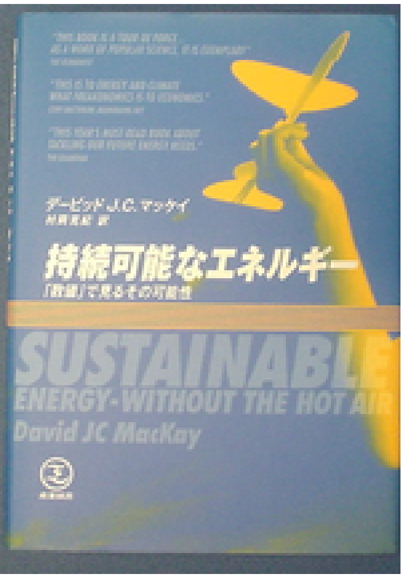
$$\left.\begin{array}{r}\text{wishful thinking}\\ + \\ \text{mistrust}\end{array}\right\}\longrightarrow\left\{\begin{array}{c}\text{poorly-designed policies}\\ + \\ \text{disagreement over solutions}\end{array}\right.$$

This book is free online



www.withouthotair.com

This book is free online



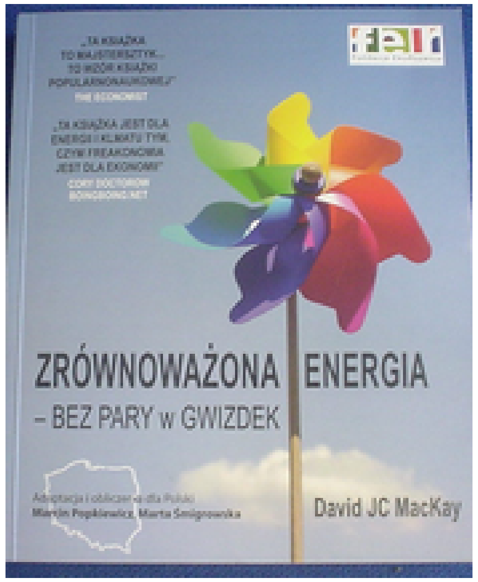
デービッド J.C. マッケイ

持続可能なエネルギー

「数値」で見るその可能性

SUSTAINABLE ENERGY–WITHOUT THE HOT AIR

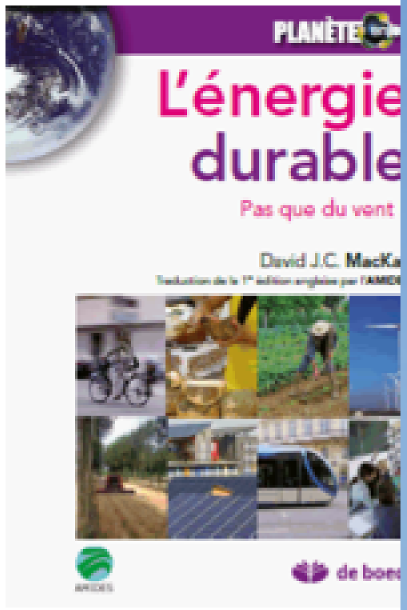
David JC MacKay



ZRÓWNOWAŻONA ENERGIA

– BEZ PARY w GWIZDEK

David JC MacKay



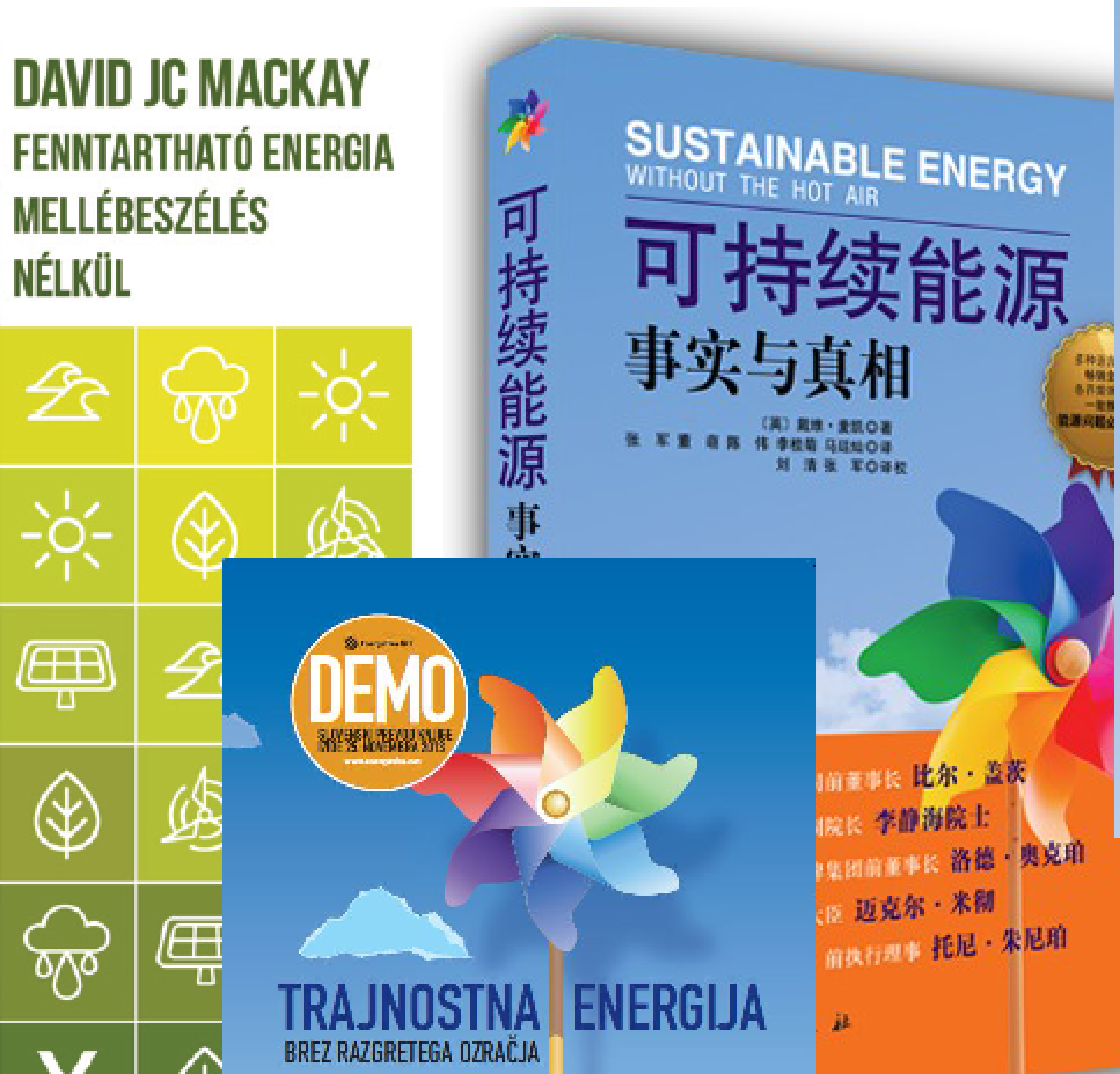
PLANÈTE

L'énergie durable

Pas que du vent

David J.C. MacKa

de boe



DAVID JC MACKAY

FENNTARTHATÓ ENERGIA MELLÉBESZÉLÉS NÉLKÜL

SUSTAINABLE ENERGY WITHOUT THE HOT AIR

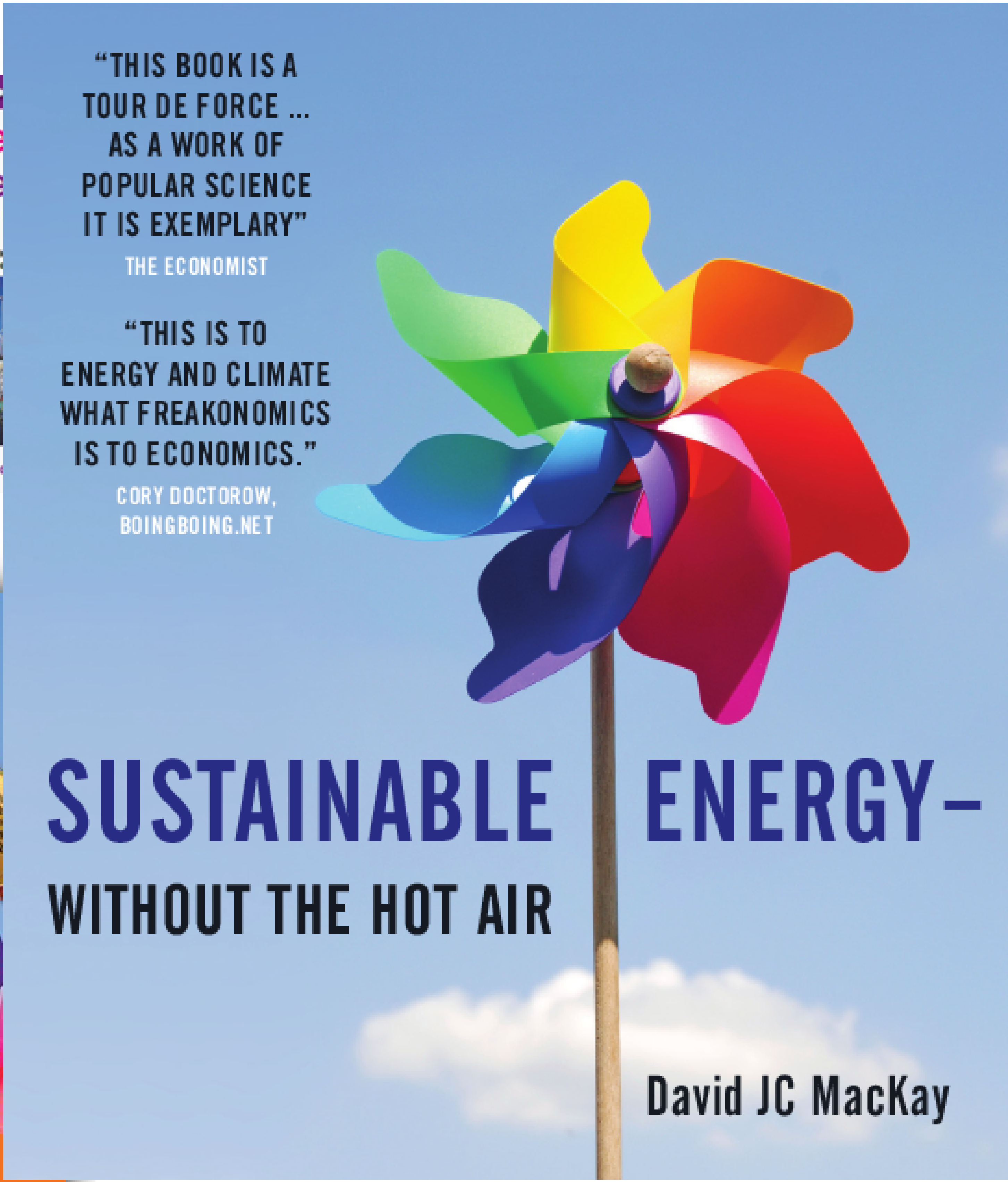
可持续能源

事实与真相

DEMO

TRAJNOSTNA ENERGIJA

BREZ RAZGRETEGA OZRAČJA



"THIS BOOK IS A TOUR DE FORCE ... AS A WORK OF POPULAR SCIENCE IT IS EXEMPLARY"

THE ECONOMIST

"THIS IS TO ENERGY AND CLIMATE WHAT FREAKONOMICS IS TO ECONOMICS."

CORY DOCTOROW, BOINGBOING.NET

SUSTAINABLE ENERGY – WITHOUT THE HOT AIR

David JC MacKay

www.withouthotair.com

How to improve this situation...

$$\left.\begin{array}{r}\text{wishful thinking}\\ + \\ \text{mistrust}\end{array}\right\} \longrightarrow \left\{\begin{array}{c}\text{poorly-designed policies}\\ + \\ \text{disagreement over solutions}\end{array}\right.$$

- Provide facts
- Use numbers, not adjectives
- Use a single set of units
- Talk about scale

- Win trust by:
  - not promoting a solution
  - showing your working
  - getting lots of people to endorse your work

Express all options in a single set of units

Huge expansion for wind turbines

There could be more than two offshore wind turbines per mile of UK coastline under plans being set out by ministers.

Business Secretary John Hutton says he wants to open up British seas to allow enough new turbines - up to 7,000 - to power all UK homes by the year 2020.

The aim is for 20% of EU energy to come from renewables by 2020

John Sauven, the executive director of Greenpeace, said that the plans amounted to a "wind energy revolution".

"And Labour needs to drop its obsession with nuclear power, which could only ever reduce emissions by about 4% at some time in the distantfu

How does nuclear's pathetic 4% compare with the proposed offshore wind?

Huge expansion for wind turbines

There could be more than two offshore wind turbines per mile of UK coastline under plans being set out by ministers.

The aim is for 20% of EU energy to come from renewables by 2020

Business Secretary John Hutton says he wants to open up British seas to allow enough new turbines - up to 7,000 - to power all UK homes by the year 2020.

John Sauven, the executive director of Greenpeace, said that the plans amounted to a "wind energy revolution".
"And Labour needs to drop its obsession with nuclear power, which could only ever reduce emissions by about 4% at some time in the distantfu

How does nuclear's pathetic 4% compare with the proposed offshore wind?

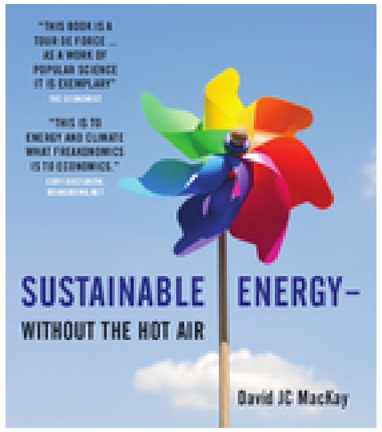
'33GW' of offshore wind would deliver on average 10GW, which is 4kWh/d per person

4%!

4 kWh/d

4 kWh/d	4 kWh/d	4 kWh/d
'all homes'	10 GW nuclear	33 GW wind

How the Calculator evolved



2f

Sustainable Energy – without the hot air

over 2 tons per person of stuff every year, of which about 1.3 tons per person are processed and manufactured stuff like vehicles, machinery, white goods, and electrical and electronic equipment. That's about 4 kg per day per person of processed stuff. Such goods are mainly made of materials whose production required at least 10 kWh of energy per kg of stuff. I thus estimate that this pile of cars, fridges, microwaves, computers, photocopiers and televisions has an embodied energy of at least 40 kWh per day per person.

To summarize all these forms of … stuff-transport, I will put on the consumption stack 48 kW… son for the making of stuff (made up of at le… ly newspaper, 2 for road-making… ng); and another 12 kWh … by sea, by road, and by

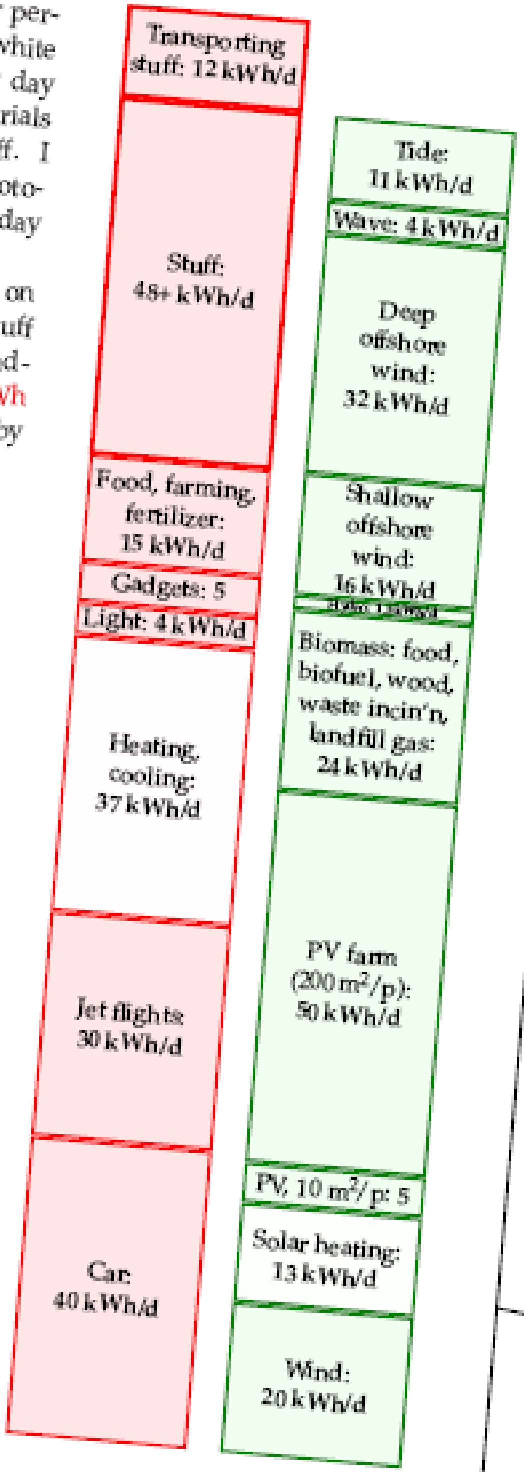


Figure 15.11. Making our stuff costs at least 48 kWh/d. Delivering the stuff costs 12 kWh/d.

4 Wind

The UK has the best wind resources in Europe.

Sustainable Development Commission

Wind farms will devastate the countryside pointlessly.

James Lovelock

How much wind power could we plausibly generate?

We can make an estimate of the potential of *on-shore* (land-based) wind in the United Kingdom by multiplying the average power per unit land-area of a wind farm by the area per person in the UK:

power per person = wind power per unit area × area per person.

Chapter B (p263) explains how to estimate the power per unit area of a wind farm in the UK. If the typical windspeed is 6 m/s (13 miles per hour, or 22 km/h), the power per unit area of wind farm is about 2 W/m².

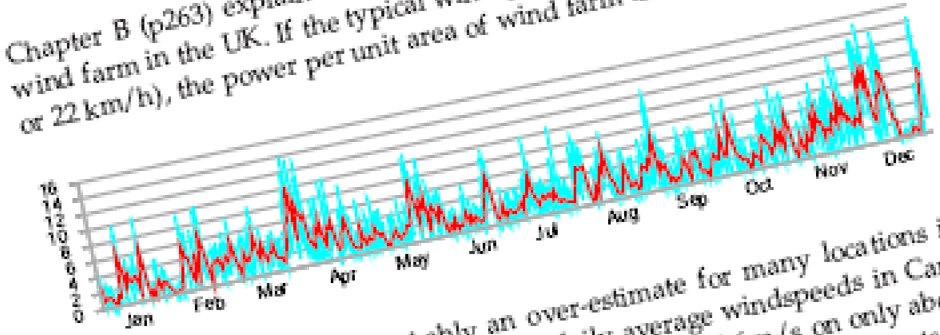
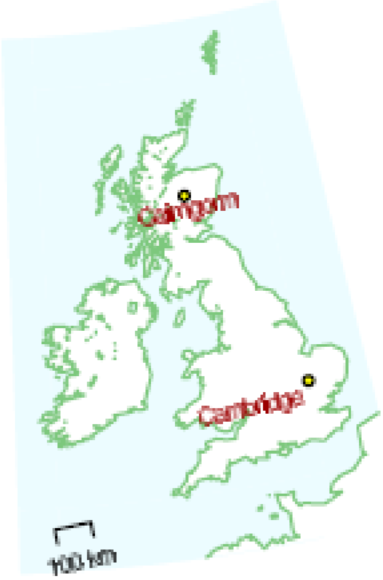
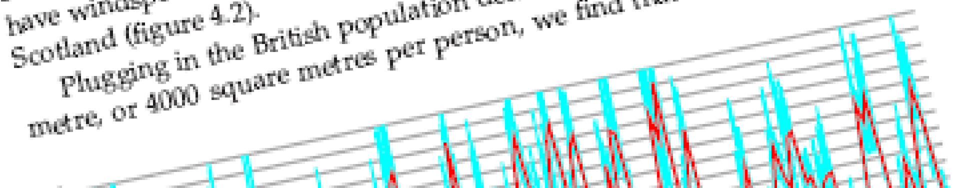


Figure 4.1. Cambridge mean wind speed in metres per second, daily (red line), and half-hourly (blue line) during 2006. See also figure 4.6.

This figure of 6 m/s is probably an over-estimate for many locations in Britain. For example, figure 4.1 shows daily average windspeeds in Cambridge during 2006. The daily average speed reached 6 m/s on only about 30 days of the year – see figure 4.6 for a histogram. But some spots do have windspeeds above 6 m/s – for example, the summit of Cairngorm in Scotland (figure 4.2).

Plugging in the British population density: 250 people per square kilometre, or 4000 square metres per person, we find that wind power could





…Cairngorm mean wind …and, during

…aditional saying

…e can is 15 g. Esti…ry from 60 MJ/kg …is from The Alu…0 kWh/kg).

…ammond and

…995, Britain

…C requires …n weight …-2 times

(2002).

…0 kg …hed …per …x.

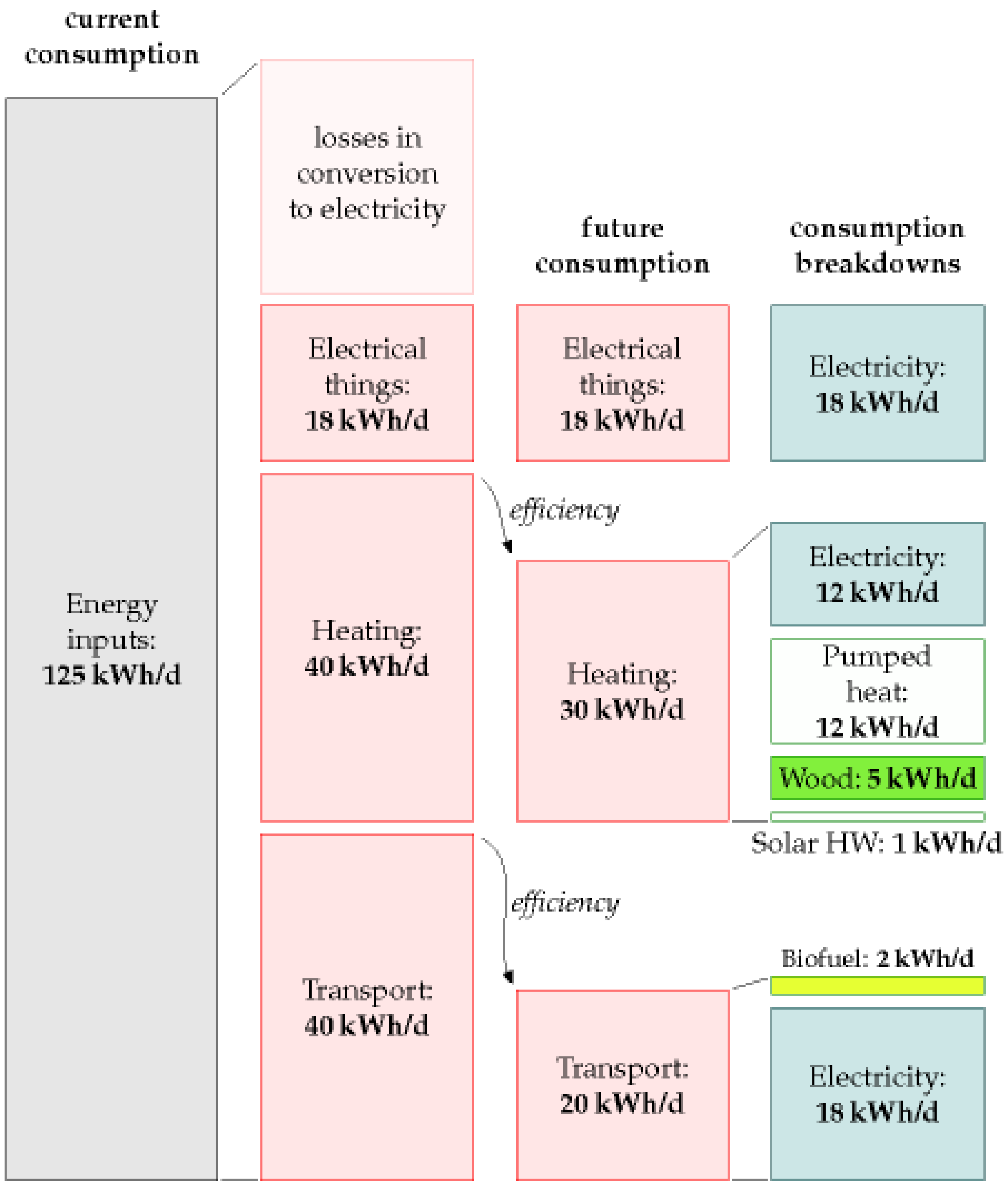
Sustainable Energy – without the hot air

…able is so-… mirrors or …ne in sev-…ries, and …rling en-…ll deliver …/m².

…ered by a square 100 km by 100 km …ncentrating solar power in deserts delivers …area of roughly 15 W/m². So, allowing …h a square, the power deliv… …as current worl…

Figure 25.3. Stirling dish engine. These beautiful concentrat… a power per unit…

Five plans for Cartoon-Britain



current consumption

Energy inputs: **125 kWh/d**

losses in conversion to electricity

Electrical things: **18 kWh/d**

Heating: **40 kWh/d**

Transport: **40 kWh/d**

efficiency

efficiency

future consumption

Electrical things: **18 kWh/d**

Heating: **30 kWh/d**

Transport: **20 kWh/d**

consumption breakdowns

Electricity: **18 kWh/d**

Electricity: **12 kWh/d**

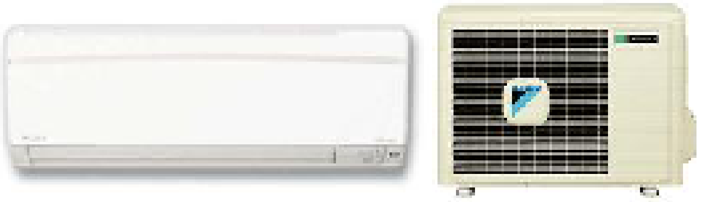
Pumped heat: **12 kWh/d**

Wood: **5 kWh/d**

Solar HW: **1 kWh/d**

Biofuel: **2 kWh/d**

Electricity: **18 kWh/d**



Key ideas

Insulation

Heat pumps

25% of UK

forests, willow, miscanthus

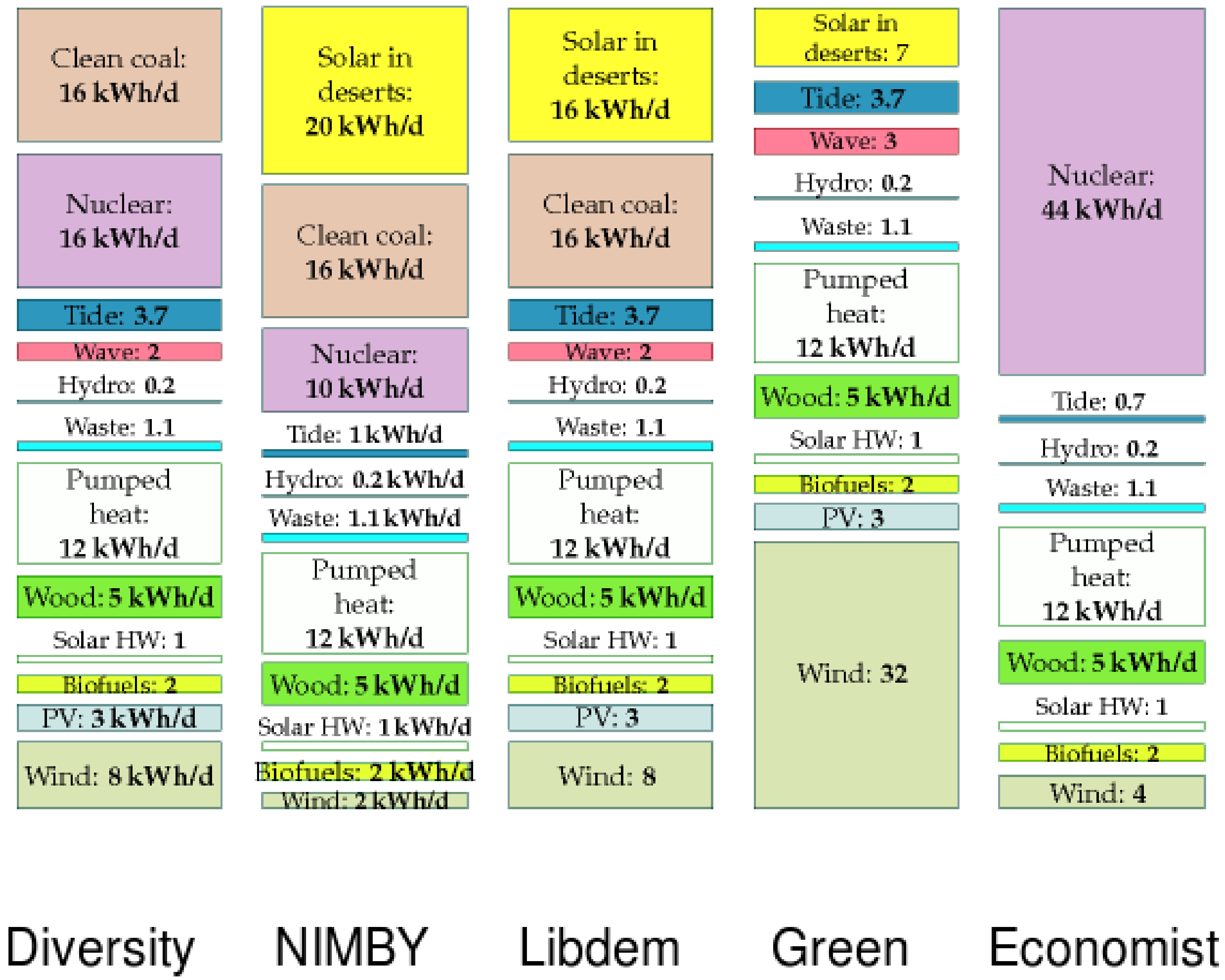
1 sq m per person HW

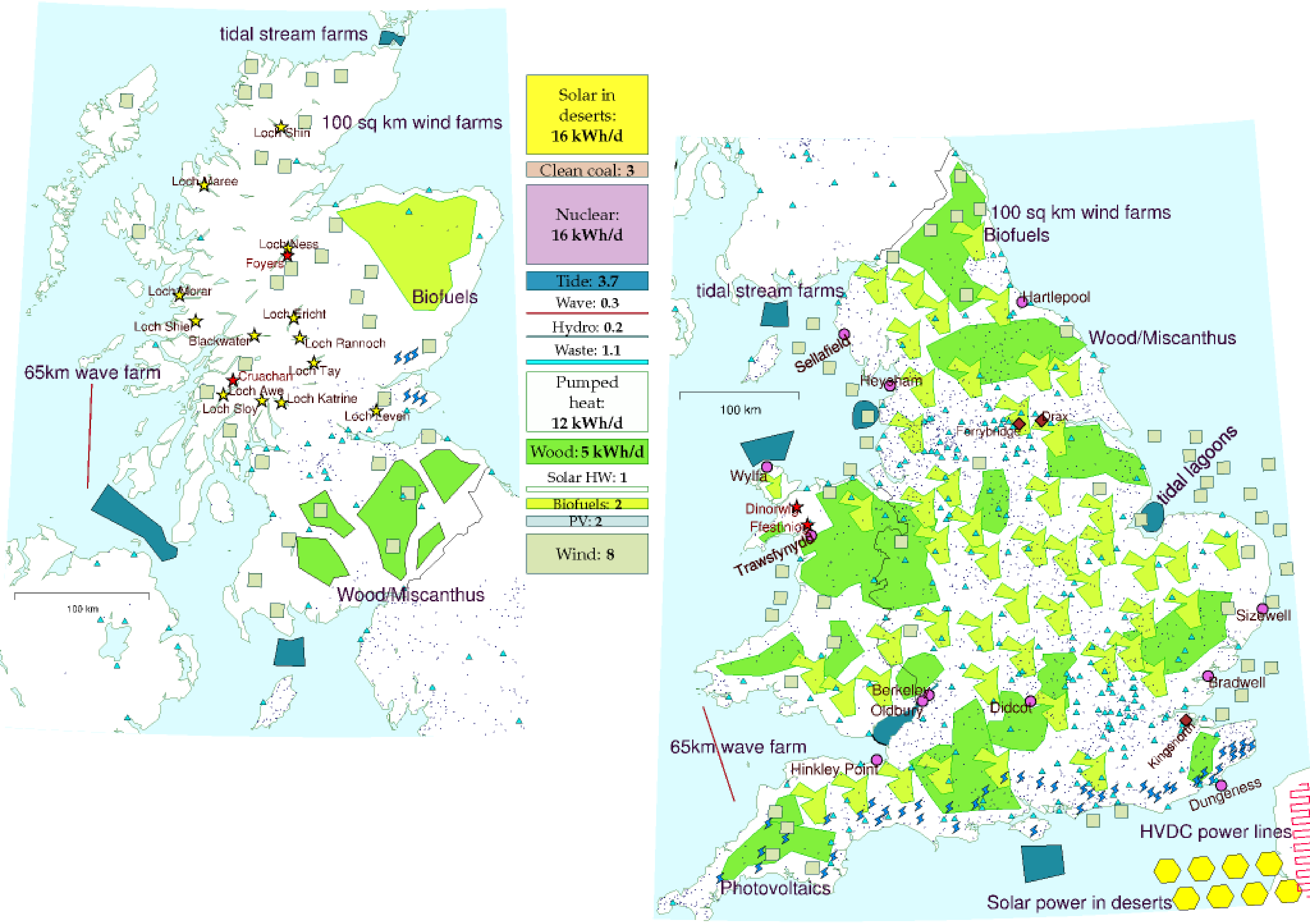
12% of UK for biofuels

Electric vehicles

50 kWh/d is 125 GW

Five plans for Cartoon-Britain




tidal stream farms
100 sq km wind farms
Loch Shin
Loch Maree
Loch Ness
Foyers
Loch Morar
Loch Ericht
Loch Shiel
Blackwater
Loch Rannoch
Loch Tay
Cruachan
Loch Awe
Loch Katrine
Loch Sloy
Loch Leven
Biofuels
65km wave farm
100 km
Wood/Miscanthus
Solar in deserts: 16 kWh/d
Clean coal: 3
Nuclear: 16 kWh/d
Tide: 3.7
Wave: 0.3
Hydro: 0.2
Waste: 1.1
Pumped heat: 12 kWh/d
Wood: 5 kWh/d
Solar HW: 1
Biofuels: 2
PV: 2
Wind: 8
100 sq km wind farms
Biofuels
tidal stream farms
Hartlepool
Wood/Miscanthus
Sellafield
Heysham
100 km
Drax
Ferrybridge
tidal lagoons
Wylfa
Dinorwig
Ffestiniog
Trawsfynydd
Sizewell
Bradwell
Berkeley
Oldbury
Didcot
Kingsnorth
65km wave farm
Hinkley Point
Dungeness
HVDC power lines
Photovoltaics
Solar power in deserts

This plan's mix

Solar in deserts: **16 kWh/d**

Four Londons' worth

Clean coal: **3**

Use for cofiring biomass with CCS

Nuclear: **16 kWh/d**

40GW - four-fold increase

Tide: **3.7**

Wave: **0.3**

Hydro: **0.2**

Waste: **1.1**

Pumped heat: **12 kWh/d**

Wood: **5 kWh/d**

25% of UK - forests, willow, miscanthus

Solar HW: **1**

1 sq m per person HW

Biofuels: **2**

12% of UK for biofuels

PV: **2**

Half of all roofs

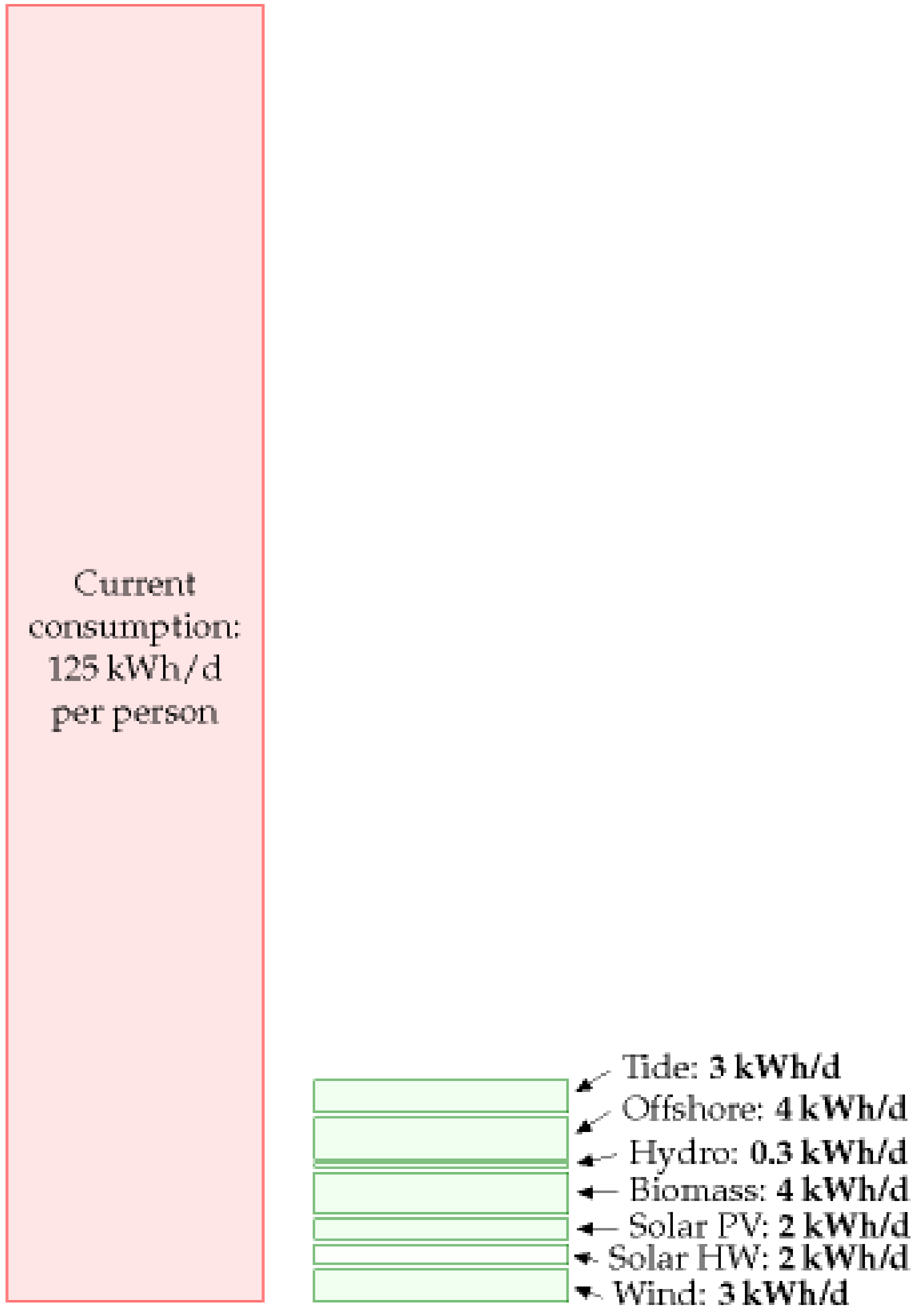
Wind: **8**

33-fold increase in wind capacity

[Jet flights: 5kWh/d/p, while oil lasts]

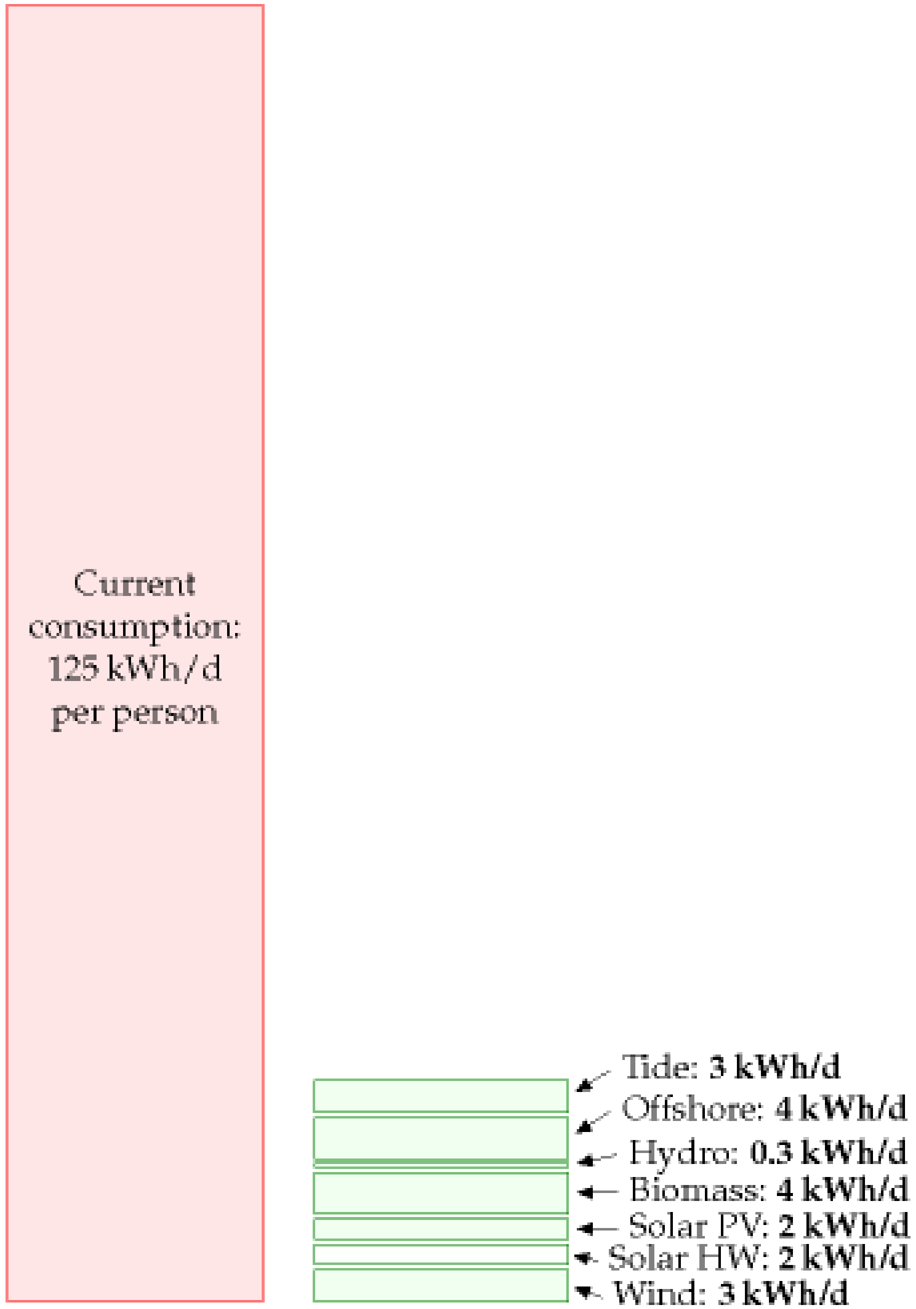
Jack-up barges cost 60M

Don't promote a solution



Don't promote a solution

"you figure it out"



Some inconvenient truths

$$2 + 2 \neq 120$$

A country like Britain
can't live on
its own renewables
- at least,
not as we currently live

Cities cannot be
self-sufficient

To make a difference,
renewables have to be
country-sized

The first Calculator - sustainableenergyboardgame.weebly.com - Emilia Melville


Supply

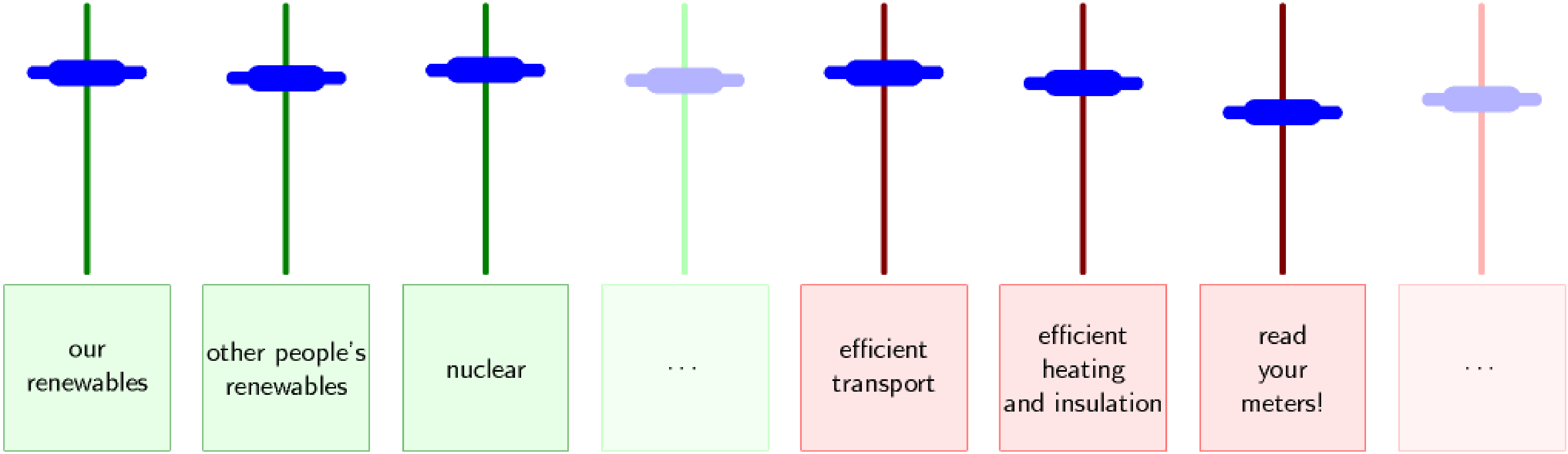

Supply
Demand


An Ene
Supply


Supply


SUSTAINABLE ENERGY — WITHOUT THE HOT AIR
David JC MacKay
Supply
An Energy

We need a plan that adds up!



our renewables

other people's renewables

nuclear

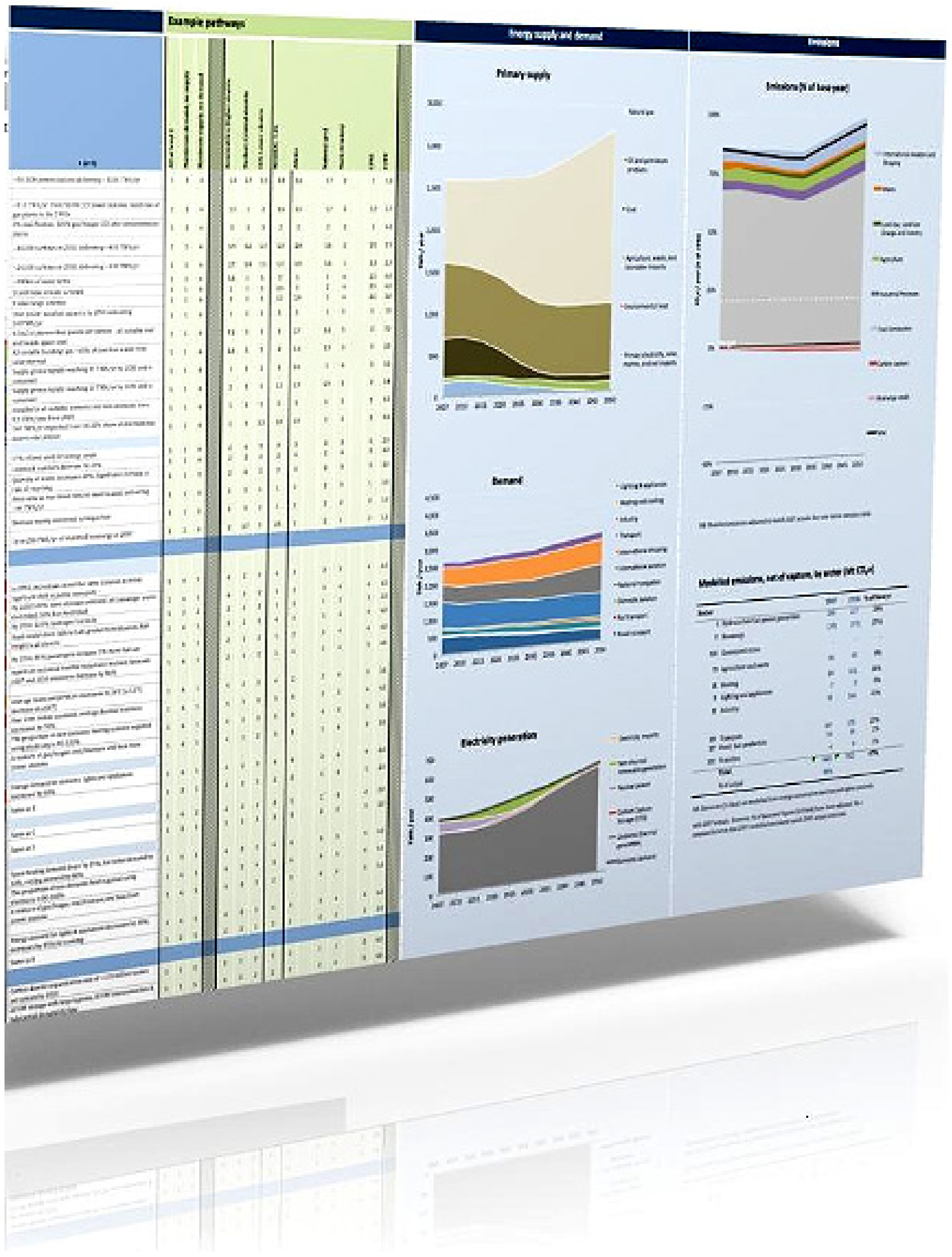
. . .

efficient transport

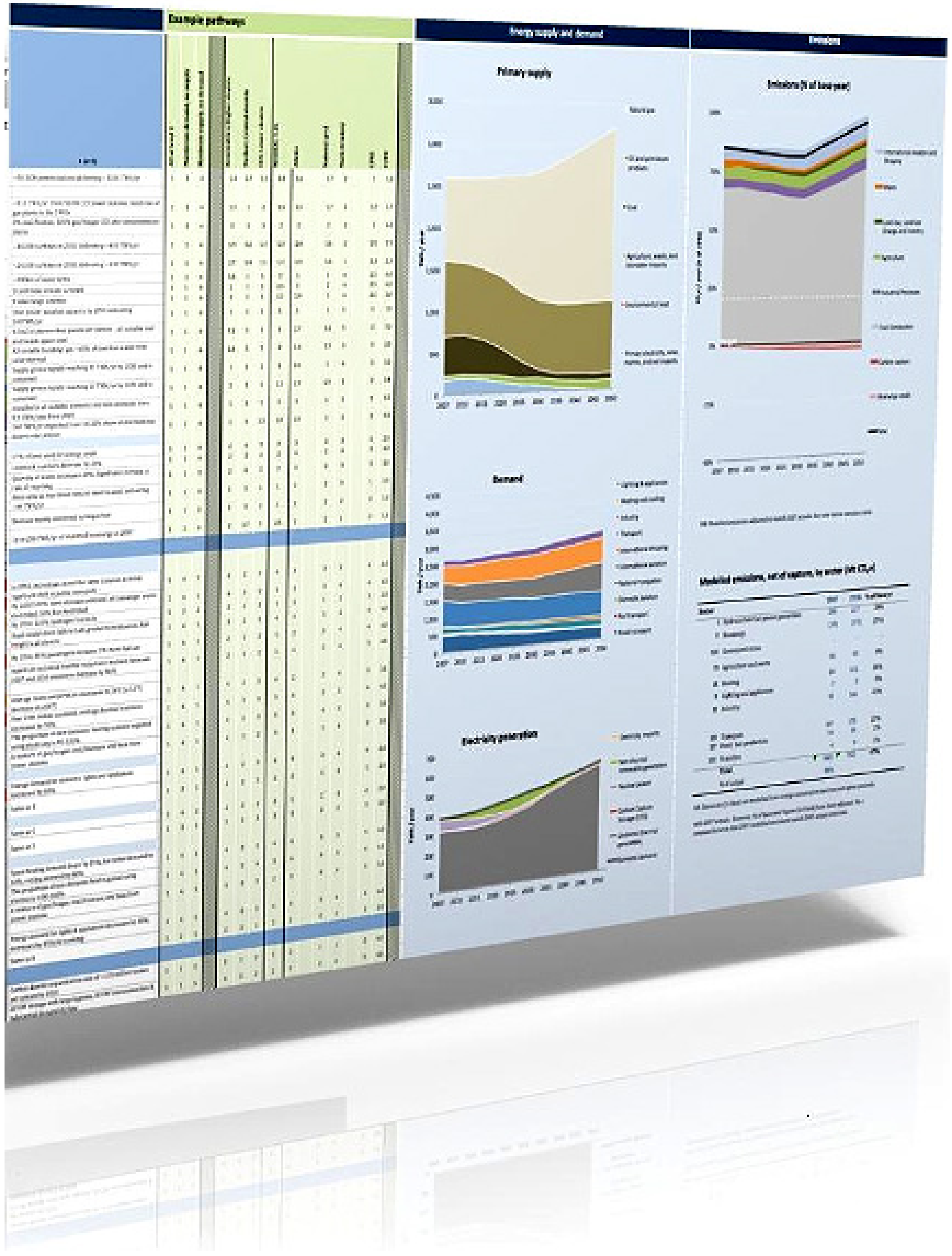
efficient heating and insulation

read your meters!

. . .



Credit: Graeme Cuthbert, James Geddes



Credit: Graeme Cuthbert, James Geddes

- Some bumps in the road...
  - Other departments
  - Our own department
  - Politicians

DEPARTMENT OF
ENERGY
& CLIMATE CHANGE

DEPARTMENT OF
ENERGY
& CLIMATE CHANGE

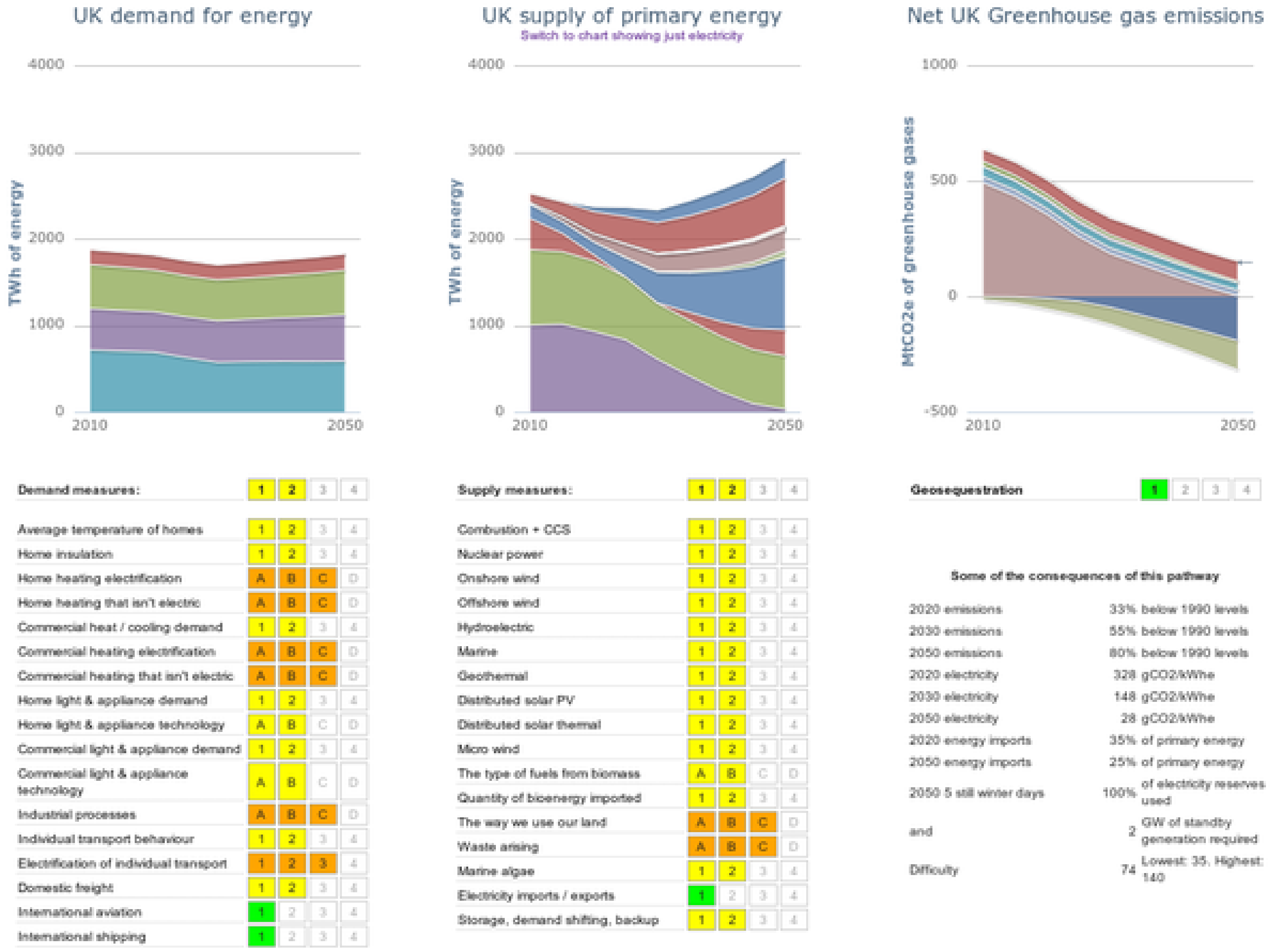
How to improve this situation...

$$\left.\begin{array}{r}\text{wishful thinking}\\ +\\ \text{mistrust}\end{array}\right\} \longrightarrow \left\{\begin{array}{c}\text{poorly-designed policies}\\ +\\ \text{disagreement over solutions}\end{array}\right.$$

- Provide facts
- Use numbers, not adjectives
- Use a single set of units
- Talk about scale

- Win trust by:
  - not promoting a solution
  - showing your working
  - getting lots of people to endorse your work

The DECC 2050 Pathways Calculator



Demand measures:	1	2	3	4
Average temperature of homes	1	2	3	4
Home insulation	1	2	3	4
Home heating electrification	A	B	C	D
Home heating that isn't electric	A	B	C	D
Commercial heat / cooling demand	1	2	3	4
Commercial heating electrification	A	B	C	D
Commercial heating that isn't electric	A	B	C	D
Home light & appliance demand	1	2	3	4
Home light & appliance technology	A	B	C	D
Commercial light & appliance demand	1	2	3	4
Commercial light & appliance technology	A	B	C	D
Industrial processes	A	B	C	D
Individual transport behaviour	1	2	3	4
Electrification of individual transport	1	2	3	4
Domestic freight	1	2	3	4
International aviation	1	2	3	4
International shipping	1	2	3	4

Supply measures:	1	2	3	4
Combustion + CCS	1	2	3	4
Nuclear power	1	2	3	4
Onshore wind	1	2	3	4
Offshore wind	1	2	3	4
Hydroelectric	1	2	3	4
Marine	1	2	3	4
Geothermal	1	2	3	4
Distributed solar PV	1	2	3	4
Distributed solar thermal	1	2	3	4
Micro wind	1	2	3	4
The type of fuels from biomass	A	B	C	D
Quantity of bioenergy imported	1	2	3	4
The way we use our land	A	B	C	D
Waste arising	A	B	C	D
Marine algae	1	2	3	4
Electricity imports / exports	1	2	3	4
Storage, demand shifting, backup	1	2	3	4

Geosequestration	1	2	3	4

Some of the consequences of this pathway

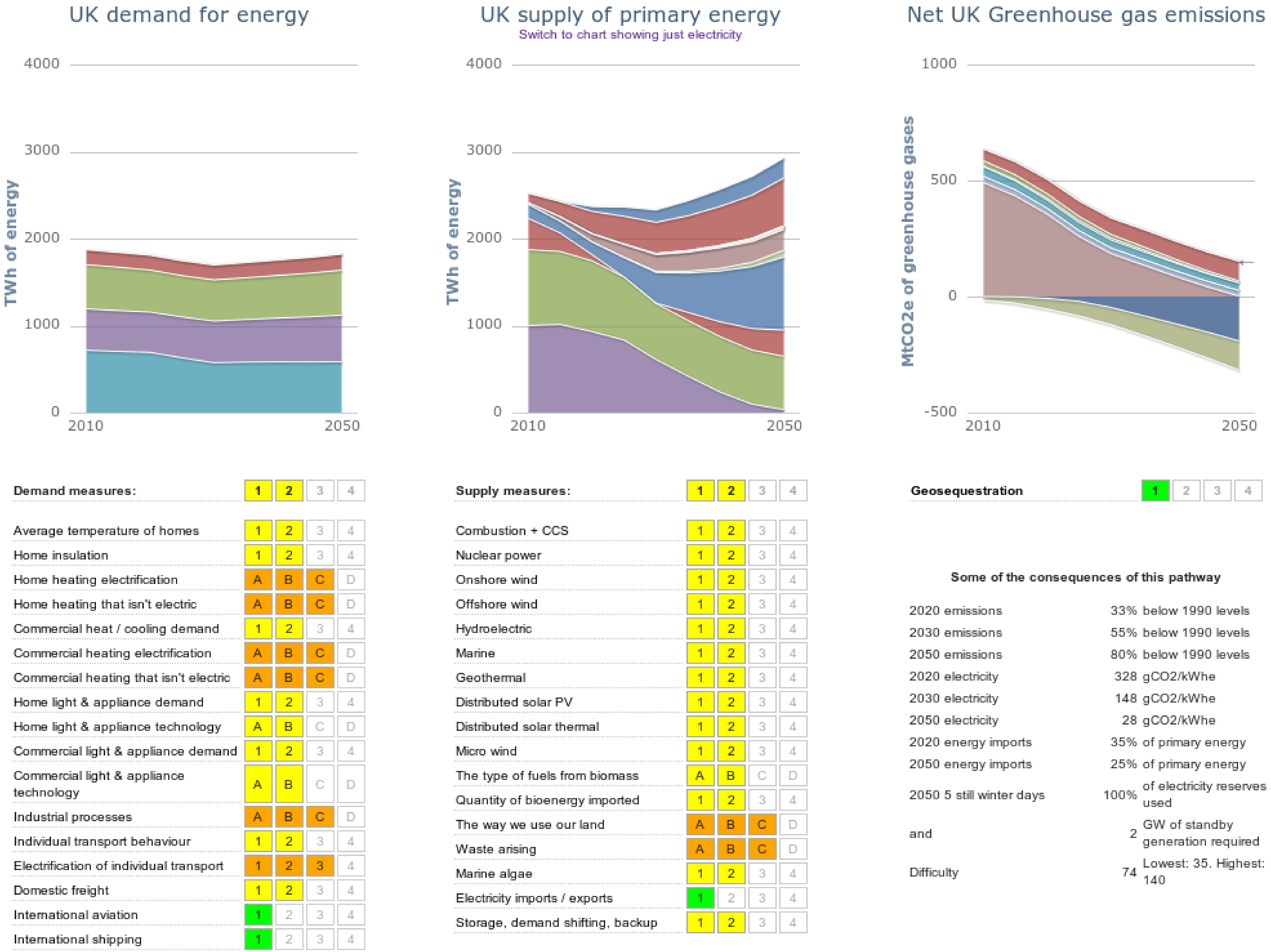
2020 emissions	33%	below 1990 levels
2030 emissions	55%	below 1990 levels
2050 emissions	80%	below 1990 levels
2020 electricity	328	gCO2/kWhe
2030 electricity	148	gCO2/kWhe
2050 electricity	28	gCO2/kWhe
2020 energy imports	35%	of primary energy
2050 energy imports	25%	of primary energy
2050 5 still winter days	100%	of electricity reserves used
and	2	GW of standby generation required
Difficulty	74	Lowest: 35. Highest: 140

DEPARTMENT OF ENERGY & CLIMATE CHANGE

2050-calculator-tool.decc.gov.uk

http://tinyurl.com/2050decc

Web Version - Tom Counsell



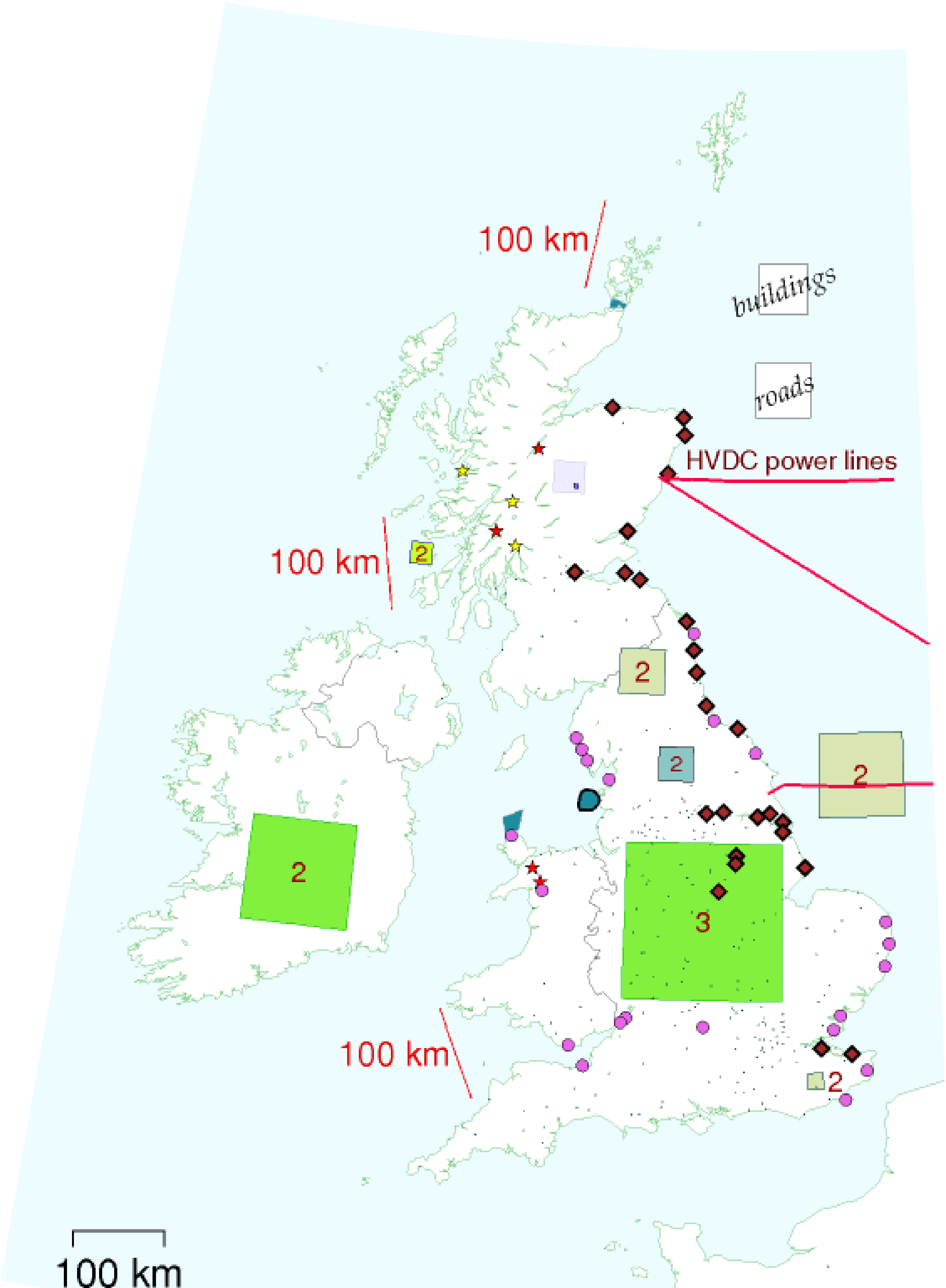
Demand measures:	1	[✓ 2]	3	4
Average temperature of homes	1	[✓ 2]	3	4
Home insulation	1	[✓ 2]	3	4
Home heating electrification	A	B	[✓ C]	D
Home heating that isn't electric	A	B	[✓ C]	D
Commercial heat / cooling demand	1	[✓ 2]	3	4
Commercial heating electrification	A	B	[✓ C]	D
Commercial heating that isn't electric	A	B	[✓ C]	D
Home light & appliance demand	1	[✓ 2]	3	4
Home light & appliance technology	A	[✓ B]	C	D
Commercial light & appliance demand	1	[✓ 2]	3	4
Commercial light & appliance technology	A	[✓ B]	C	D
Industrial processes	A	B	[✓ C]	D
Individual transport behaviour	1	[✓ 2]	3	4
Electrification of individual transport	1	2	[✓ 3]	4
Domestic freight	1	[✓ 2]	3	4
International aviation	[✓ 1]	2	3	4
International shipping	[✓ 1]	2	3	4

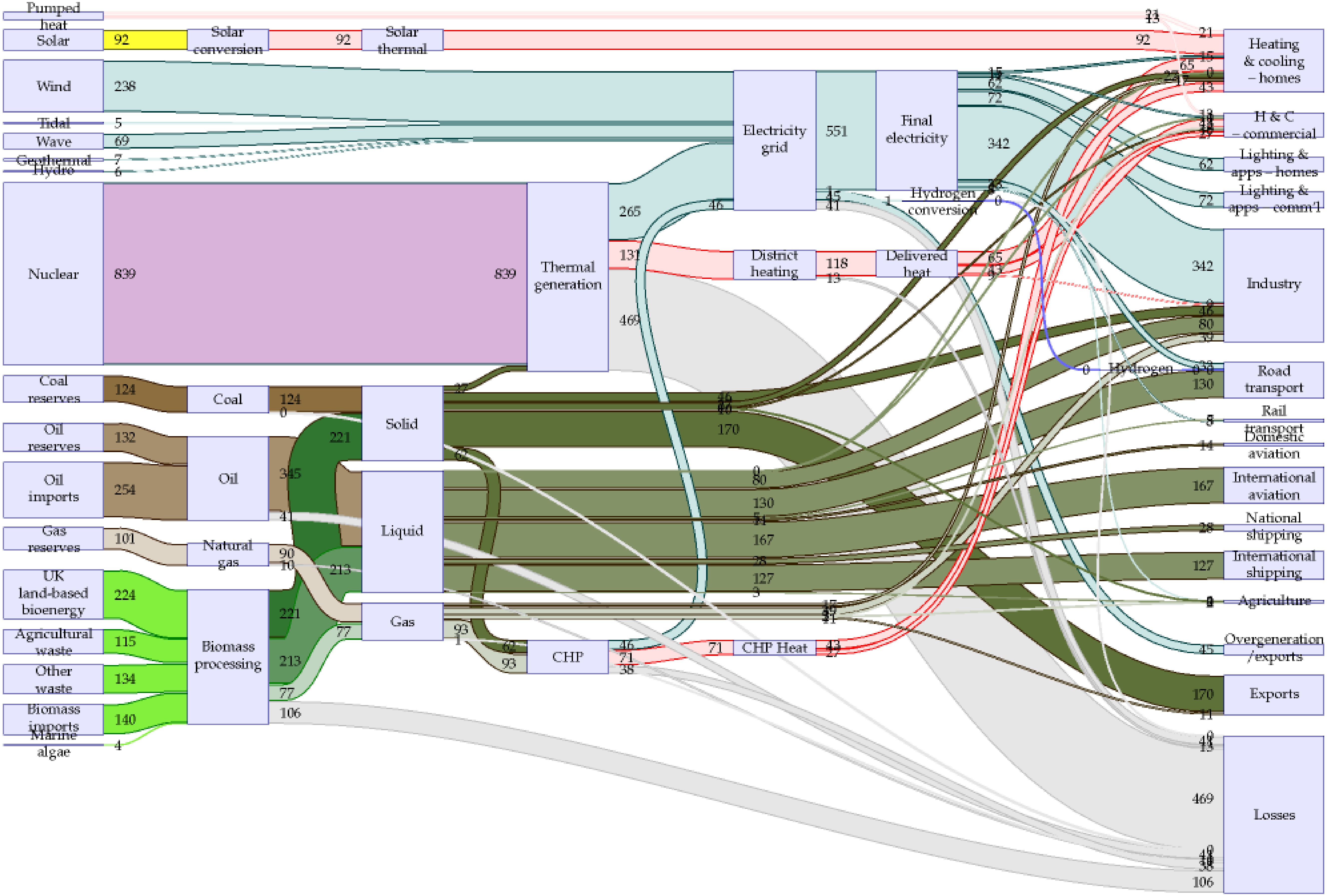
Supply measures:	1	[✓ 2]	3	4
Combustion + CCS	1	[✓ 2]	3	4
Nuclear power	1	[✓ 2]	3	4
Onshore wind	1	[✓ 2]	3	4
Offshore wind	1	[✓ 2]	3	4
Hydroelectric	1	[✓ 2]	3	4
Marine	1	[✓ 2]	3	4
Geothermal	1	[✓ 2]	3	4
Distributed solar PV	1	[✓ 2]	3	4
Distributed solar thermal	1	[✓ 2]	3	4
Micro wind	1	[✓ 2]	3	4
The type of fuels from biomass	A	[✓ B]	C	D
Quantity of bioenergy imported	1	[✓ 2]	3	4
The way we use our land	A	B	[✓ C]	D
Waste arising	A	B	[✓ C]	D
Marine algae	1	[✓ 2]	3	4
Electricity imports / exports	[✓ 1]	2	3	4
Storage, demand shifting, backup	1	[✓ 2]	3	4

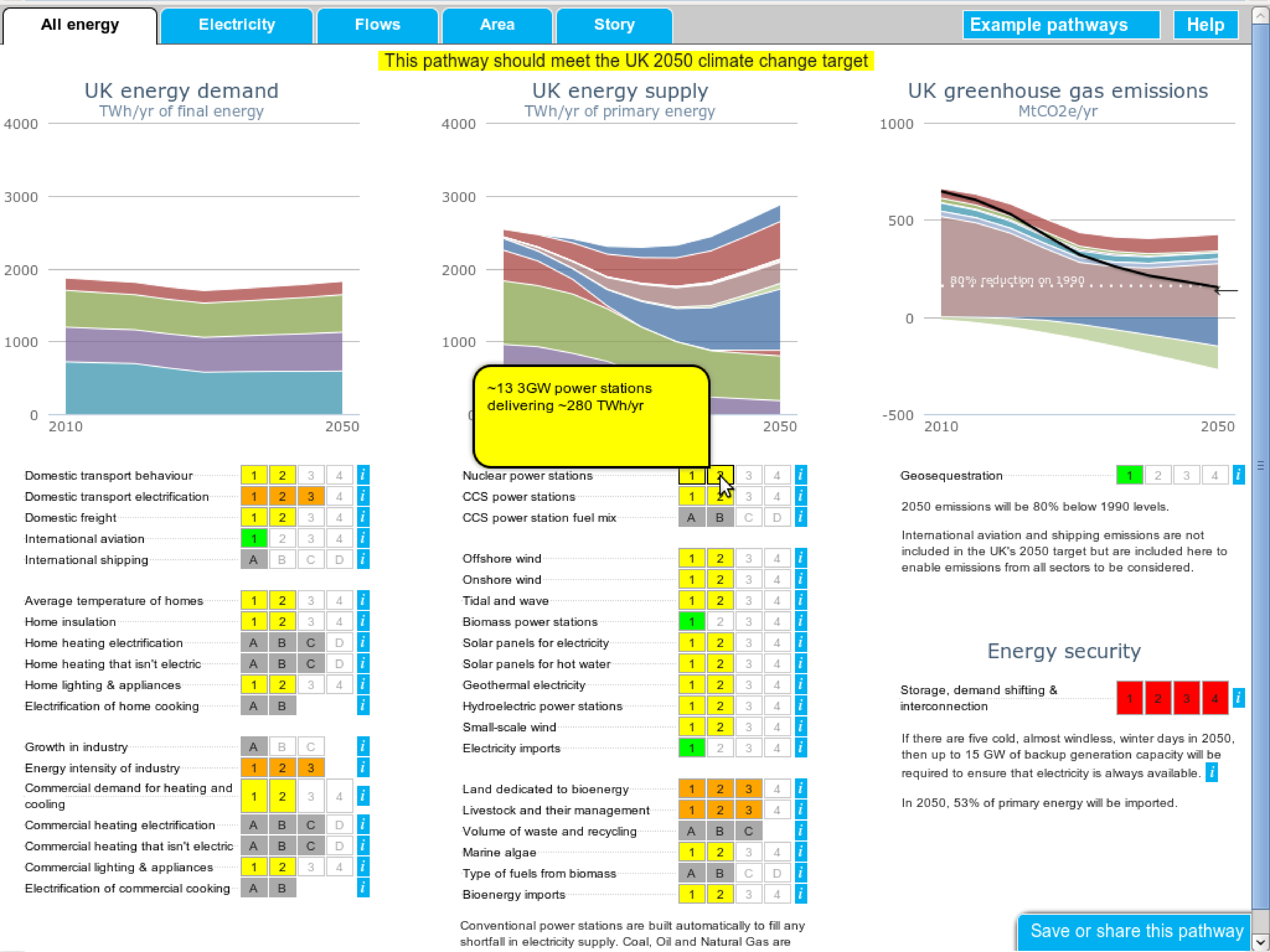
Geosequestration	[✓ 1]	2	3	4

Some of the consequences of this pathway

2020 emissions	33%	below 1990 levels
2030 emissions	55%	below 1990 levels
2050 emissions	80%	below 1990 levels
2020 electricity	328	gCO2/kWhe
2030 electricity	148	gCO2/kWhe
2050 electricity	28	gCO2/kWhe
2020 energy imports	35%	of primary energy
2050 energy imports	25%	of primary energy
2050 5 still winter days	100%	of electricity reserves used
and	2	GW of standby generation required
Difficulty	74	Lowest: 35. Highest: 140


100 km
buildings
roads
HVDC power lines
100 km
2
2
2
2
2
3
2
100 km
2
100 km


Pumped heat
Solar
92
Solar conversion
92
Solar thermal
92
Wind
238
Tidal
5
Wave
69
Geothermal
7
Hydro
6
Nuclear
839
839
Thermal generation
265
131
469
Electricity grid
46
551
Final electricity
342
Hydrogen conversion
1
0
District heating
118
13
Delivered heat
65
43
Coal reserves
124
Coal
124
0
Oil reserves
132
Oil imports
254
Oil
345
41
Gas reserves
101
Natural gas
90
10
UK land-based bioenergy
224
Agricultural waste
115
Other waste
134
Biomass imports
140
Marine algae
4
Biomass processing
221
213
77
106
Solid
221
37
62
170
Liquid
213
80
130
167
28
127
3
Gas
77
93
1
CHP
62
93
46
71
38
CHP Heat
71
43
27
Hydrogen
0
Heating & cooling – homes
21
15
65
0
43
H & C – commercial
Lighting & apps – homes
62
Lighting & apps – comm'l
72
Industry
342
46
80
39
Road transport
130
Rail transport
5
Domestic aviation
14
International aviation
167
National shipping
28
International shipping
127
Agriculture
Overgeneration /exports
45
Exports
170
11
Losses
469
106



This pathway should meet the UK 2050 climate change target

~13 3GW power stations delivering ~280 TWh/yr

Domestic transport behaviour	1	2	3	4	i
Domestic transport electrification	1	2	3	4	i
Domestic freight	1	2	3	4	i
International aviation	1	2	3	4	i
International shipping	A	B	C	D	i
Average temperature of homes	1	2	3	4	i
Home insulation	1	2	3	4	i
Home heating electrification	A	B	C	D	i
Home heating that isn't electric	A	B	C	D	i
Home lighting & appliances	1	2	3	4	i
Electrification of home cooking	A	B			i
Growth in industry	A	B	C		i
Energy intensity of industry	1	2	3		i
Commercial demand for heating and cooling	1	2	3	4	i
Commercial heating electrification	A	B	C	D	i
Commercial heating that isn't electric	A	B	C	D	i
Commercial lighting & appliances	1	2	3	4	i
Electrification of commercial cooking	A	B			i

Nuclear power stations	1	2	3	4	i
CCS power stations	1	2	3	4	i
CCS power station fuel mix	A	B	C	D	i
Offshore wind	1	2	3	4	i
Onshore wind	1	2	3	4	i
Tidal and wave	1	2	3	4	i
Biomass power stations	1	2	3	4	i
Solar panels for electricity	1	2	3	4	i
Solar panels for hot water	1	2	3	4	i
Geothermal electricity	1	2	3	4	i
Hydroelectric power stations	1	2	3	4	i
Small-scale wind	1	2	3	4	i
Electricity imports	1	2	3	4	i
Land dedicated to bioenergy	1	2	3	4	i
Livestock and their management	1	2	3	4	i
Volume of waste and recycling	A	B	C		i
Marine algae	1	2	3	4	i
Type of fuels from biomass	A	B	C	D	i
Bioenergy imports	1	2	3	4	i

Conventional power stations are built automatically to fill any shortfall in electricity supply. Coal, Oil and Natural Gas are

Geosequestration	1	2	3	4	i

2050 emissions will be 80% below 1990 levels.

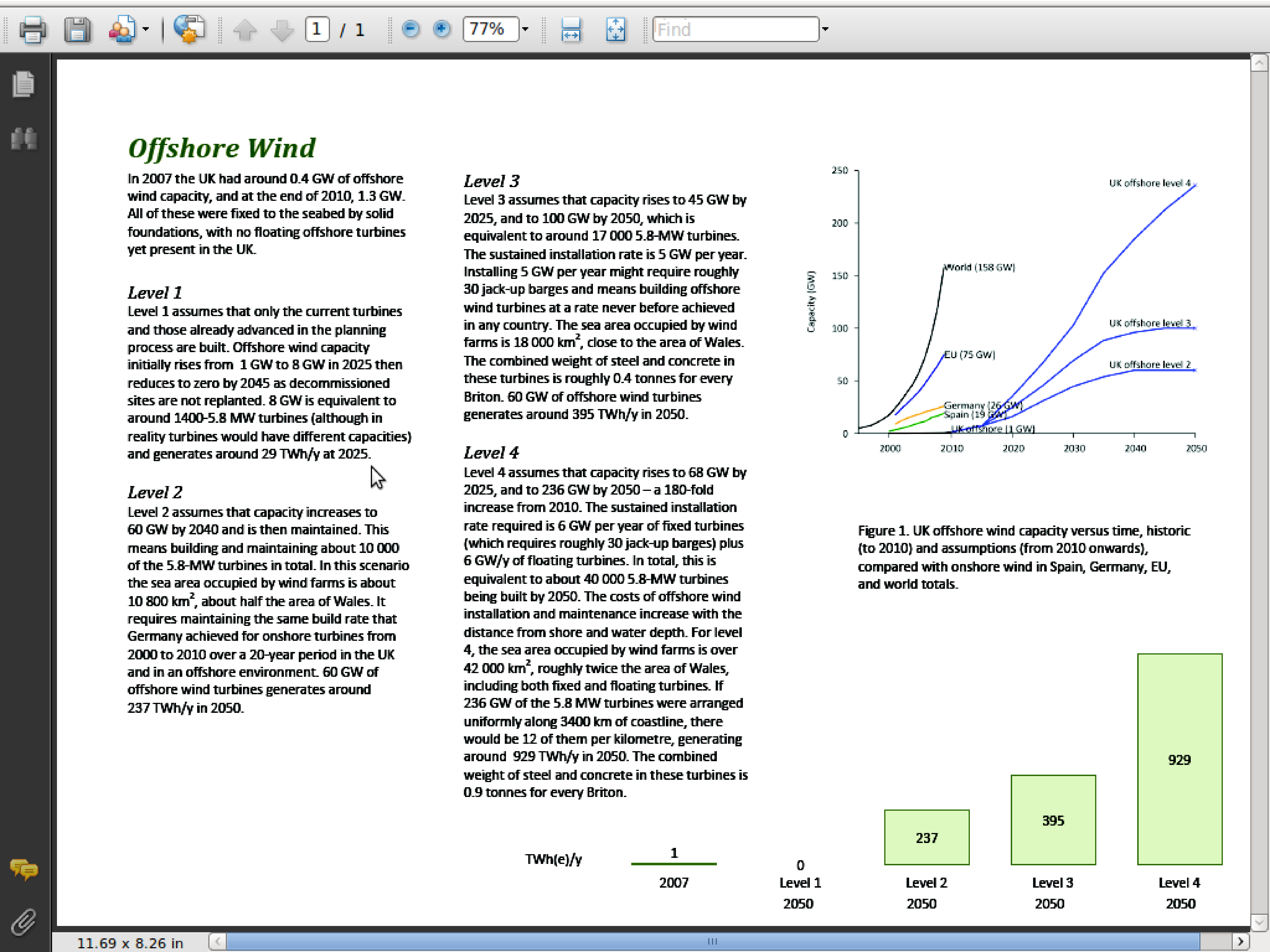
International aviation and shipping emissions are not included in the UK's 2050 target but are included here to enable emissions from all sectors to be considered.

Energy security

Storage, demand shifting & interconnection	1	2	3	4	i

If there are five cold, almost windless, winter days in 2050, then up to 15 GW of backup generation capacity will be required to ensure that electricity is always available. i

In 2050, 53% of primary energy will be imported.



Offshore Wind

In 2007 the UK had around 0.4 GW of offshore wind capacity, and at the end of 2010, 1.3 GW. All of these were fixed to the seabed by solid foundations, with no floating offshore turbines yet present in the UK.

Level 1

Level 1 assumes that only the current turbines and those already advanced in the planning process are built. Offshore wind capacity initially rises from 1 GW to 8 GW in 2025 then reduces to zero by 2045 as decommissioned sites are not replanted. 8 GW is equivalent to around 1400-5.8 MW turbines (although in reality turbines would have different capacities) and generates around 29 TWh/y at 2025.

Level 2

Level 2 assumes that capacity increases to 60 GW by 2040 and is then maintained. This means building and maintaining about 10 000 of the 5.8-MW turbines in total. In this scenario the sea area occupied by wind farms is about 10 800 km^2, about half the area of Wales. It requires maintaining the same build rate that Germany achieved for onshore turbines from 2000 to 2010 over a 20-year period in the UK and in an offshore environment. 60 GW of offshore wind turbines generates around 237 TWh/y in 2050.

Level 3

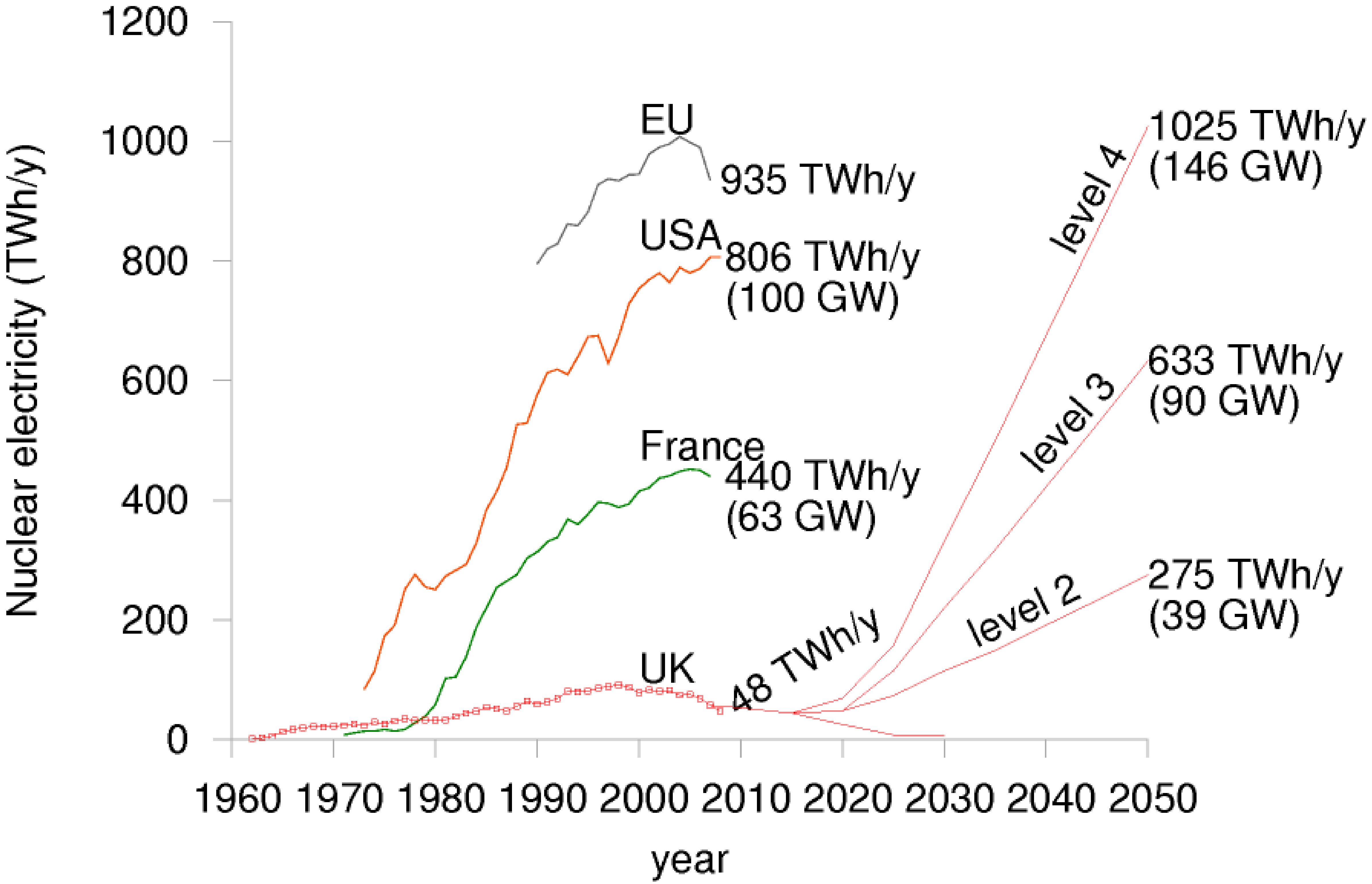
Level 3 assumes that capacity rises to 45 GW by 2025, and to 100 GW by 2050, which is equivalent to around 17 000 5.8-MW turbines. The sustained installation rate is 5 GW per year. Installing 5 GW per year might require roughly 30 jack-up barges and means building offshore wind turbines at a rate never before achieved in any country. The sea area occupied by wind farms is 18 000 km^2, close to the area of Wales. The combined weight of steel and concrete in these turbines is roughly 0.4 tonnes for every Briton. 60 GW of offshore wind turbines generates around 395 TWh/y in 2050.

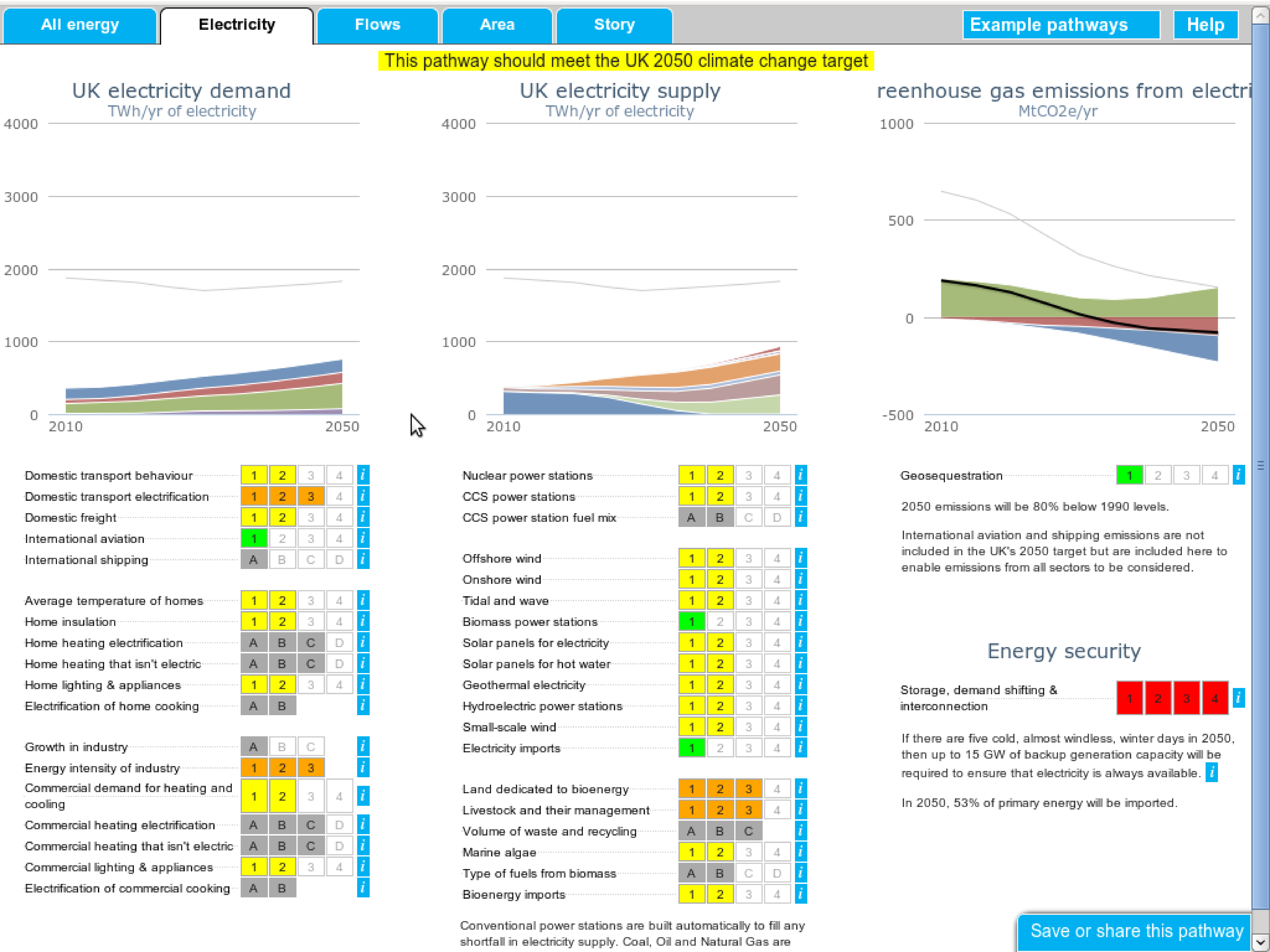
Level 4

Level 4 assumes that capacity rises to 68 GW by 2025, and to 236 GW by 2050 – a 180-fold increase from 2010. The sustained installation rate required is 6 GW per year of fixed turbines (which requires roughly 30 jack-up barges) plus 6 GW/y of floating turbines. In total, this is equivalent to about 40 000 5.8-MW turbines being built by 2050. The costs of offshore wind installation and maintenance increase with the distance from shore and water depth. For level 4, the sea area occupied by wind farms is over 42 000 km^2, roughly twice the area of Wales, including both fixed and floating turbines. If 236 GW of the 5.8 MW turbines were arranged uniformly along 3400 km of coastline, there would be 12 of them per kilometre, generating around 929 TWh/y in 2050. The combined weight of steel and concrete in these turbines is 0.9 tonnes for every Briton.

Figure 1. UK offshore wind capacity versus time, historic (to 2010) and assumptions (from 2010 onwards), compared with onshore wind in Spain, Germany, EU, and world totals.

Nuclear trajectories





This pathway should meet the UK 2050 climate change target

Domestic transport behaviour	**1**	**2**	3	4
Domestic transport electrification	**1**	**2**	**3**	4
Domestic freight	**1**	**2**	3	4
International aviation	**1**	2	3	4
International shipping	**A**	B	C	D
Average temperature of homes	**1**	**2**	3	4
Home insulation	**1**	**2**	3	4
Home heating electrification	**A**	**B**	**C**	D
Home heating that isn't electric	**A**	**B**	**C**	D
Home lighting & appliances	**1**	**2**	3	4
Electrification of home cooking	**A**	**B**		
Growth in industry	**A**	B	C	
Energy intensity of industry	**1**	**2**	**3**	
Commercial demand for heating and cooling	**1**	**2**	3	4
Commercial heating electrification	**A**	**B**	**C**	D
Commercial heating that isn't electric	**A**	**B**	**C**	D
Commercial lighting & appliances	**1**	**2**	3	4
Electrification of commercial cooking	**A**	**B**		

Nuclear power stations	**1**	**2**	3	4
CCS power stations	**1**	**2**	3	4
CCS power station fuel mix	**A**	**B**	C	D
Offshore wind	**1**	**2**	3	4
Onshore wind	**1**	**2**	3	4
Tidal and wave	**1**	**2**	3	4
Biomass power stations	**1**	2	3	4
Solar panels for electricity	**1**	**2**	3	4
Solar panels for hot water	**1**	**2**	3	4
Geothermal electricity	**1**	**2**	3	4
Hydroelectric power stations	**1**	**2**	3	4
Small-scale wind	**1**	**2**	3	4
Electricity imports	**1**	2	3	4
Land dedicated to bioenergy	**1**	**2**	**3**	4
Livestock and their management	**1**	**2**	**3**	4
Volume of waste and recycling	**A**	**B**	**C**	
Marine algae	**1**	**2**	3	4
Type of fuels from biomass	**A**	**B**	C	D
Bioenergy imports	**1**	**2**	3	4

Conventional power stations are built automatically to fill any shortfall in electricity supply. Coal, Oil and Natural Gas are

Geosequestration	**1**	2	3	4

2050 emissions will be 80% below 1990 levels.

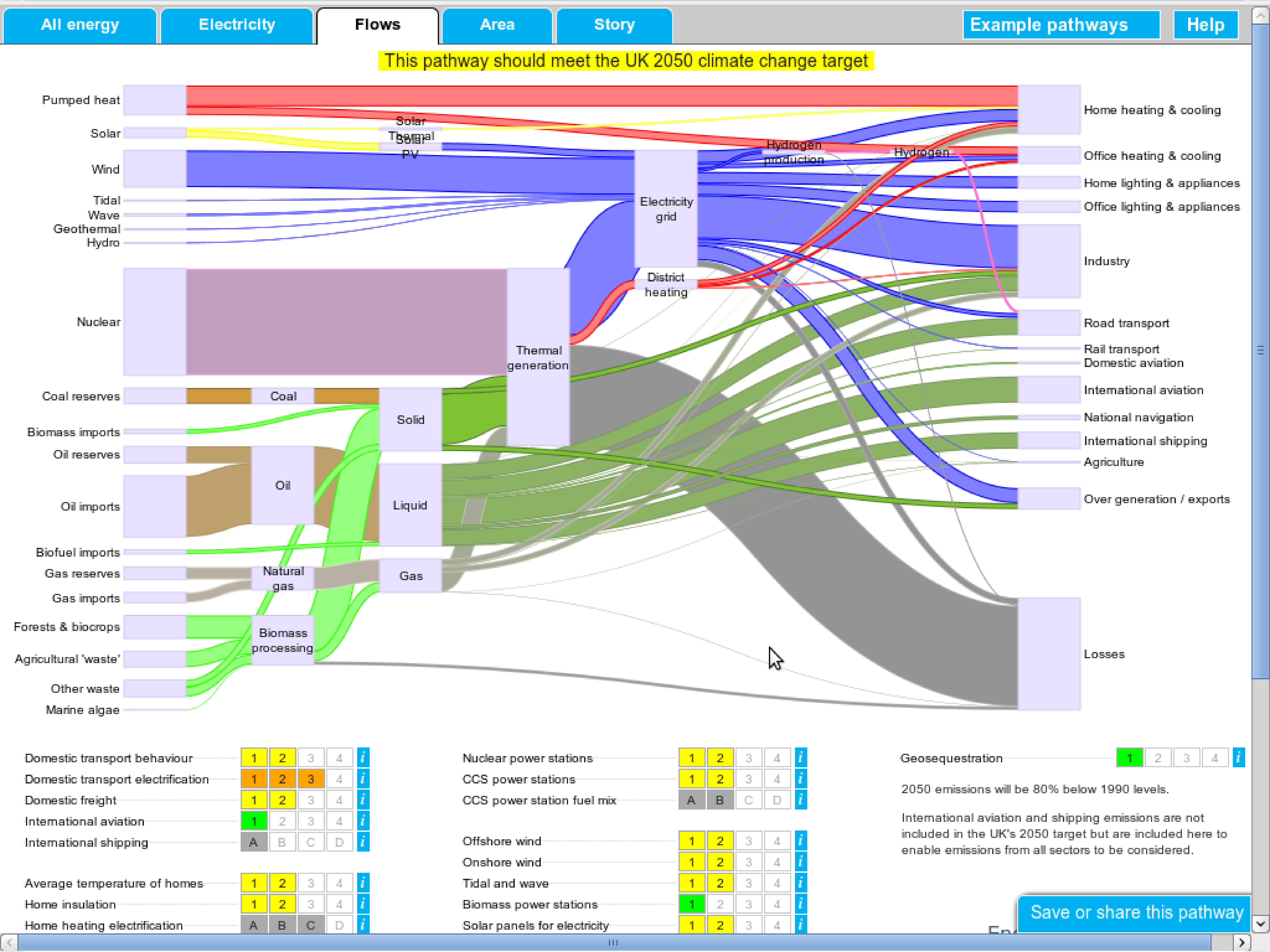
International aviation and shipping emissions are not included in the UK's 2050 target but are included here to enable emissions from all sectors to be considered.

Energy security

Storage, demand shifting & interconnection	**1**	**2**	**3**	**4**

If there are five cold, almost windless, winter days in 2050, then up to 15 GW of backup generation capacity will be required to ensure that electricity is always available.

In 2050, 53% of primary energy will be imported.



This pathway should meet the UK 2050 climate change target

Domestic transport behaviour 1 2 3 4 i
Domestic transport electrification 1 2 3 4 i
Domestic freight 1 2 3 4 i
International aviation 1 2 3 4 i
International shipping A B C D i

Average temperature of homes 1 2 3 4 i
Home insulation 1 2 3 4 i
Home heating electrification A B C D i

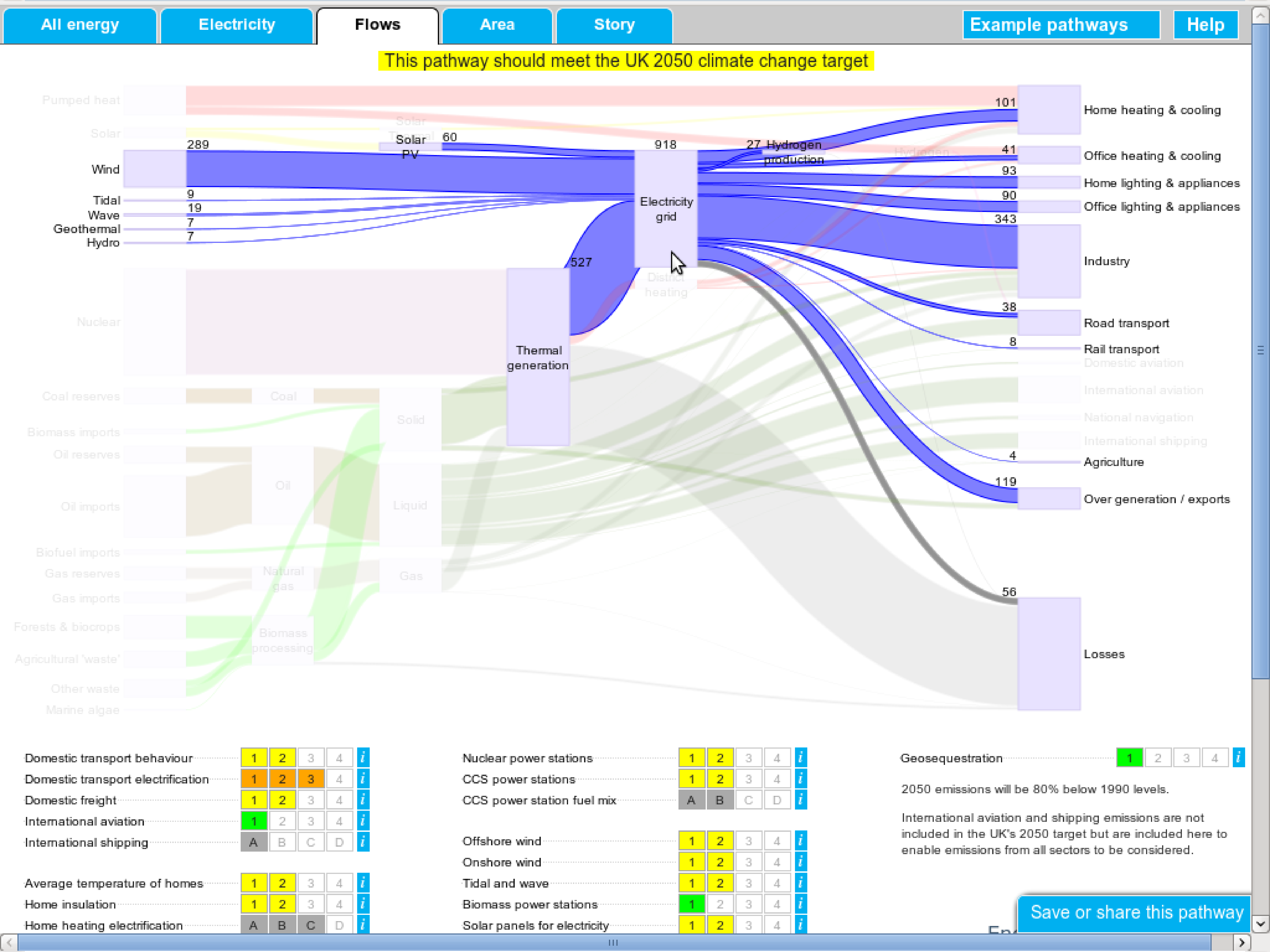
Nuclear power stations 1 2 3 4 i
CCS power stations 1 2 3 4 i
CCS power station fuel mix A B C D i

Offshore wind 1 2 3 4 i
Onshore wind 1 2 3 4 i
Tidal and wave 1 2 3 4 i
Biomass power stations 1 2 3 4 i
Solar panels for electricity 1 2 3 4 i

Geosequestration 1 2 3 4 i

2050 emissions will be 80% below 1990 levels.

International aviation and shipping emissions are not included in the UK's 2050 target but are included here to enable emissions from all sectors to be considered.



This pathway should meet the UK 2050 climate change target

Domestic transport behaviour 1 2 3 4 i
Domestic transport electrification 1 2 3 4 i
Domestic freight 1 2 3 4 i
International aviation 1 2 3 4 i
International shipping A B C D i

Average temperature of homes 1 2 3 4 i
Home insulation 1 2 3 4 i
Home heating electrification A B C D i

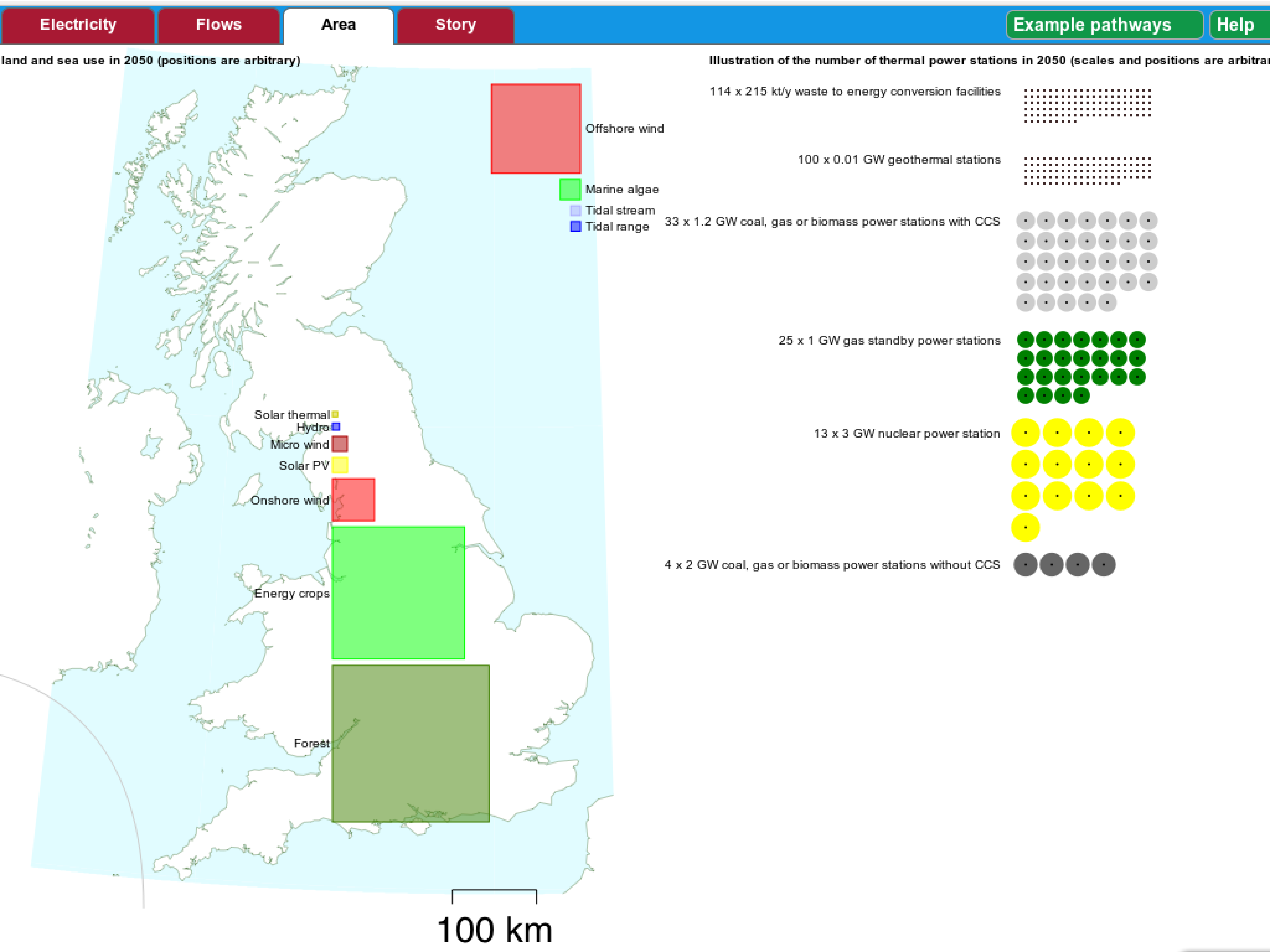
Nuclear power stations 1 2 3 4 i
CCS power stations 1 2 3 4 i
CCS power station fuel mix A B C D i

Offshore wind 1 2 3 4 i
Onshore wind 1 2 3 4 i
Tidal and wave 1 2 3 4 i
Biomass power stations 1 2 3 4 i
Solar panels for electricity 1 2 3 4 i

Geosequestration 1 2 3 4 i

2050 emissions will be 80% below 1990 levels.

International aviation and shipping emissions are not included in the UK's 2050 target but are included here to enable emissions from all sectors to be considered.



land and sea use in 2050 (positions are arbitrary)

Illustration of the number of thermal power stations in 2050 (scales and positions are arbitrar

114 x 215 kt/y waste to energy conversion facilities

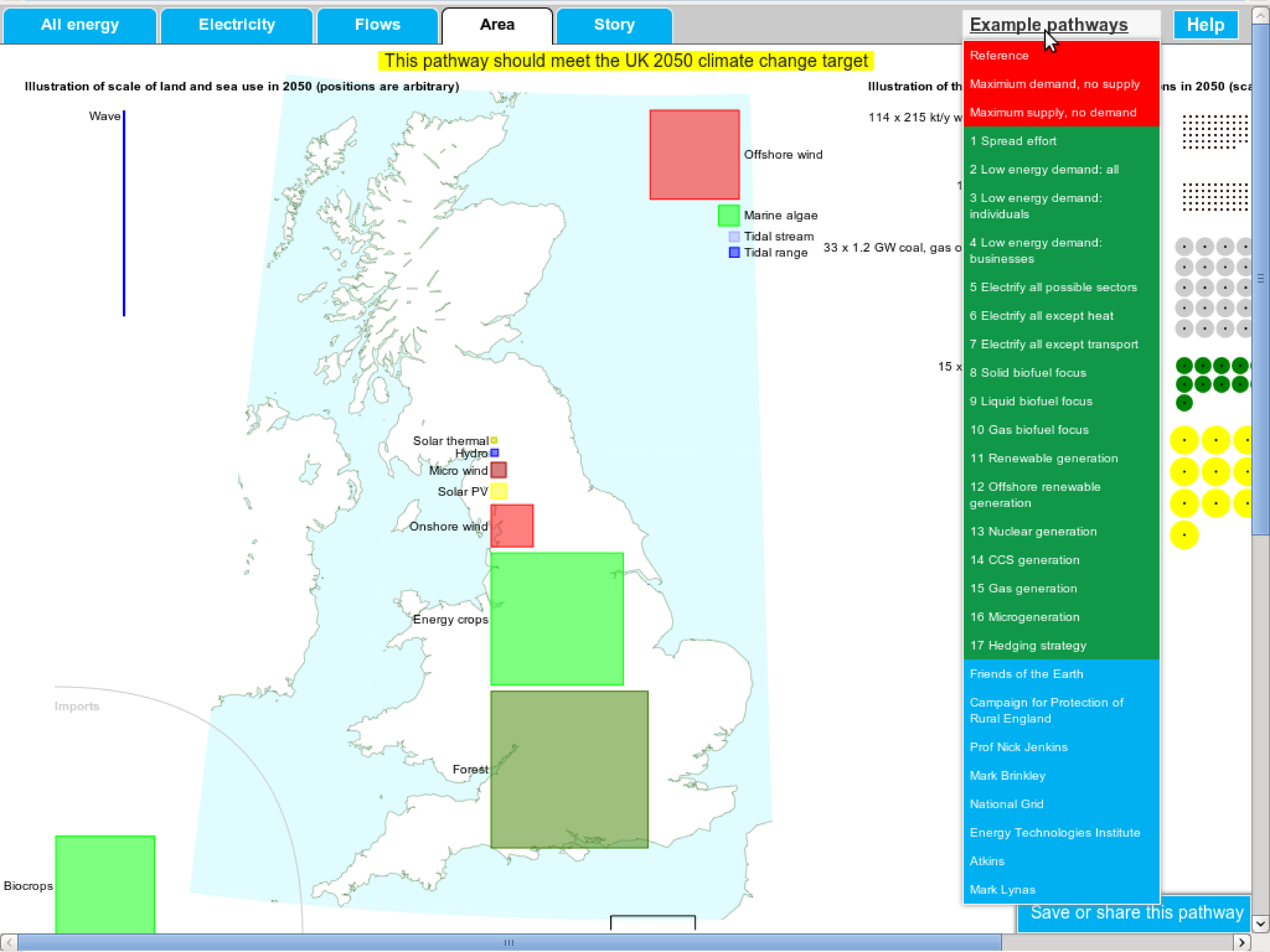
100 x 0.01 GW geothermal stations

33 x 1.2 GW coal, gas or biomass power stations with CCS

25 x 1 GW gas standby power stations

13 x 3 GW nuclear power station

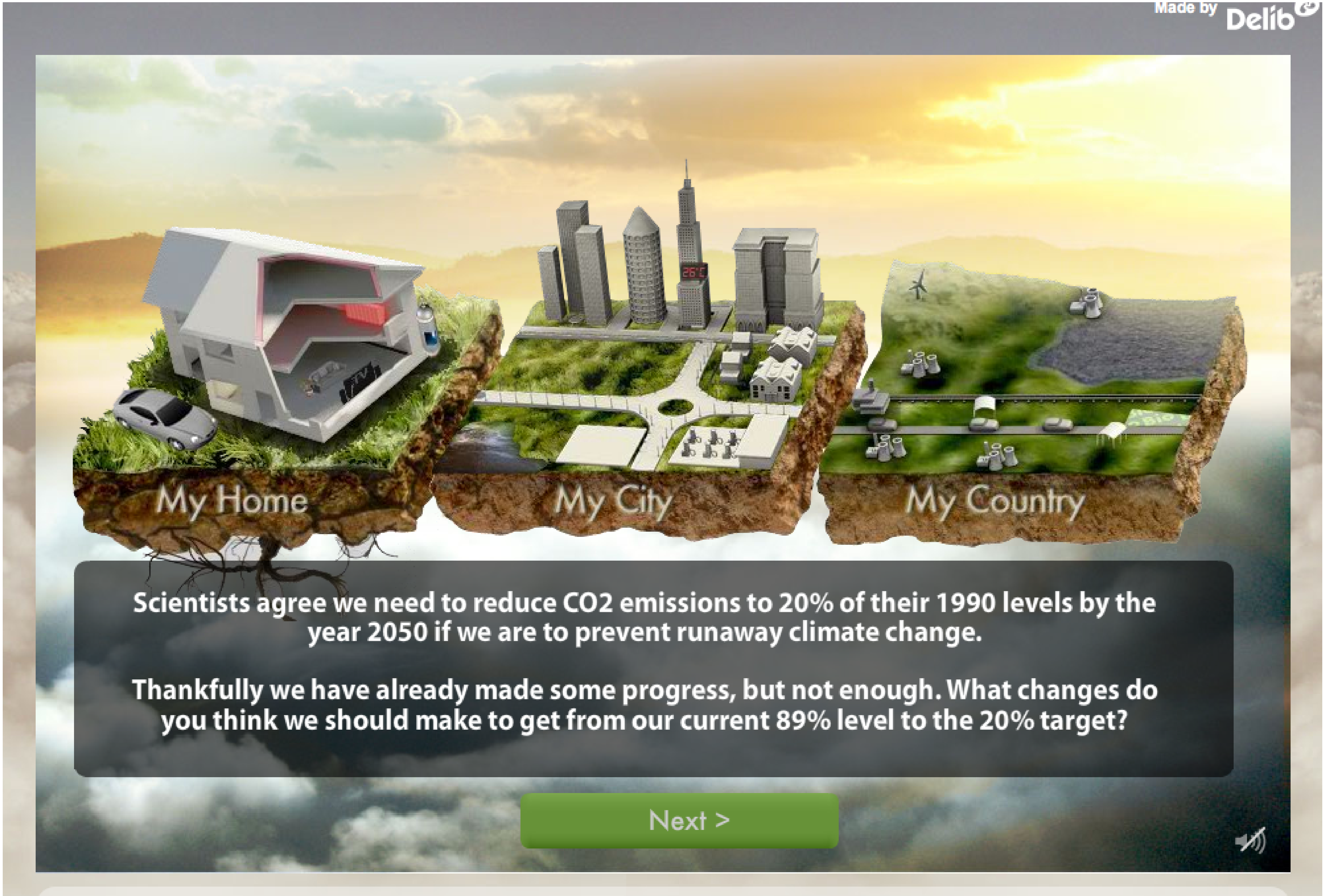
4 x 2 GW coal, gas or biomass power stations without CCS



This pathway should meet the UK 2050 climate change target

Illustration of scale of land and sea use in 2050 (positions are arbitrary)

2050 Calculator for kids



Scientists agree we need to reduce CO2 emissions to 20% of their 1990 levels by the year 2050 if we are to prevent runaway climate change.

Thankfully we have already made some progress, but not enough. What changes do you think we should make to get from our current 89% level to the 20% target?

7 likes. Sign Up to see what your friends like.

Brought to you by Department of Energy and Climate Change,
Sciencewise-ERC and Delib.

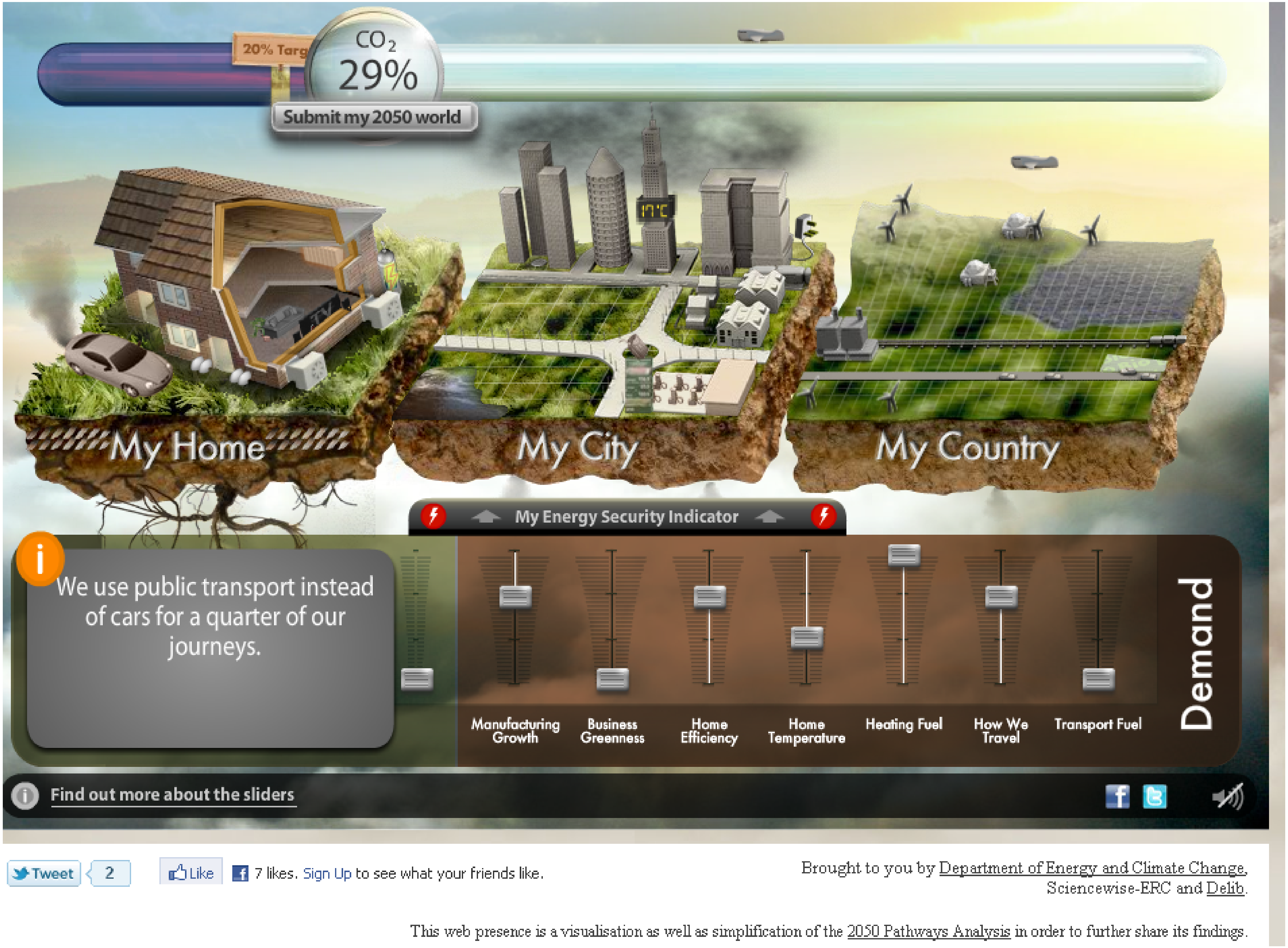
This web presence is a visualisation as well as simplification of the 2050 Pathways Analysis in order to further share its findings.

8,000 onshore wind turbines built by 2050. In 2010 we had 3,000.

7 likes. Sign Up to see what your friends like.

Brought to you by Department of Energy and Climate Change,
Sciencewise-ERC and Delib.

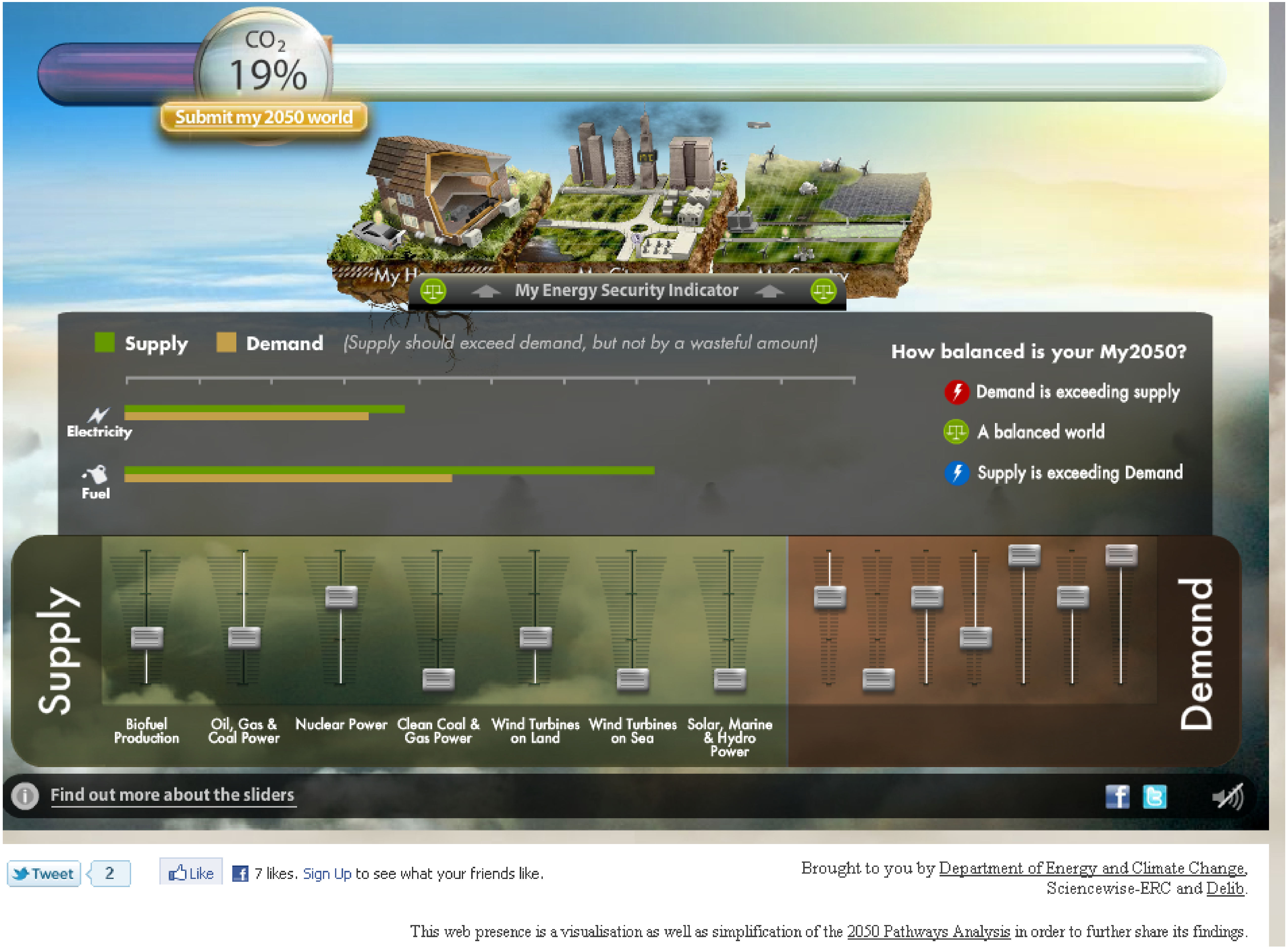
This web presence is a visualisation as well as simplification of the 2050 Pathways Analysis in order to further share its findings.



We use public transport instead of cars for a quarter of our journeys.

Brought to you by Department of Energy and Climate Change, Sciencewise-ERC and Delib.

This web presence is a visualisation as well as simplification of the 2050 Pathways Analysis in order to further share its findings.



(Supply should exceed demand, but not by a wasteful amount)

How balanced is your My2050?

- Demand is exceeding supply
- A balanced world
- Supply is exceeding Demand

7 likes. Sign Up to see what your friends like.

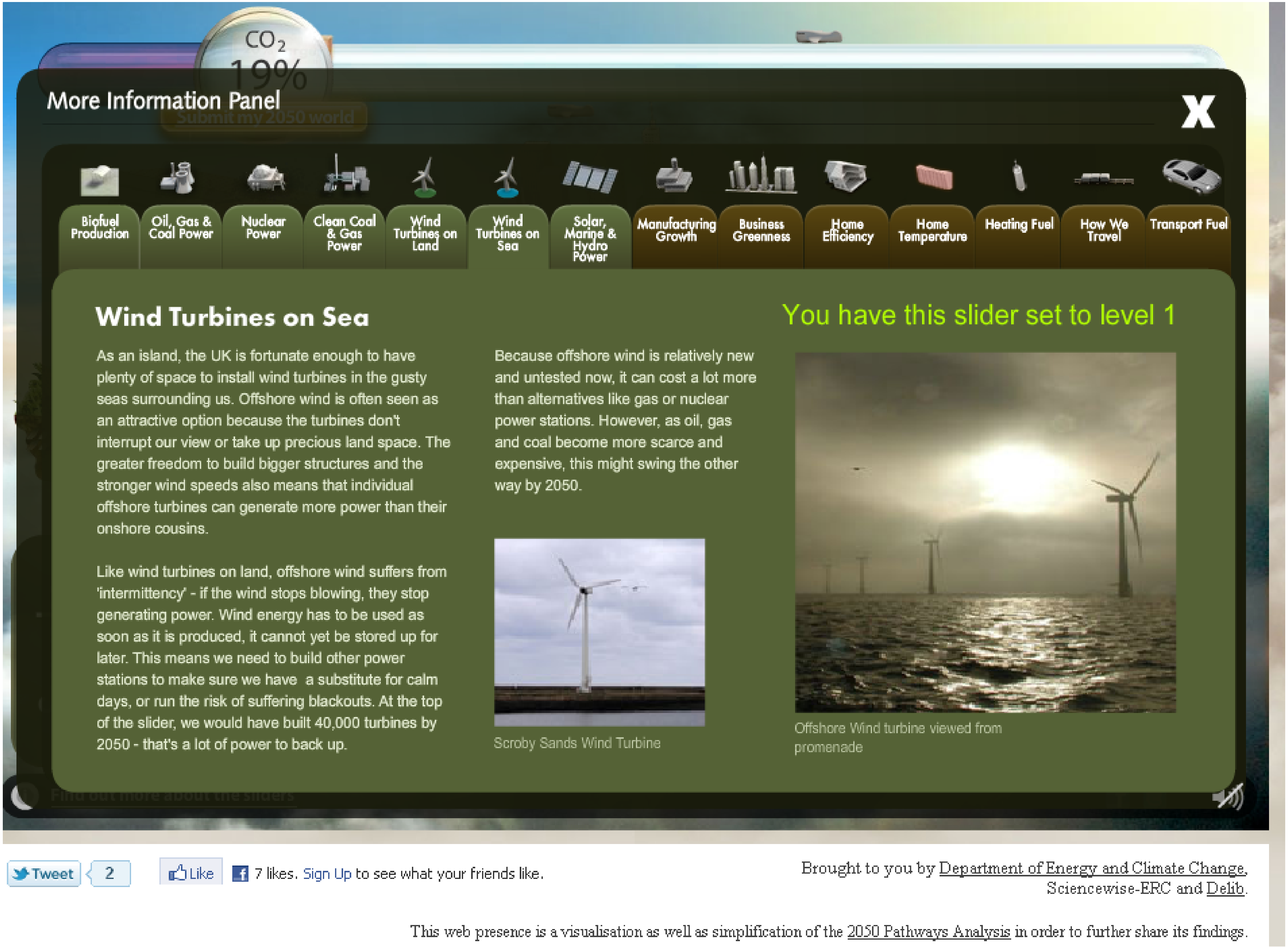
Brought to you by Department of Energy and Climate Change, Sciencewise-ERC and Delib.

This web presence is a visualisation as well as simplification of the 2050 Pathways Analysis in order to further share its findings.

7 likes. Sign Up to see what your friends like.

Brought to you by Department of Energy and Climate Change, Sciencewise-ERC and Delib.

This web presence is a visualisation as well as simplification of the 2050 Pathways Analysis in order to further share its findings.



More Information Panel

Wind Turbines on Sea

You have this slider set to level 1

As an island, the UK is fortunate enough to have plenty of space to install wind turbines in the gusty seas surrounding us. Offshore wind is often seen as an attractive option because the turbines don't interrupt our view or take up precious land space. The greater freedom to build bigger structures and the stronger wind speeds also means that individual offshore turbines can generate more power than their onshore cousins.

Like wind turbines on land, offshore wind suffers from 'intermittency' - if the wind stops blowing, they stop generating power. Wind energy has to be used as soon as it is produced, it cannot yet be stored up for later. This means we need to build other power stations to make sure we have a substitute for calm days, or run the risk of suffering blackouts. At the top of the slider, we would have built 40,000 turbines by 2050 - that's a lot of power to back up.

Because offshore wind is relatively new and untested now, it can cost a lot more than alternatives like gas or nuclear power stations. However, as oil, gas and coal become more scarce and expensive, this might swing the other way by 2050.

Scroby Sands Wind Turbine

Offshore Wind turbine viewed from promenade

7 likes. Sign Up to see what your friends like.

Brought to you by Department of Energy and Climate Change, Sciencewise-ERC and Delib.

This web presence is a visualisation as well as simplification of the 2050 Pathways Analysis in order to further share its findings.

More Information Panel

Nuclear Power

Nuclear power is a proven technology which can provide reliable and low carbon power. Nuclear power emits about the same amount of carbon as wind power over the course of its lifetime, and it works in all weathers.

Nuclear power stations in the UK like Sizewell B have been generating electricity since the 1950s, producing almost 20% of our electricity in 2009. They work by using controlled reactions to heat water, which turns into steam. This steam turns a turbine which generates electricity.

Although we have a good understanding about how to make safe and efficient nuclear power, there are still some issues we need to think about for 2050. There is the question of deciding what to do with nuclear waste. All nuclear power stations produce waste, some of it remaining dangerous to humans and the environment for thousands of years. Working out how and where to store and dispose this waste safely will be very important.

Nuclear reactors use uranium as fuel and although supplies are predicted to last much longer than our oil, coal and gas reserves, there is some uncertainty about exactly how long they will last. We do not produce any uranium in the UK, so we will need to rely on imports. However, more countries have supplies of uranium than oil and gas, so our sources are more secure.

To produce the amount needed at the top of the slider, we would need to build around fifty large nuclear power stations by 2050.

You have this slider set to level 3

The main safety vessel at 'Sizewell B' Nuclear Power Station. Sizewell B's average output is roughly 1 GW – 9 TWh/y. In the Calculator, we imagine that a new generation of 3 GW plants will be available, and that we are able to build fewer but more powerful reactors.

7 likes. Sign Up to see what your friends like.

Brought to you by Department of Energy and Climate Change, Sciencewise-ERC and Delib.

This web presence is a visualisation as well as simplification of the 2050 Pathways Analysis in order to further share its findings.

Other people's My2050 worlds Click on a My2050 below to expand

Interesting My2050 from:

Understand other people's solutions?
Learn more about other points of view?
Debate on how to tackle the challenge?

8 likes. Sign Up to see what your friends like.

Brought to you by Department of Energy and Climate Change, Sciencewise-ERC and Delib.

This web presence is a visualisation as well as simplification of the 2050 Pathways Analysis in order to further share its findings.

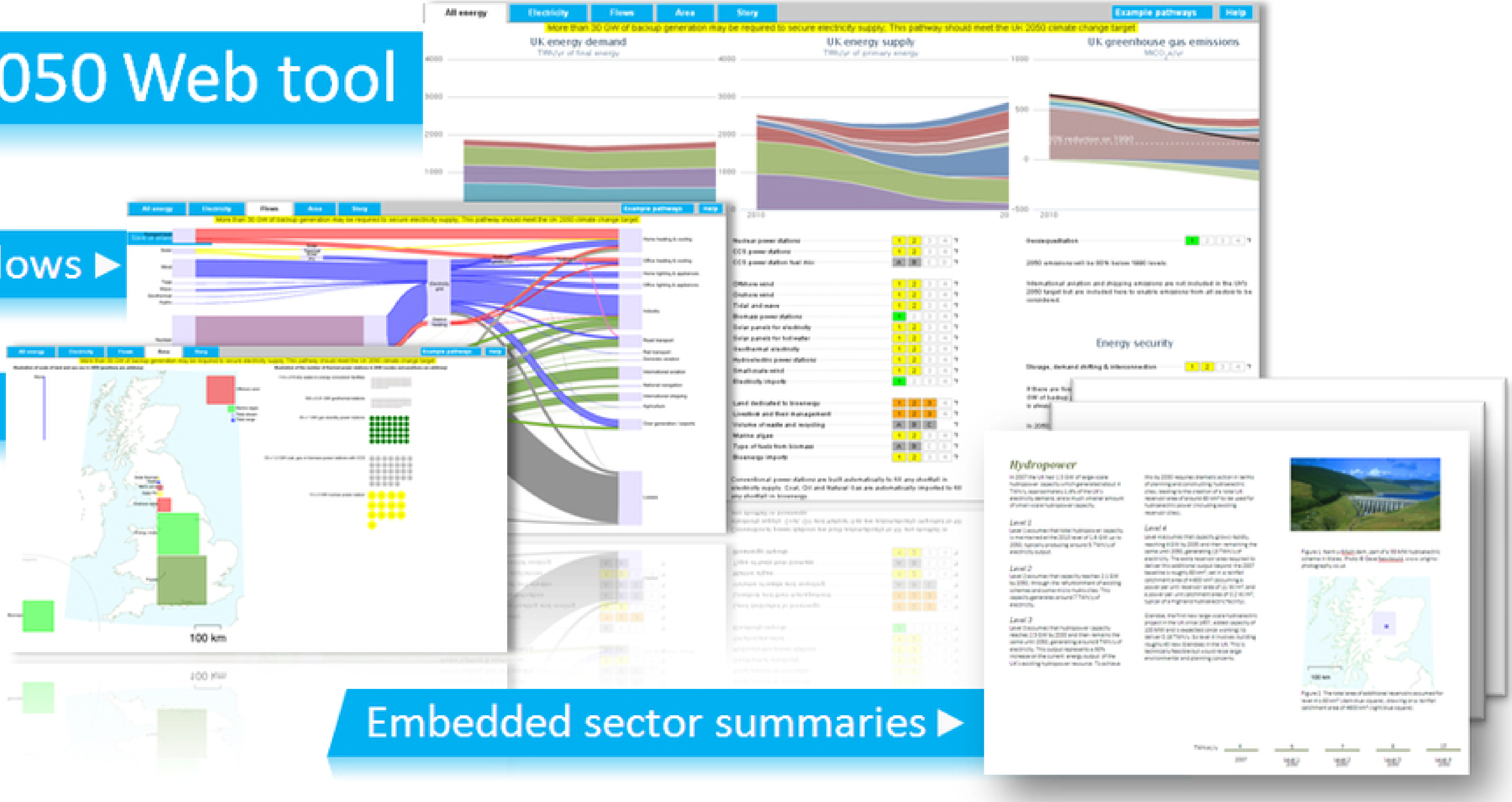
How to improve this situation...

$$\left.\begin{array}{r}\text{wishful thinking}\\ +\\ \text{mistrust}\end{array}\right\}\longrightarrow\left\{\begin{array}{c}\text{poorly-designed policies}\\ +\\ \text{disagreement over solutions}\end{array}\right.$$

- Provide facts
- Use numbers, not adjectives
- Use a single set of units
- Talk about scale

- Win trust by:
  - not promoting a solution
  - showing your working
  - getting lots of people to endorse your work

2050 Web tool



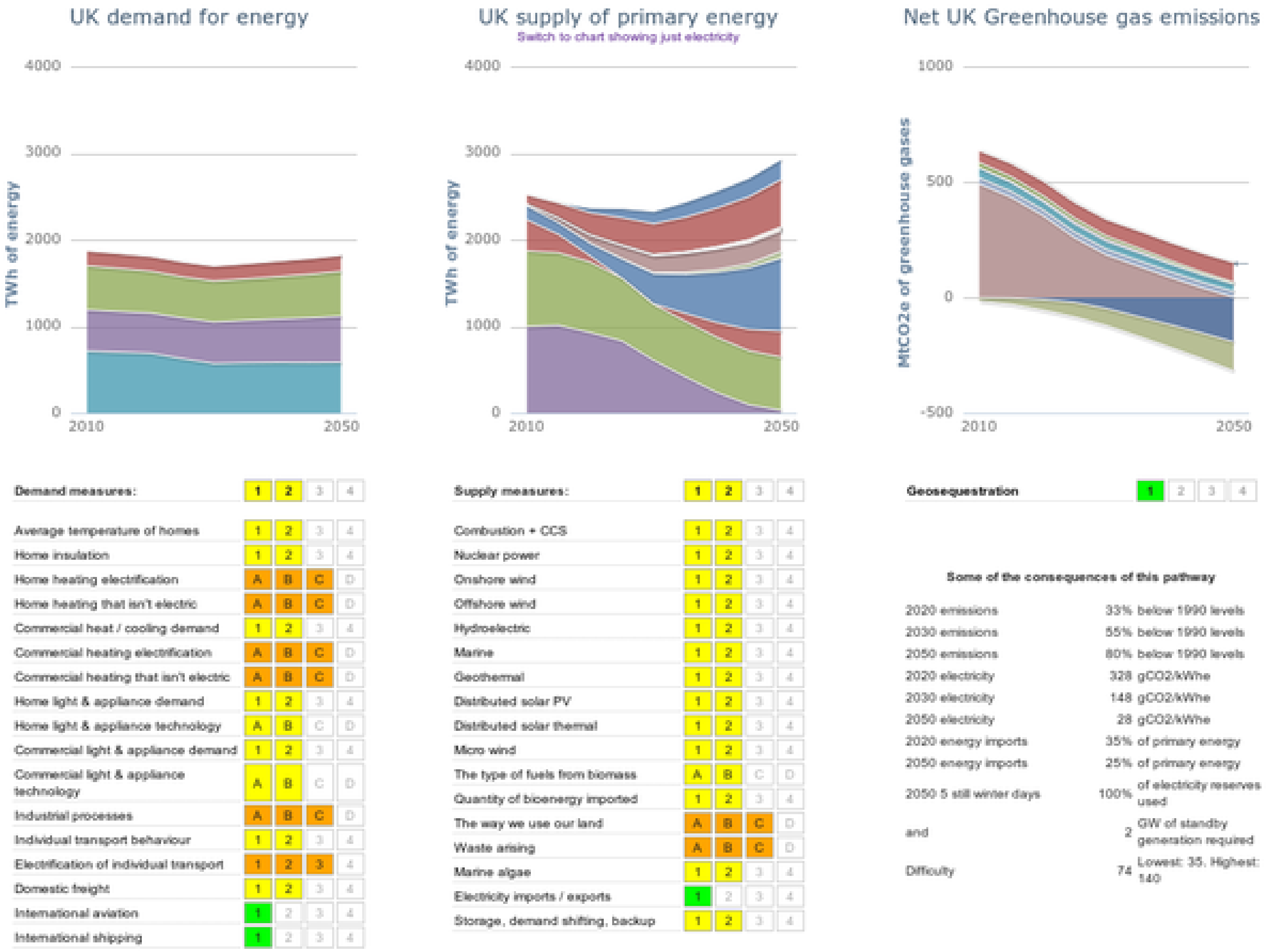
More than 30 GW of backup generation may be required to secure electricity supply. This pathway should meet the UK 2050 climate change target

Energy flows ▶

Area used ▶

Embedded sector summaries ▶

2050-calculator-tool.decc.gov.uk



Demand measures:	1	2	3	4
Average temperature of homes	1	2	3	4
Home insulation	1	2	3	4
Home heating electrification	A	B	C	D
Home heating that isn't electric	A	B	C	D
Commercial heat / cooling demand	1	2	3	4
Commercial heating electrification	A	B	C	D
Commercial heating that isn't electric	A	B	C	D
Home light & appliance demand	1	2	3	4
Home light & appliance technology	A	B	C	D
Commercial light & appliance demand	1	2	3	4
Commercial light & appliance technology	A	B	C	D
Industrial processes	A	B	C	D
Individual transport behaviour	1	2	3	4
Electrification of individual transport	1	2	3	4
Domestic freight	1	2	3	4
International aviation	1	2	3	4
International shipping	1	2	3	4

Supply measures:	1	2	3	4
Combustion + CCS	1	2	3	4
Nuclear power	1	2	3	4
Onshore wind	1	2	3	4
Offshore wind	1	2	3	4
Hydroelectric	1	2	3	4
Marine	1	2	3	4
Geothermal	1	2	3	4
Distributed solar PV	1	2	3	4
Distributed solar thermal	1	2	3	4
Micro wind	1	2	3	4
The type of fuels from biomass	A	B	C	D
Quantity of bioenergy imported	1	2	3	4
The way we use our land	A	B	C	D
Waste arising	A	B	C	D
Marine algae	1	2	3	4
Electricity imports / exports	1	2	3	4
Storage, demand shifting, backup	1	2	3	4

Geosequestration	1	2	3	4

Some of the consequences of this pathway

2020 emissions	33%	below 1990 levels
2030 emissions	55%	below 1990 levels
2050 emissions	80%	below 1990 levels
2020 electricity	328	gCO2/kWhe
2030 electricity	148	gCO2/kWhe
2050 electricity	28	gCO2/kWhe
2020 energy imports	35%	of primary energy
2050 energy imports	25%	of primary energy
2050 5 still winter days	100%	of electricity reserves used
and	2	GW of standby generation required
Difficulty	74	Lowest: 35. Highest: 140

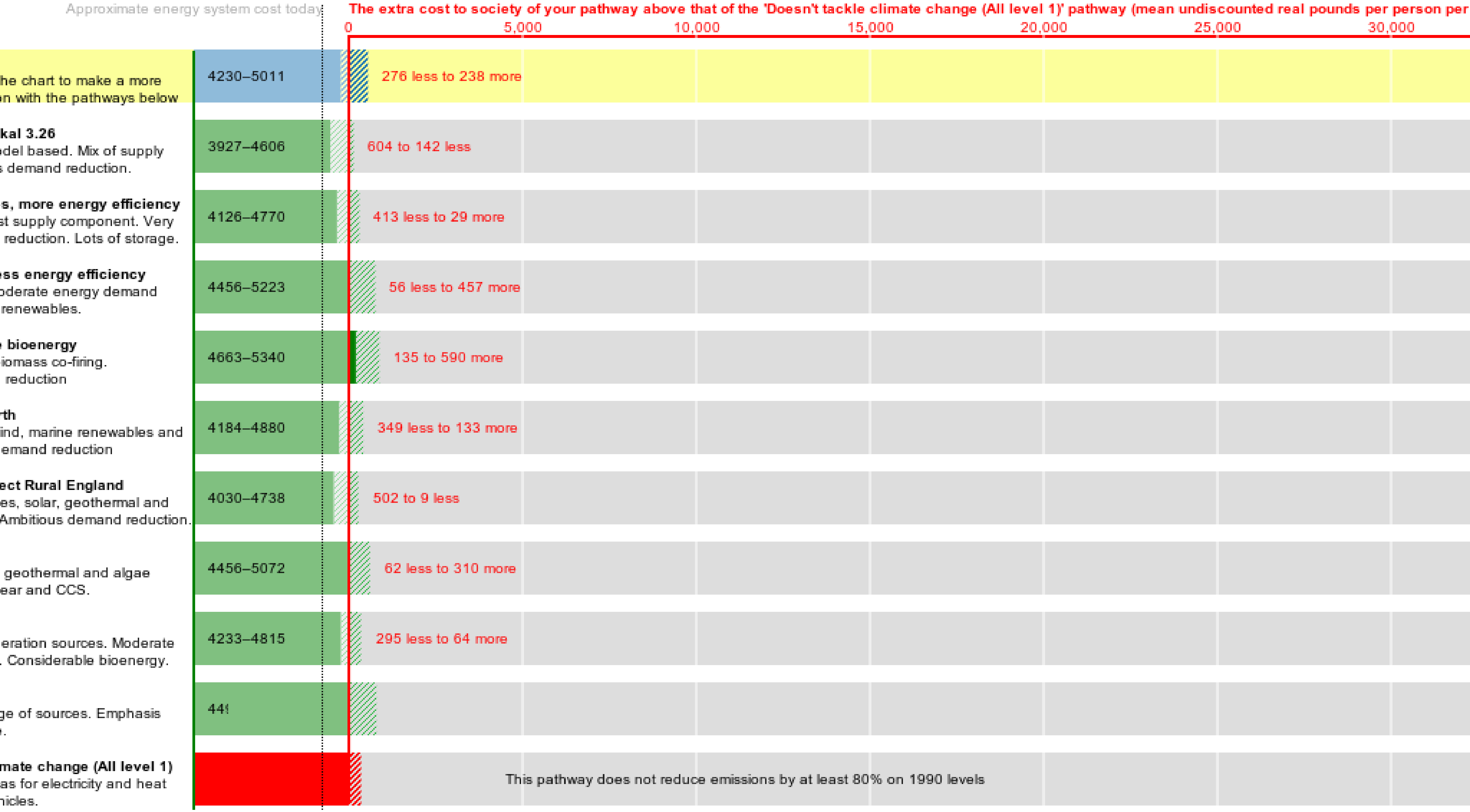
- Some bumps in the road...

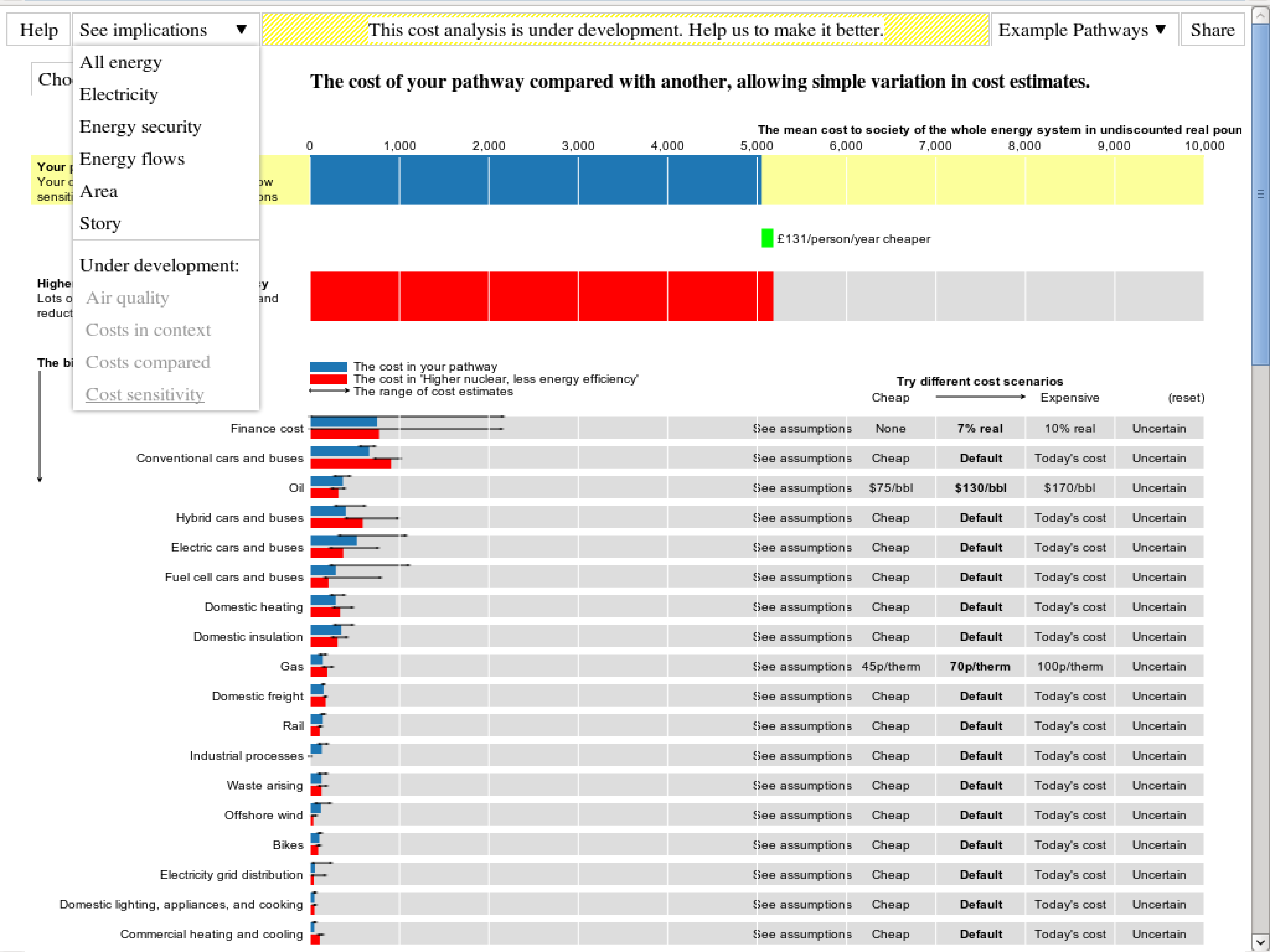
Our own department

Costs (version 3) (December 2011)

not on default values

The cost to society of your pathway. This is not your energy bill. For comparison, UK average GDP 2010-2050 is forecast to be roug person.

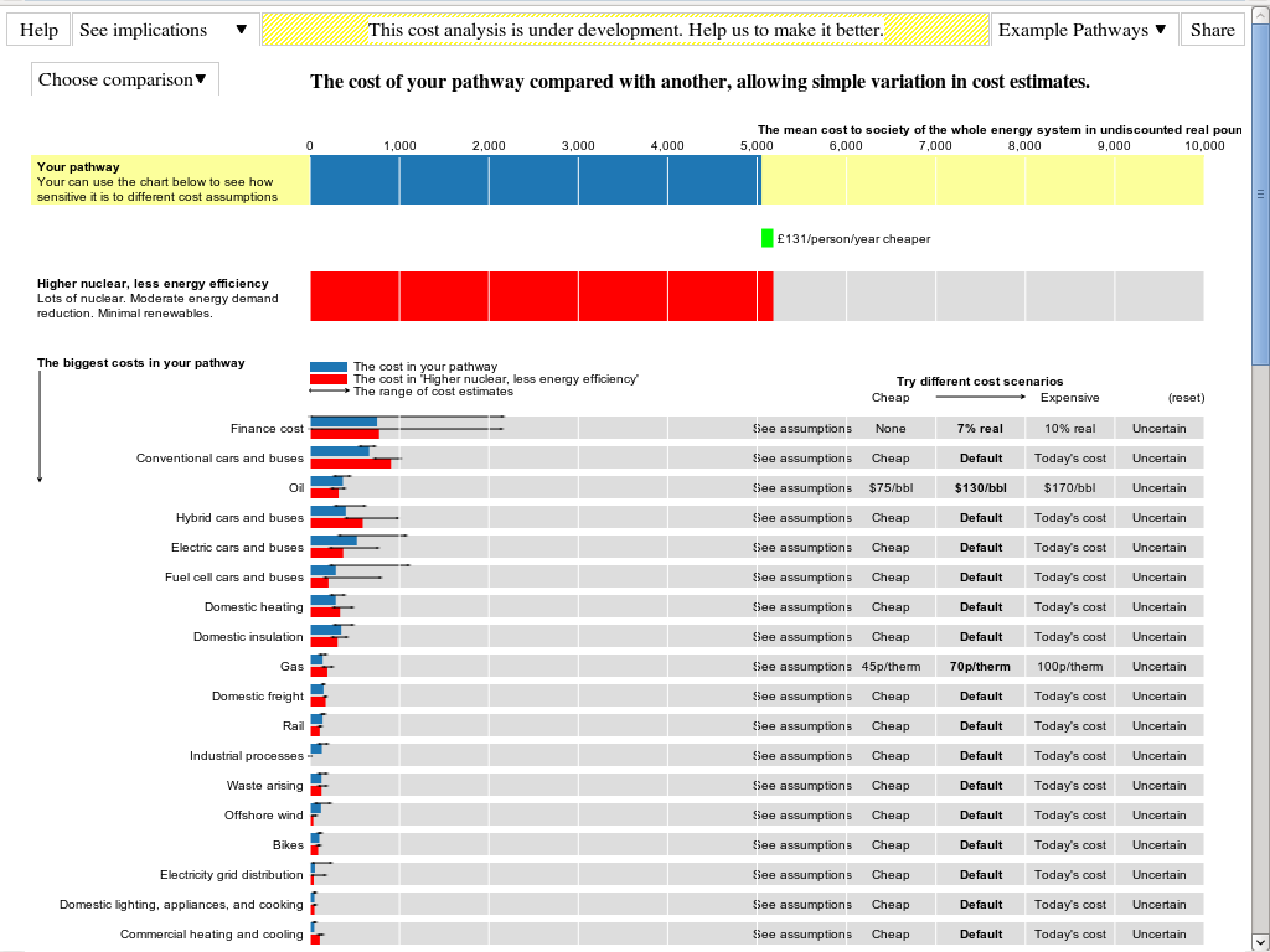




This cost analysis is under development. Help us to make it better.

The cost of your pathway compared with another, allowing simple variation in cost estimates.

		Try different cost scenarios Cheap	→	Expensive	(reset)
Finance cost	See assumptions	None	**7% real**	10% real	Uncertain
Conventional cars and buses	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Oil	See assumptions	$75/bbl	**$130/bbl**	$170/bbl	Uncertain
Hybrid cars and buses	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Electric cars and buses	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Fuel cell cars and buses	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Domestic heating	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Domestic insulation	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Gas	See assumptions	45p/therm	**70p/therm**	100p/therm	Uncertain
Domestic freight	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Rail	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Industrial processes	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Waste arising	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Offshore wind	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Bikes	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Electricity grid distribution	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Domestic lighting, appliances, and cooking	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Commercial heating and cooling	See assumptions	Cheap	**Default**	Today's cost	Uncertain



This cost analysis is under development. Help us to make it better.

The cost of your pathway compared with another, allowing simple variation in cost estimates.

The mean cost to society of the whole energy system in undiscounted real poun

Your pathway
Your can use the chart below to see how sensitive it is to different cost assumptions

🟩 £131/person/year cheaper

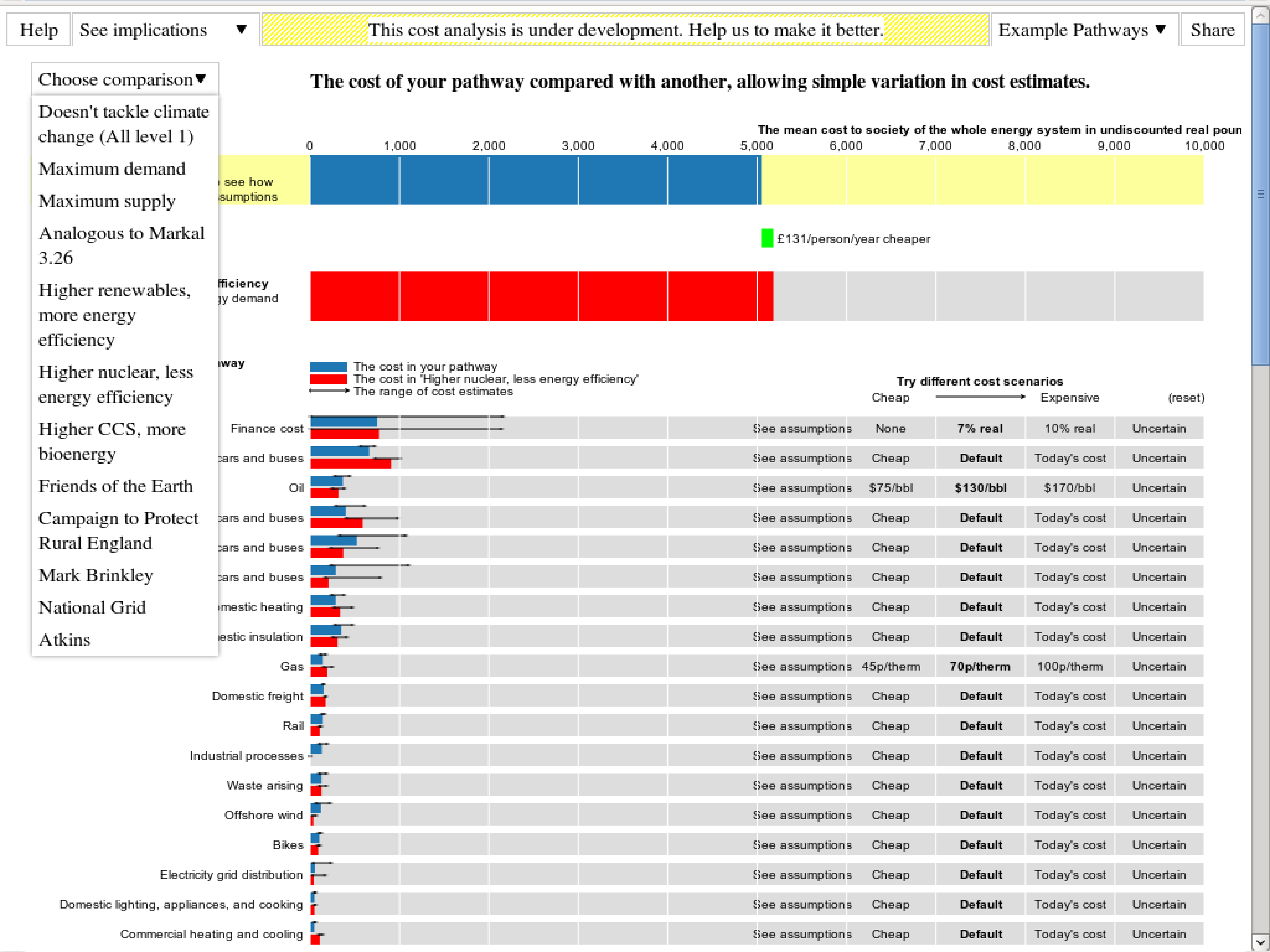
Higher nuclear, less energy efficiency
Lots of nuclear. Moderate energy demand reduction. Minimal renewables.

The biggest costs in your pathway

🟦 The cost in your pathway
🟥 The cost in 'Higher nuclear, less energy efficiency'
⟷ The range of cost estimates

Try different cost scenarios
Cheap → Expensive (reset)

Finance cost	See assumptions	None	**7% real**	10% real	Uncertain
Conventional cars and buses	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Oil	See assumptions	$75/bbl	**$130/bbl**	$170/bbl	Uncertain
Hybrid cars and buses	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Electric cars and buses	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Fuel cell cars and buses	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Domestic heating	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Domestic insulation	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Gas	See assumptions	45p/therm	**70p/therm**	100p/therm	Uncertain
Domestic freight	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Rail	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Industrial processes	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Waste arising	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Offshore wind	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Bikes	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Electricity grid distribution	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Domestic lighting, appliances, and cooking	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Commercial heating and cooling	See assumptions	Cheap	**Default**	Today's cost	Uncertain



Help | See implications ▼ | This cost analysis is under development. Help us to make it better. | Example Pathways ▼ | Share

Choose comparison ▼

- Doesn't tackle climate change (All level 1)
- Maximum demand
- Maximum supply
- Analogous to Markal 3.26
- Higher renewables, more energy efficiency
- Higher nuclear, less energy efficiency
- Higher CCS, more bioenergy
- Friends of the Earth
- Campaign to Protect Rural England
- Mark Brinkley
- National Grid
- Atkins

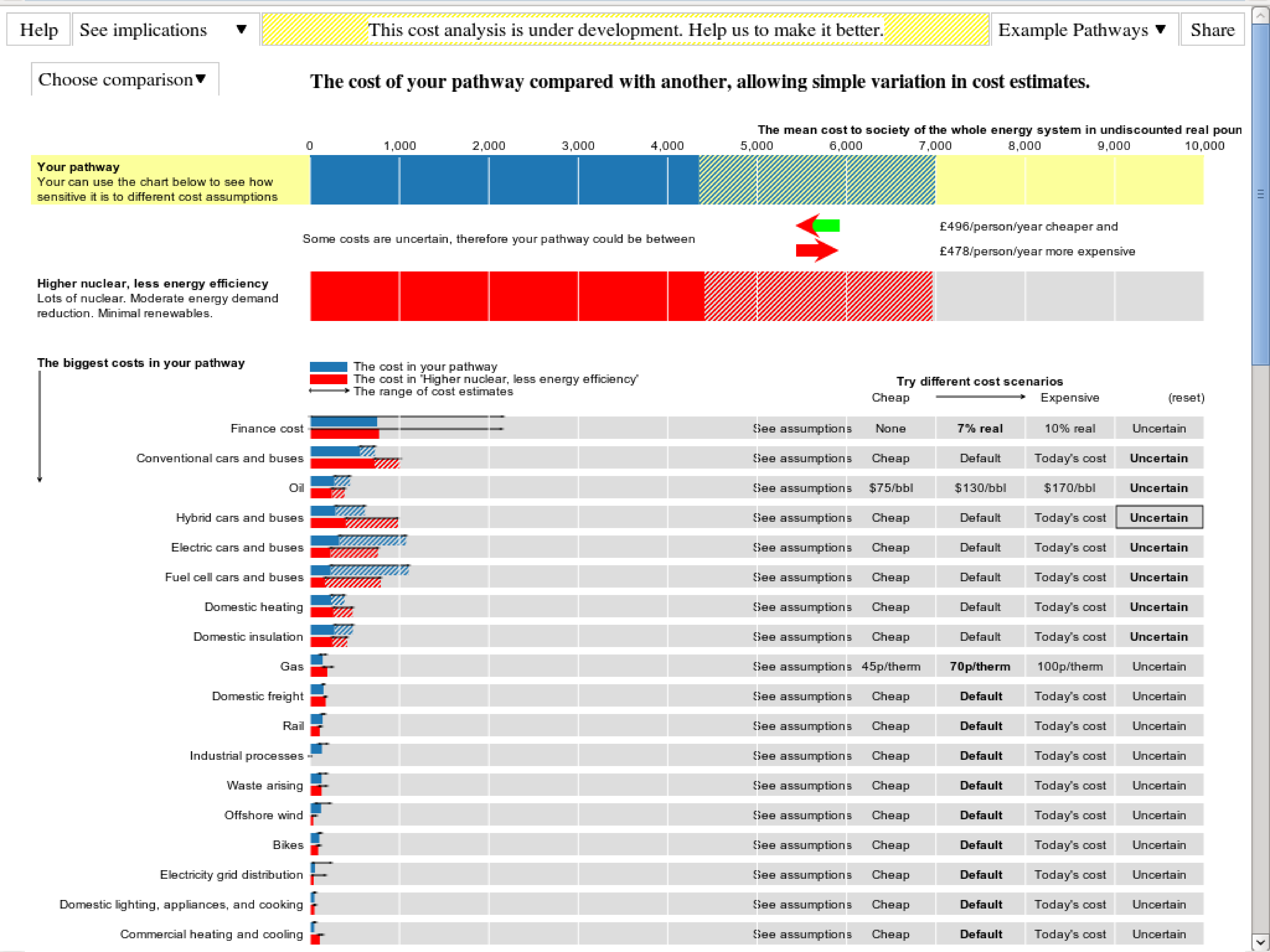
The cost of your pathway compared with another, allowing simple variation in cost estimates.

🟦 The cost in your pathway
🟥 The cost in 'Higher nuclear, less energy efficiency'
⟷ The range of cost estimates

Try different cost scenarios

Cheap ⟶ Expensive (reset)

Finance cost	See assumptions	None	**7% real**	10% real	Uncertain
cars and buses	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Oil	See assumptions	$75/bbl	**$130/bbl**	$170/bbl	Uncertain
cars and buses	See assumptions	Cheap	**Default**	Today's cost	Uncertain
cars and buses	See assumptions	Cheap	**Default**	Today's cost	Uncertain
cars and buses	See assumptions	Cheap	**Default**	Today's cost	Uncertain
mestic heating	See assumptions	Cheap	**Default**	Today's cost	Uncertain
estic insulation	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Gas	See assumptions	45p/therm	**70p/therm**	100p/therm	Uncertain
Domestic freight	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Rail	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Industrial processes	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Waste arising	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Offshore wind	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Bikes	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Electricity grid distribution	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Domestic lighting, appliances, and cooking	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Commercial heating and cooling	See assumptions	Cheap	**Default**	Today's cost	Uncertain



The cost of your pathway compared with another, allowing simple variation in cost estimates.

The mean cost to society of the whole energy system in undiscounted real poun

Your pathway
Your can use the chart below to see how sensitive it is to different cost assumptions

Some costs are uncertain, therefore your pathway could be between

£496/person/year cheaper and

£478/person/year more expensive

Higher nuclear, less energy efficiency
Lots of nuclear. Moderate energy demand reduction. Minimal renewables.

The biggest costs in your pathway

- The cost in your pathway
- The cost in 'Higher nuclear, less energy efficiency'
- The range of cost estimates

Try different cost scenarios

		Cheap	→	Expensive	(reset)
Finance cost	See assumptions	None	**7% real**	10% real	Uncertain
Conventional cars and buses	See assumptions	Cheap	Default	Today's cost	**Uncertain**
Oil	See assumptions	$75/bbl	$130/bbl	$170/bbl	**Uncertain**
Hybrid cars and buses	See assumptions	Cheap	Default	Today's cost	**Uncertain**
Electric cars and buses	See assumptions	Cheap	Default	Today's cost	**Uncertain**
Fuel cell cars and buses	See assumptions	Cheap	Default	Today's cost	**Uncertain**
Domestic heating	See assumptions	Cheap	Default	Today's cost	**Uncertain**
Domestic insulation	See assumptions	Cheap	Default	Today's cost	**Uncertain**
Gas	See assumptions	45p/therm	**70p/therm**	100p/therm	Uncertain
Domestic freight	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Rail	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Industrial processes	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Waste arising	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Offshore wind	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Bikes	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Electricity grid distribution	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Domestic lighting, appliances, and cooking	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Commercial heating and cooling	See assumptions	Cheap	**Default**	Today's cost	Uncertain

III.C TIDAL AND WAVE COSTS

improve this page see who wrote which bits of this page get an email if this page changes

Search
help home page a-z index recent changes
add a page
add a cost

CONTENTS OF THIS PAGE

RELATED CATEGORIES

Sector by sector cost assumptions

RELATED PAGES, PICTURES AND USERS

Costs by sector

TECHNOLOGIES COSTED IN THIS SECTOR

- Wave turbine - Please click on: Wave Cost Data
- Tidal range/barrage - Please click on: Tidal Range Cost Data
- Tidal Stream - Please click on: Tidal Stream Cost Data

COSTS METHODOLOGY

METHODOLOGY USED

The user defines the number of wave and tidal turbines. Once the trajectory is set by the user, the number of plants to be built are defined. Investment costs are a function of new build and operating cost are a function of the number of plants operating within that time period. We assume turbines retire and the cost of replacement is included.

Please see 2050 Methodology for a full description of the costs approach in the Calculator.

METHODOLOGY ISSUES AND UNCERTAINTIES

- May need to revisit assumption of 25 year economic life for wave and tidal stream (tidal stream and wave likely to be similar or less than offshore wind - tidal range will be much longer -eg La Rance which has been operating now for more than 40 years without any major refurbishment and with predictions for 80+ yers of further operation).
- Need to check Tidal Barage costs against the studies reported in D11/1030385 (tidal barrage costs and lives are available from Severn, Duddon and Mersey Studies)
- Investment cost includes the cost of grid connection, need to make sure we don't double count the cost of an offshore grid or under-represent transmission costs

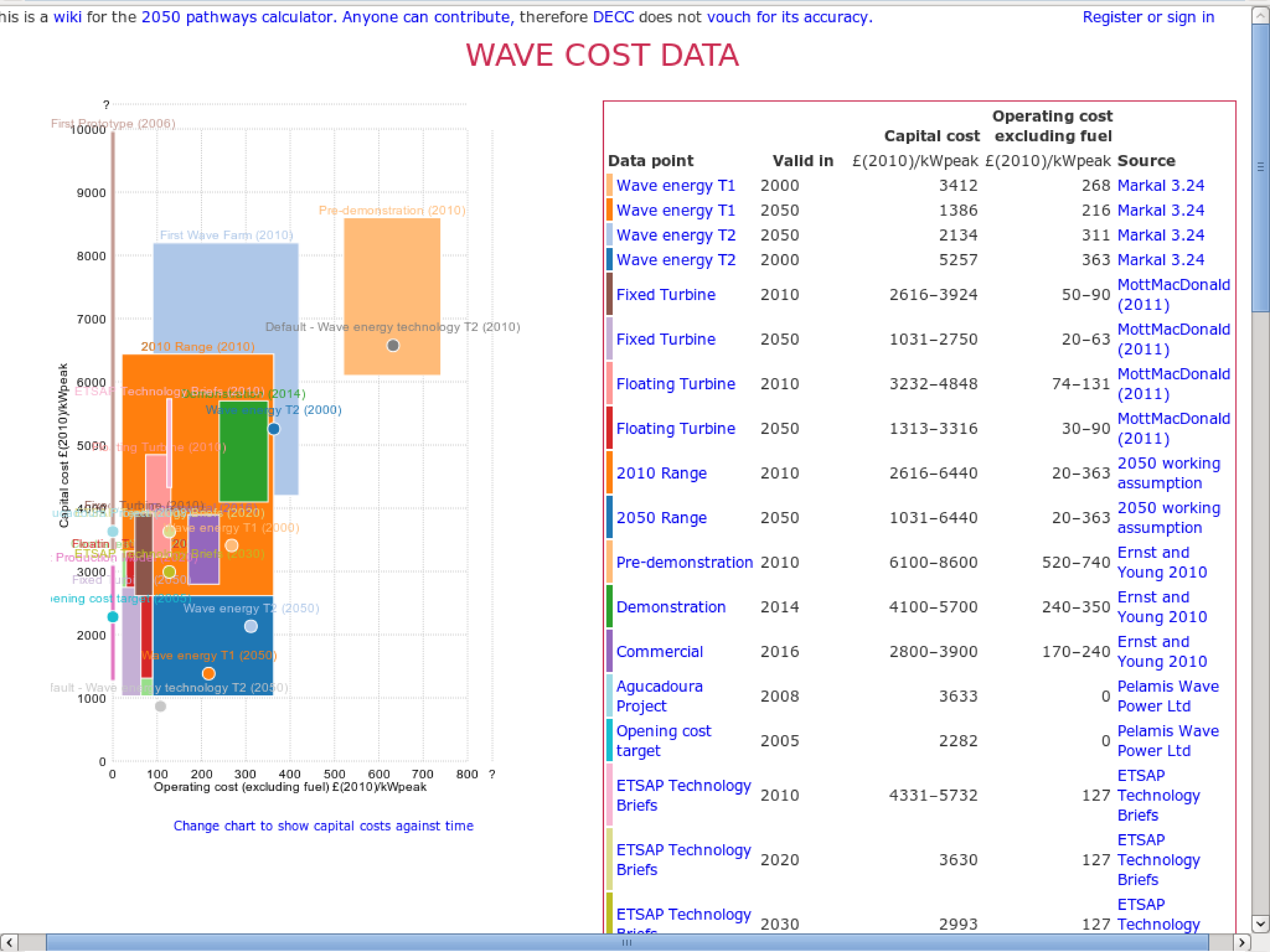
TECHNICAL ASSUMPTIONS

WAVE TURBINE

- Lifetime = 25yrs[1]
- Availability = 90%
- Load Factor = 25%
- Input Fuel = Wave

TIDAL RANGE/BARRAGE

- Lifetime = 120yrs[2]



his is a wiki for the 2050 pathways calculator. Anyone can contribute, therefore DECC does not vouch for its accuracy.

Register or sign in

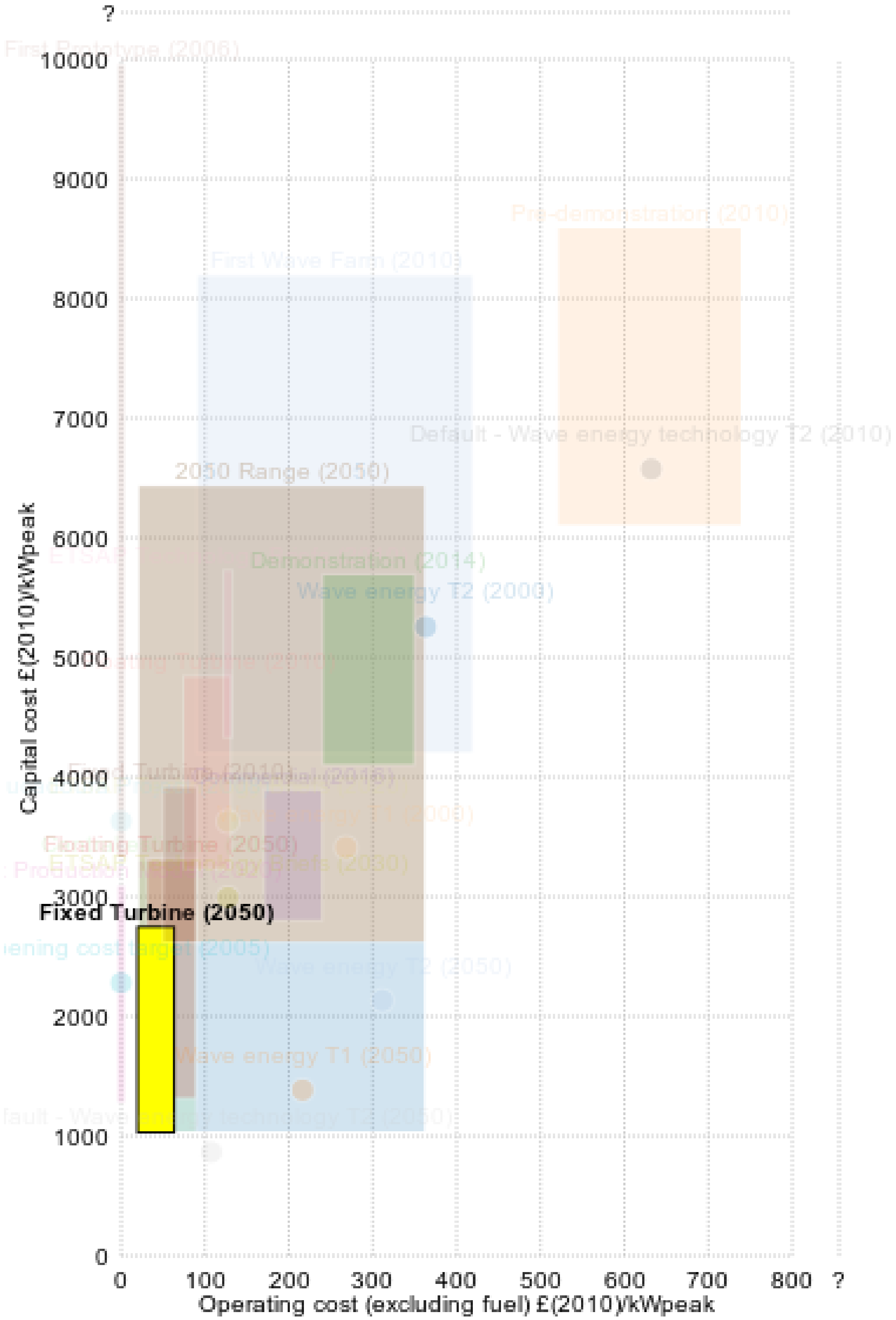
WAVE COST DATA

Change chart to show capital costs against time

Data point	Valid in	Capital cost £(2010)/kWpeak	Operating cost excluding fuel £(2010)/kWpeak	Source
Wave energy T1	2000	3412	268	Markal 3.24
Wave energy T1	2050	1386	216	Markal 3.24
Wave energy T2	2050	2134	311	Markal 3.24
Wave energy T2	2000	5257	363	Markal 3.24
Fixed Turbine	2010	2616–3924	50–90	MottMacDonald (2011)
Fixed Turbine	2050	1031–2750	20–63	MottMacDonald (2011)
Floating Turbine	2010	3232–4848	74–131	MottMacDonald (2011)
Floating Turbine	2050	1313–3316	30–90	MottMacDonald (2011)
2010 Range	2010	2616–6440	20–363	2050 working assumption
2050 Range	2050	1031–6440	20–363	2050 working assumption
Pre-demonstration	2010	6100–8600	520–740	Ernst and Young 2010
Demonstration	2014	4100–5700	240–350	Ernst and Young 2010
Commercial	2016	2800–3900	170–240	Ernst and Young 2010
Agucadoura Project	2008	3633	0	Pelamis Wave Power Ltd
Opening cost target	2005	2282	0	Pelamis Wave Power Ltd
ETSAP Technology Briefs	2010	4331–5732	127	ETSAP Technology Briefs
ETSAP Technology Briefs	2020	3630	127	ETSAP Technology Briefs
ETSAP Technology	2030	2993	127	ETSAP Technology

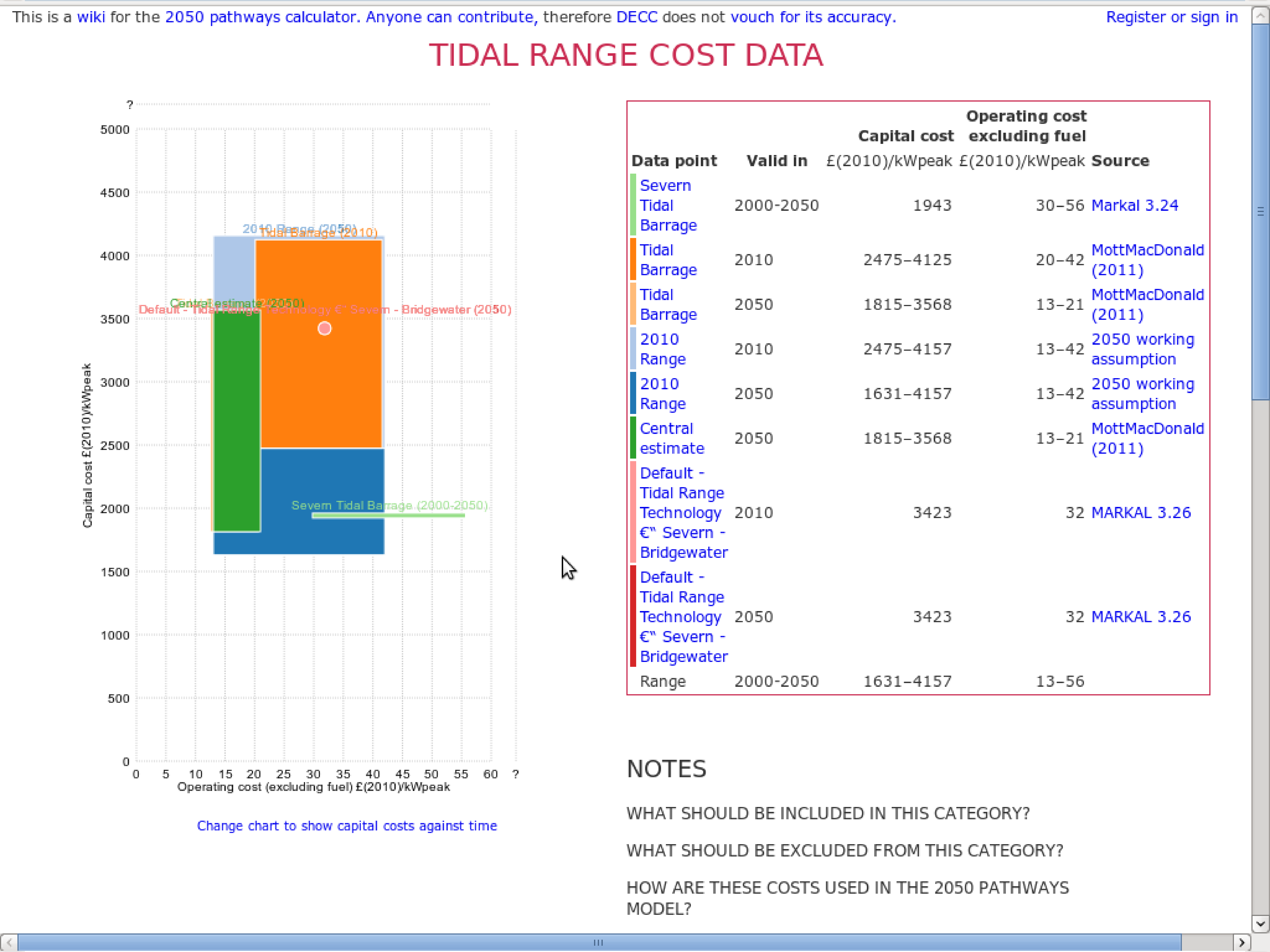
Register or sign in

WAVE COST DATA



Change chart to show capital costs against time

Data point	Valid in	Capital cost £(2010)/kWpeak	Operating cost excluding fuel £(2010)/kWpeak	Source
Wave energy T1	2000	3412	268	Markal 3.24
Wave energy T1	2050	1386	216	Markal 3.24
Wave energy T2	2050	2134	311	Markal 3.24
Wave energy T2	2000	5257	363	Markal 3.24
Fixed Turbine	2010	2616–3924	50–90	MottMacDonald (2011)
Fixed Turbine	2050	1031–2750	20–63	MottMacDonald (2011)
Floating Turbine	2010	3232–4848	74–131	MottMacDonald (2011)
Floating Turbine	2050	1313–3316	30–90	MottMacDonald (2011)
2010 Range	2010	2616–6440	20–363	2050 working assumption
2050 Range	2050	1031–6440	20–363	2050 working assumption
Pre-demonstration	2010	6100–8600	520–740	Ernst and Young 2010
Demonstration	2014	4100–5700	240–350	Ernst and Young 2010
Commercial	2016	2800–3900	170–240	Ernst and Young 2010
Agucadoura Project	2008	3633	0	Pelamis Wave Power Ltd
Opening cost target	2005	2282	0	Pelamis Wave Power Ltd
ETSAP Technology Briefs	2010	4331–5732	127	ETSAP Technology Briefs
ETSAP Technology Briefs	2020	3630	127	ETSAP Technology Briefs
ETSAP Technology	2030	2993	127	ETSAP Technology



This is a wiki for the 2050 pathways calculator. Anyone can contribute, therefore DECC does not vouch for its accuracy. Register or sign in

TIDAL RANGE COST DATA

Change chart to show capital costs against time

Data point	Valid in	Capital cost £(2010)/kWpeak	Operating cost excluding fuel £(2010)/kWpeak	Source
Severn Tidal Barrage	2000-2050	1943	30–56	Markal 3.24
Tidal Barrage	2010	2475–4125	20–42	MottMacDonald (2011)
Tidal Barrage	2050	1815–3568	13–21	MottMacDonald (2011)
2010 Range	2010	2475–4157	13–42	2050 working assumption
2010 Range	2050	1631–4157	13–42	2050 working assumption
Central estimate	2050	1815–3568	13–21	MottMacDonald (2011)
Default - Tidal Range Technology €" Severn - Bridgewater	2010	3423	32	MARKAL 3.26
Default - Tidal Range Technology €" Severn - Bridgewater	2050	3423	32	MARKAL 3.26
Range	2000-2050	1631–4157	13–56	

NOTES

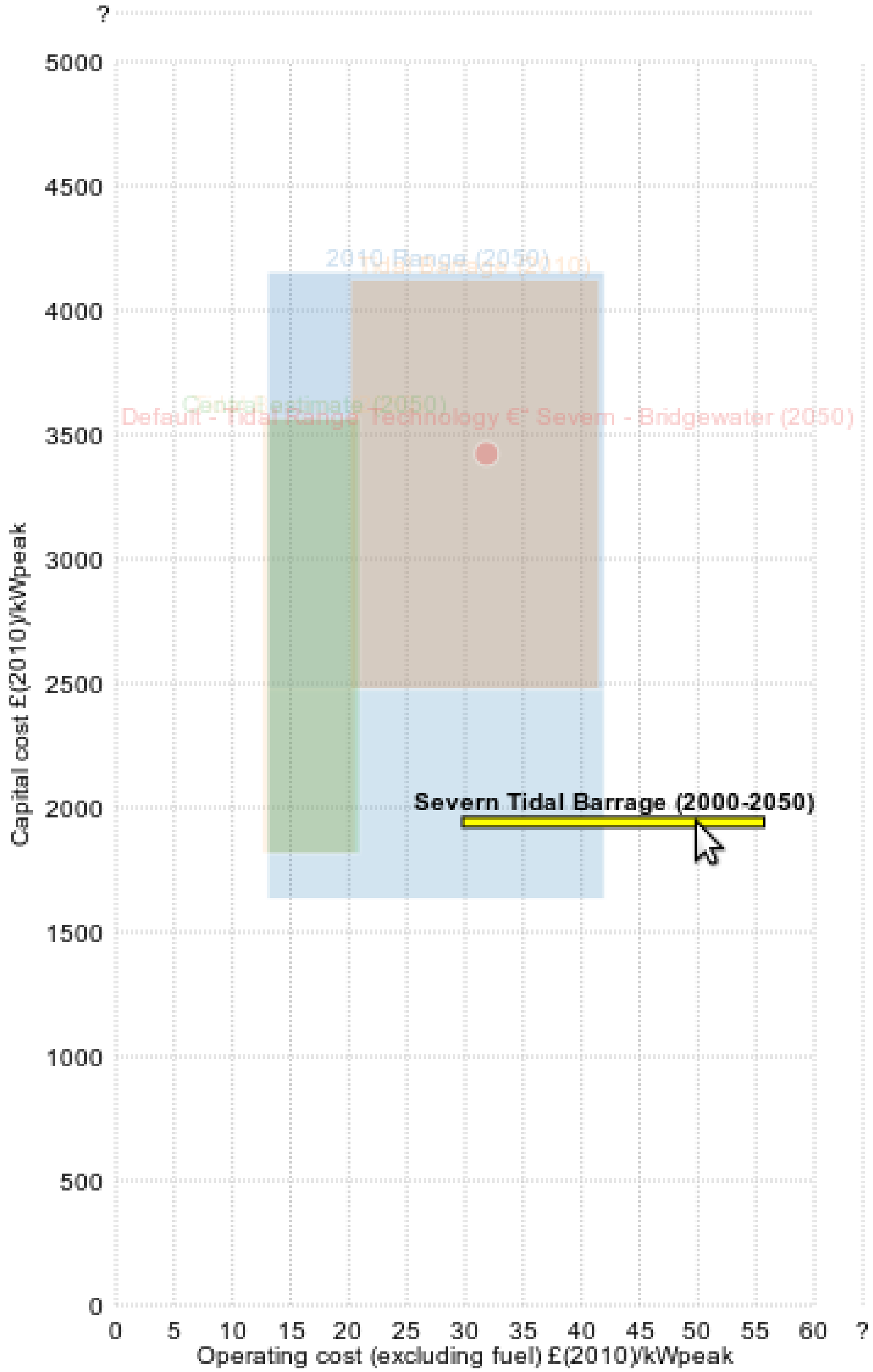
WHAT SHOULD BE INCLUDED IN THIS CATEGORY?

WHAT SHOULD BE EXCLUDED FROM THIS CATEGORY?

HOW ARE THESE COSTS USED IN THE 2050 PATHWAYS MODEL?

This is a wiki for the 2050 pathways calculator. Anyone can contribute, therefore DECC does not vouch for its accuracy. Register or sign in

TIDAL RANGE COST DATA



Change chart to show capital costs against time

Data point	Valid in	Capital cost £(2010)/kWpeak	Operating cost excluding fuel £(2010)/kWpeak	Source
Severn Tidal Barrage	2000-2050	1943	30–56	Markal 3.24
Tidal Barrage	2010	2475–4125	20–42	MottMacDonald (2011)
Tidal Barrage	2050	1815–3568	13–21	MottMacDonald (2011)
2010 Range	2010	2475–4157	13–42	2050 working assumption
2010 Range	2050	1631–4157	13–42	2050 working assumption
Central estimate	2050	1815–3568	13–21	MottMacDonald (2011)
Default - Tidal Range Technology €" Severn - Bridgewater	2010	3423	32	MARKAL 3.26
Default - Tidal Range Technology €" Severn - Bridgewater	2050	3423	32	MARKAL 3.26
Range	2000-2050	1631–4157	13–56	

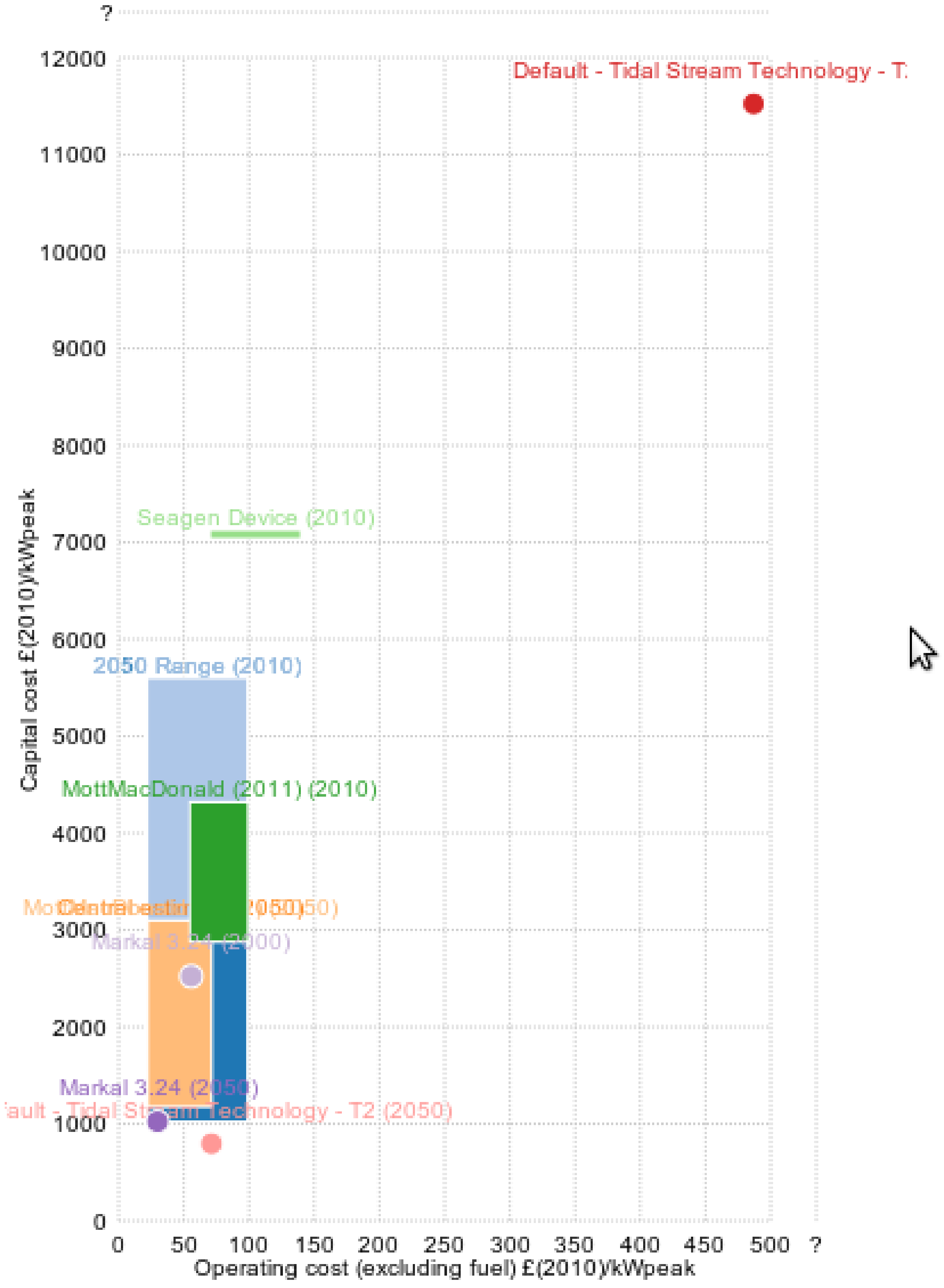
NOTES

WHAT SHOULD BE INCLUDED IN THIS CATEGORY?

WHAT SHOULD BE EXCLUDED FROM THIS CATEGORY?

HOW ARE THESE COSTS USED IN THE 2050 PATHWAYS MODEL?

TIDAL STREAM COST DATA



Change chart to show capital costs against time

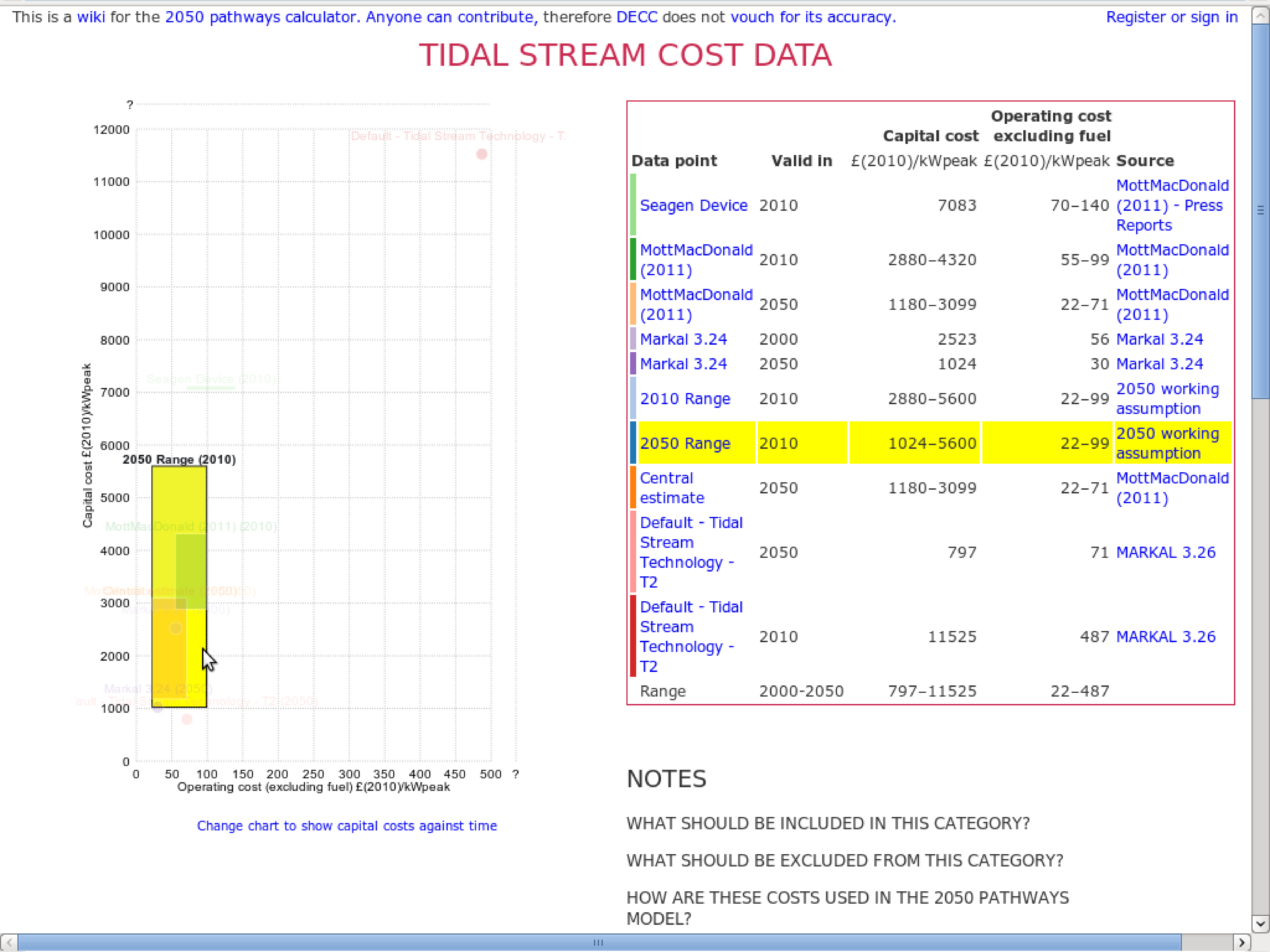
Data point	Valid in	Capital cost £(2010)/kWpeak	Operating cost excluding fuel £(2010)/kWpeak	Source
Seagen Device	2010	7083	70–140	MottMacDonald (2011) - Press Reports
MottMacDonald (2011)	2010	2880–4320	55–99	MottMacDonald (2011)
MottMacDonald (2011)	2050	1180–3099	22–71	MottMacDonald (2011)
Markal 3.24	2000	2523	56	Markal 3.24
Markal 3.24	2050	1024	30	Markal 3.24
2010 Range	2010	2880–5600	22–99	2050 working assumption
2050 Range	2010	1024–5600	22–99	2050 working assumption
Central estimate	2050	1180–3099	22–71	MottMacDonald (2011)
Default - Tidal Stream Technology - T2	2050	797	71	MARKAL 3.26
Default - Tidal Stream Technology - T2	2010	11525	487	MARKAL 3.26
Range	2000-2050	797–11525	22–487	

NOTES

WHAT SHOULD BE INCLUDED IN THIS CATEGORY?

WHAT SHOULD BE EXCLUDED FROM THIS CATEGORY?

HOW ARE THESE COSTS USED IN THE 2050 PATHWAYS MODEL?



This is a wiki for the 2050 pathways calculator. Anyone can contribute, therefore DECC does not vouch for its accuracy.

TIDAL STREAM COST DATA

Change chart to show capital costs against time

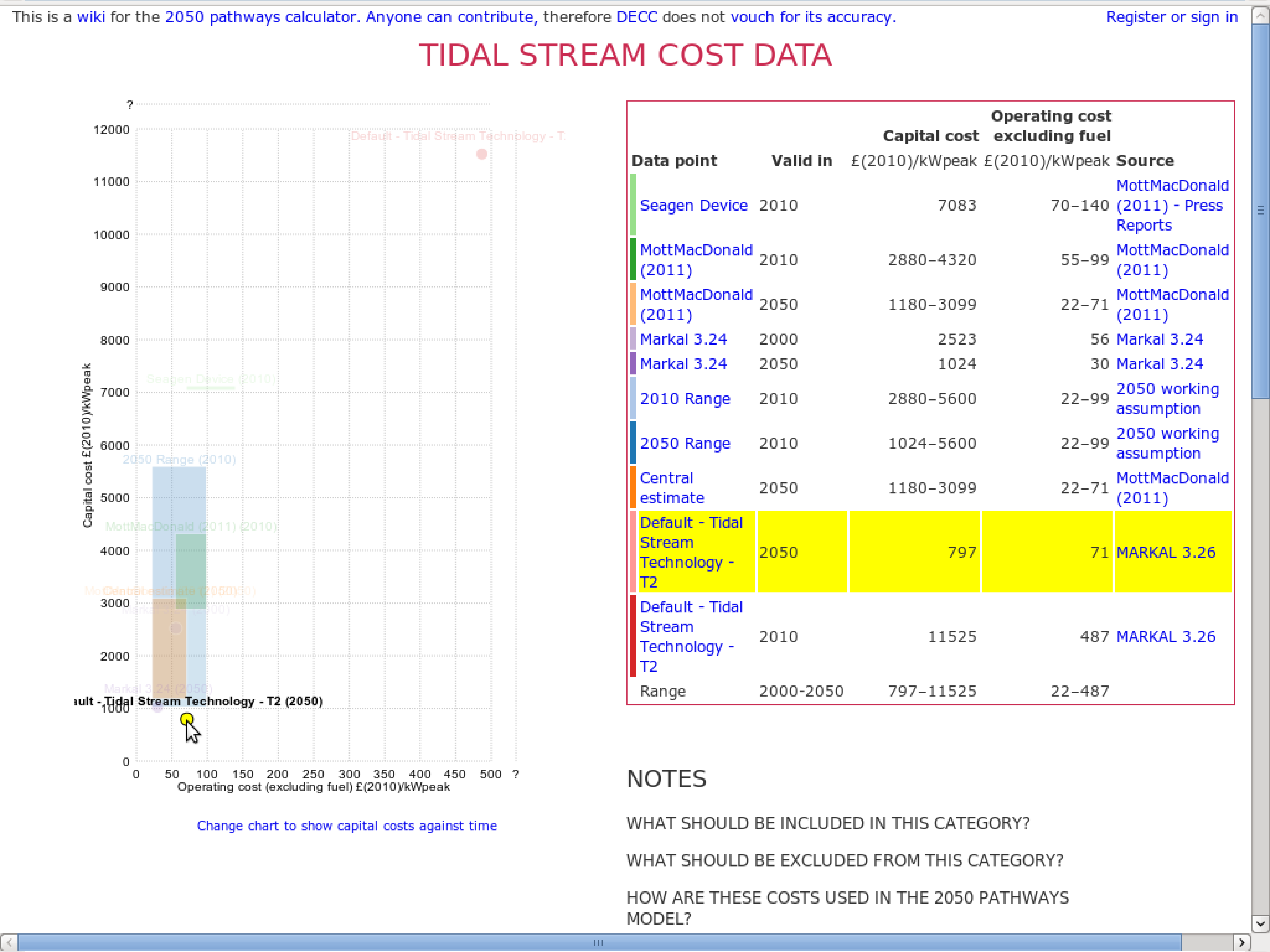
Data point	Valid in	Capital cost £(2010)/kWpeak	Operating cost excluding fuel £(2010)/kWpeak	Source
Seagen Device	2010	7083	70–140	MottMacDonald (2011) - Press Reports
MottMacDonald (2011)	2010	2880–4320	55–99	MottMacDonald (2011)
MottMacDonald (2011)	2050	1180–3099	22–71	MottMacDonald (2011)
Markal 3.24	2000	2523	56	Markal 3.24
Markal 3.24	2050	1024	30	Markal 3.24
2010 Range	2010	2880–5600	22–99	2050 working assumption
2050 Range	2010	1024–5600	22–99	2050 working assumption
Central estimate	2050	1180–3099	22–71	MottMacDonald (2011)
Default - Tidal Stream Technology - T2	2050	797	71	MARKAL 3.26
Default - Tidal Stream Technology - T2	2010	11525	487	MARKAL 3.26
Range	2000-2050	797–11525	22–487	

NOTES

WHAT SHOULD BE INCLUDED IN THIS CATEGORY?

WHAT SHOULD BE EXCLUDED FROM THIS CATEGORY?

HOW ARE THESE COSTS USED IN THE 2050 PATHWAYS MODEL?



This is a wiki for the 2050 pathways calculator. Anyone can contribute, therefore DECC does not vouch for its accuracy.

Register or sign in

TIDAL STREAM COST DATA

Change chart to show capital costs against time

Data point	Valid in	Capital cost £(2010)/kWpeak	Operating cost excluding fuel £(2010)/kWpeak	Source
Seagen Device	2010	7083	70–140	MottMacDonald (2011) - Press Reports
MottMacDonald (2011)	2010	2880–4320	55–99	MottMacDonald (2011)
MottMacDonald (2011)	2050	1180–3099	22–71	MottMacDonald (2011)
Markal 3.24	2000	2523	56	Markal 3.24
Markal 3.24	2050	1024	30	Markal 3.24
2010 Range	2010	2880–5600	22–99	2050 working assumption
2050 Range	2010	1024–5600	22–99	2050 working assumption
Central estimate	2050	1180–3099	22–71	MottMacDonald (2011)
Default - Tidal Stream Technology - T2	2050	797	71	MARKAL 3.26
Default - Tidal Stream Technology - T2	2010	11525	487	MARKAL 3.26
Range	2000-2050	797–11525	22–487	

NOTES

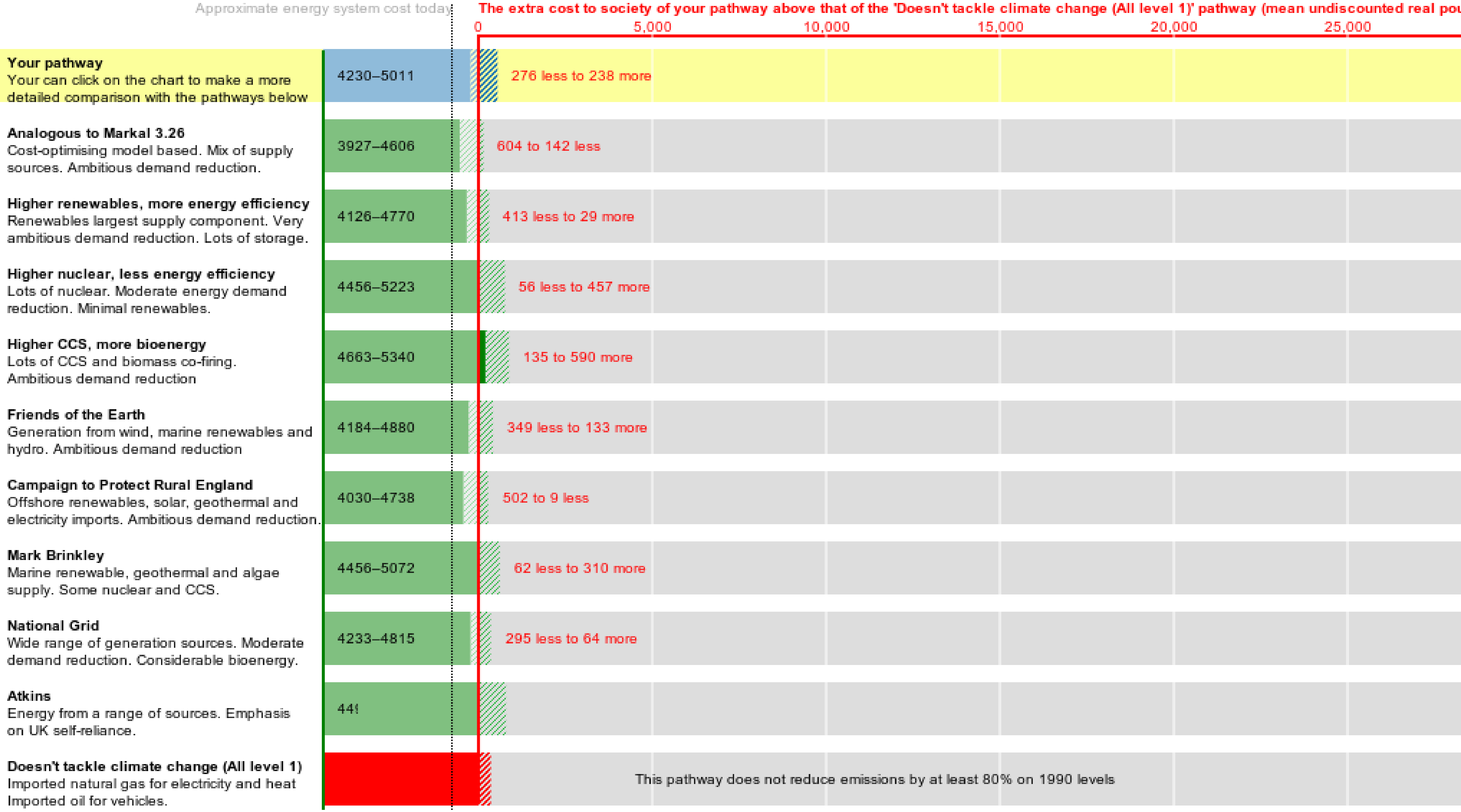
WHAT SHOULD BE INCLUDED IN THIS CATEGORY?

WHAT SHOULD BE EXCLUDED FROM THIS CATEGORY?

HOW ARE THESE COSTS USED IN THE 2050 PATHWAYS MODEL?

NB Some costs not on default values

The cost to society of your pathway. This is not your energy bill. For comparison, UK average GDP 2010-2050 is fore
person.

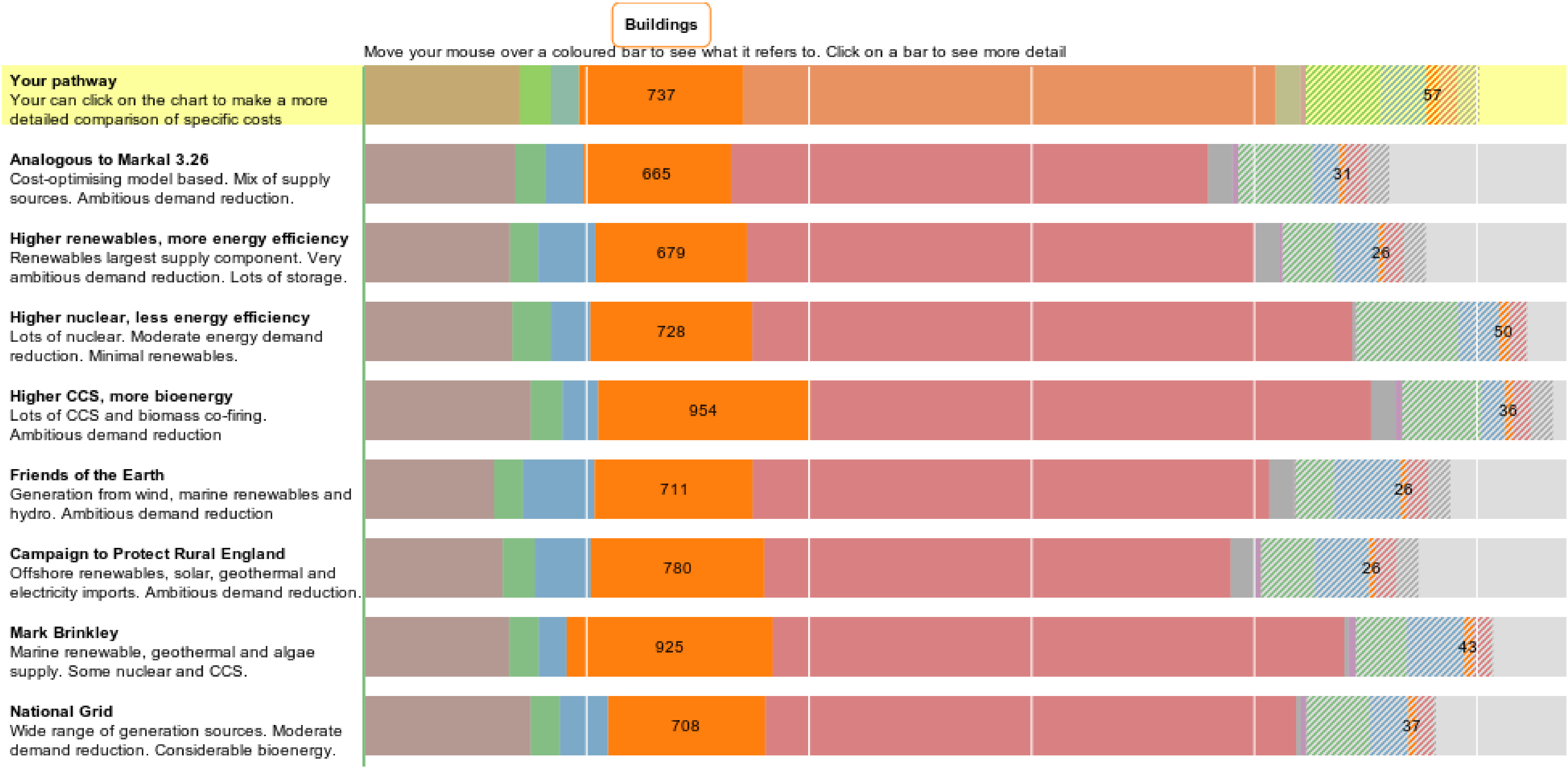


Your pathway Your can click on the chart to make a more detailed comparison with the pathways below	4230–5011	276 less to 238 more
Analogous to Markal 3.26 Cost-optimising model based. Mix of supply sources. Ambitious demand reduction.	3927–4606	604 to 142 less
Higher renewables, more energy efficiency Renewables largest supply component. Very ambitious demand reduction. Lots of storage.	4126–4770	413 less to 29 more
Higher nuclear, less energy efficiency Lots of nuclear. Moderate energy demand reduction. Minimal renewables.	4456–5223	56 less to 457 more
Higher CCS, more bioenergy Lots of CCS and biomass co-firing. Ambitious demand reduction	4663–5340	135 to 590 more
Friends of the Earth Generation from wind, marine renewables and hydro. Ambitious demand reduction	4184–4880	349 less to 133 more
Campaign to Protect Rural England Offshore renewables, solar, geothermal and electricity imports. Ambitious demand reduction.	4030–4738	502 to 9 less
Mark Brinkley Marine renewable, geothermal and algae supply. Some nuclear and CCS.	4456–5072	62 less to 310 more
National Grid Wide range of generation sources. Moderate demand reduction. Considerable bioenergy.	4233–4815	295 less to 64 more
Atkins Energy from a range of sources. Emphasis on UK self-reliance.	44	
Doesn't tackle climate change (All level 1) Imported natural gas for electricity and heat Imported oil for vehicles.		This pathway does not reduce emissions by at least 80% on 1990 levels

es

The cost to society of your pathway. This is not your energy bill. For comparison, UK average GDP 2010-2050 is forecast to be roughly £35000 per person.

The cost of your pathway, compared with other pathways. This is not your energy bill.



Move your mouse over a coloured bar to see what it refers to. Click on a bar to see more detail

Your pathway
Your can click on the chart to make a more detailed comparison of specific costs

Analogous to Markal 3.26
Cost-optimising model based. Mix of supply sources. Ambitious demand reduction.

Higher renewables, more energy efficiency
Renewables largest supply component. Very ambitious demand reduction. Lots of storage.

Higher nuclear, less energy efficiency
Lots of nuclear. Moderate energy demand reduction. Minimal renewables.

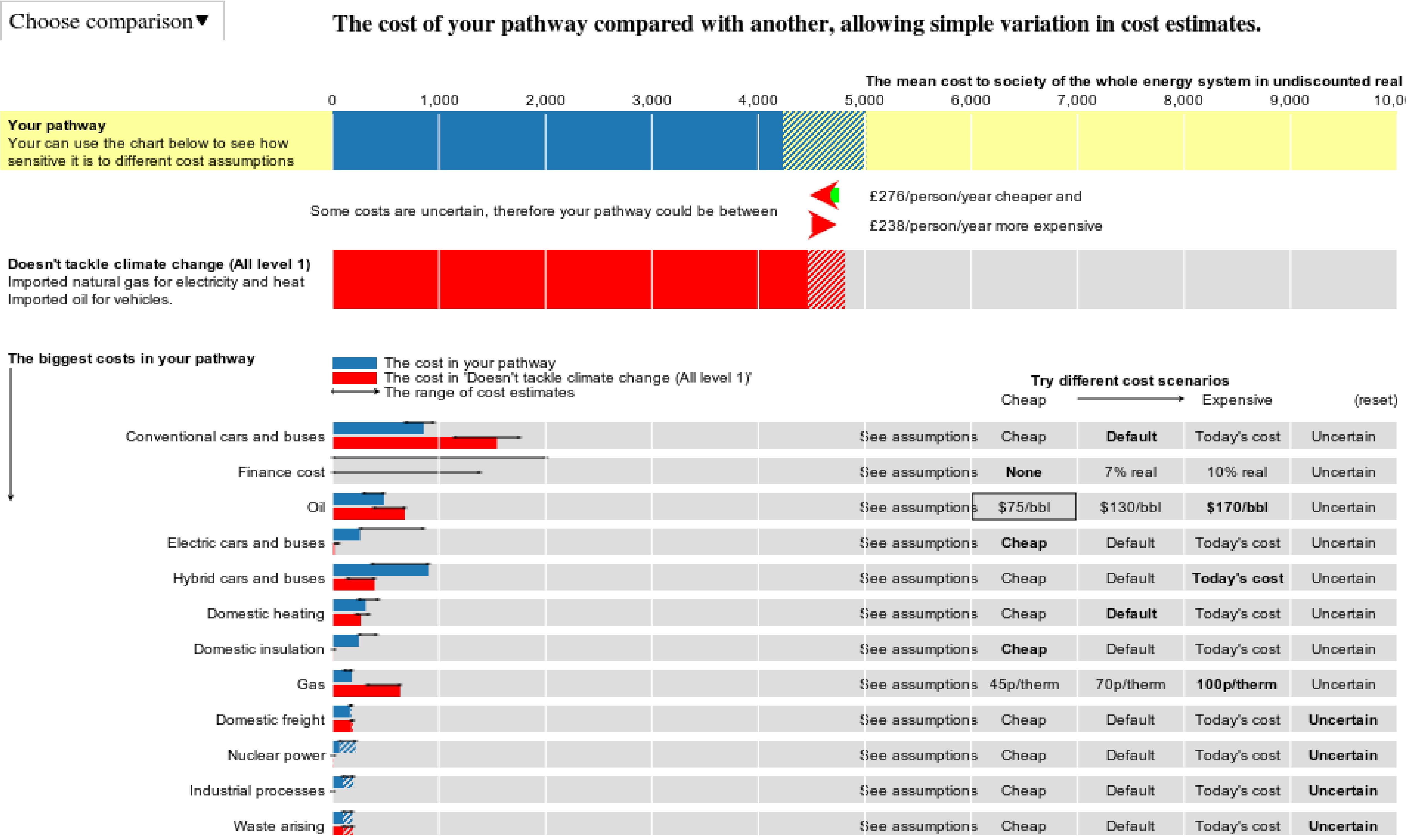
Higher CCS, more bioenergy
Lots of CCS and biomass co-firing. Ambitious demand reduction

Friends of the Earth
Generation from wind, marine renewables and hydro. Ambitious demand reduction

Campaign to Protect Rural England
Offshore renewables, solar, geothermal and electricity imports. Ambitious demand reduction.

Mark Brinkley
Marine renewable, geothermal and algae supply. Some nuclear and CCS.

National Grid
Wide range of generation sources. Moderate demand reduction. Considerable bioenergy.



Choose comparison ▾

The cost of your pathway compared with another, allowing simple variation in cost estimates.

Your pathway
Your can use the chart below to see how
sensitive it is to different cost assumptions

Some costs are uncertain, therefore your pathway could be between

£276/person/year cheaper and

£238/person/year more expensive

Doesn't tackle climate change (All level 1)
Imported natural gas for electricity and heat
Imported oil for vehicles.

The biggest costs in your pathway

🟦 The cost in your pathway
🟥 The cost in 'Doesn't tackle climate change (All level 1)'
⟷ The range of cost estimates

Try different cost scenarios

		Cheap	→	Expensive	(reset)
Conventional cars and buses	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Finance cost	See assumptions	**None**	7% real	10% real	Uncertain
Oil	See assumptions	$75/bbl	$130/bbl	**$170/bbl**	Uncertain
Electric cars and buses	See assumptions	**Cheap**	Default	Today's cost	Uncertain
Hybrid cars and buses	See assumptions	Cheap	Default	**Today's cost**	Uncertain
Domestic heating	See assumptions	Cheap	**Default**	Today's cost	Uncertain
Domestic insulation	See assumptions	**Cheap**	Default	Today's cost	Uncertain
Gas	See assumptions	45p/therm	70p/therm	**100p/therm**	Uncertain
Domestic freight	See assumptions	Cheap	Default	Today's cost	**Uncertain**
Nuclear power	See assumptions	Cheap	Default	Today's cost	**Uncertain**
Industrial processes	See assumptions	Cheap	Default	Today's cost	**Uncertain**
Waste arising	See assumptions	Cheap	Default	Today's cost	**Uncertain**

The Carbon Plan:
Delivering our low carbon future

December 2011

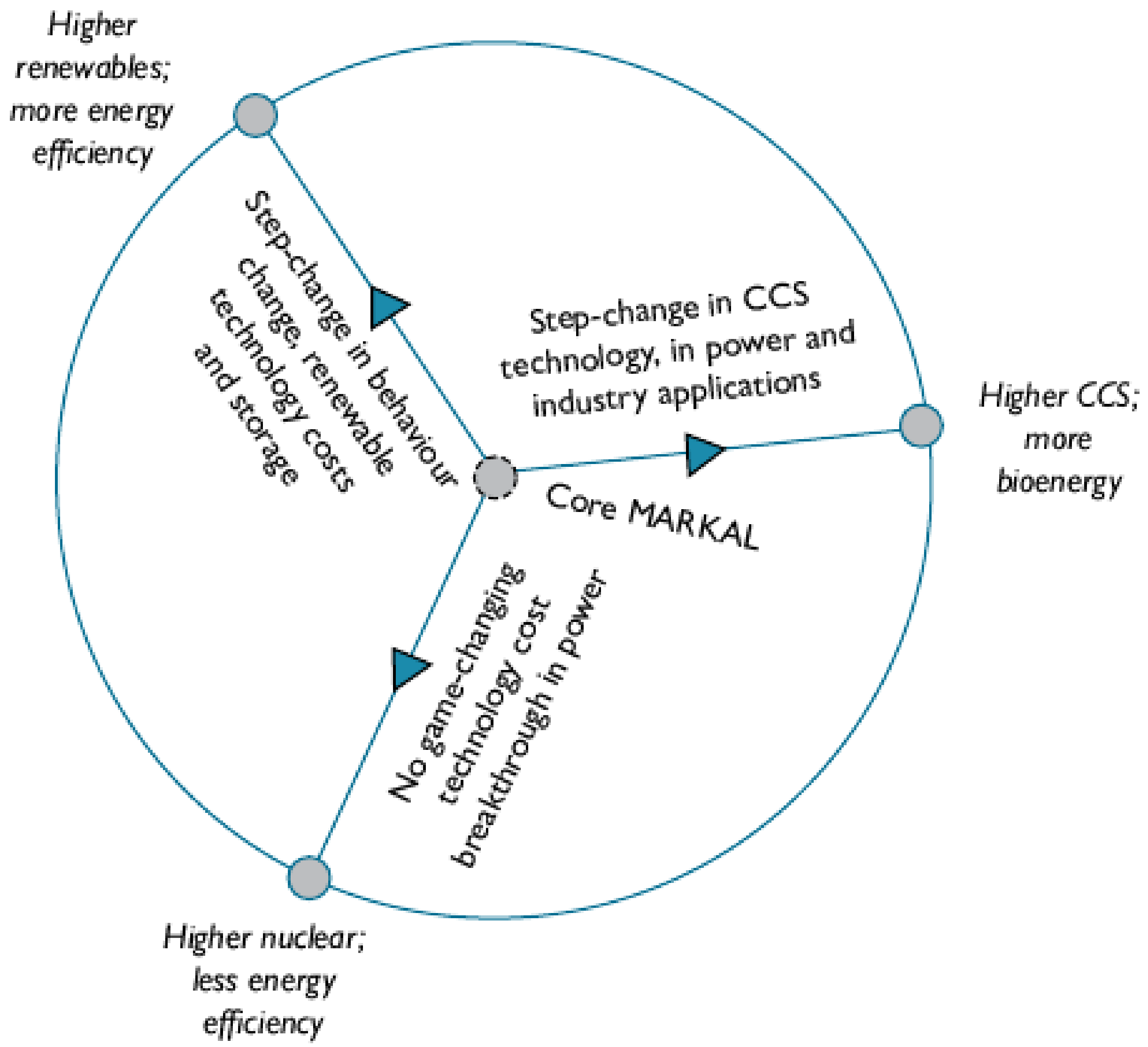
HM Government

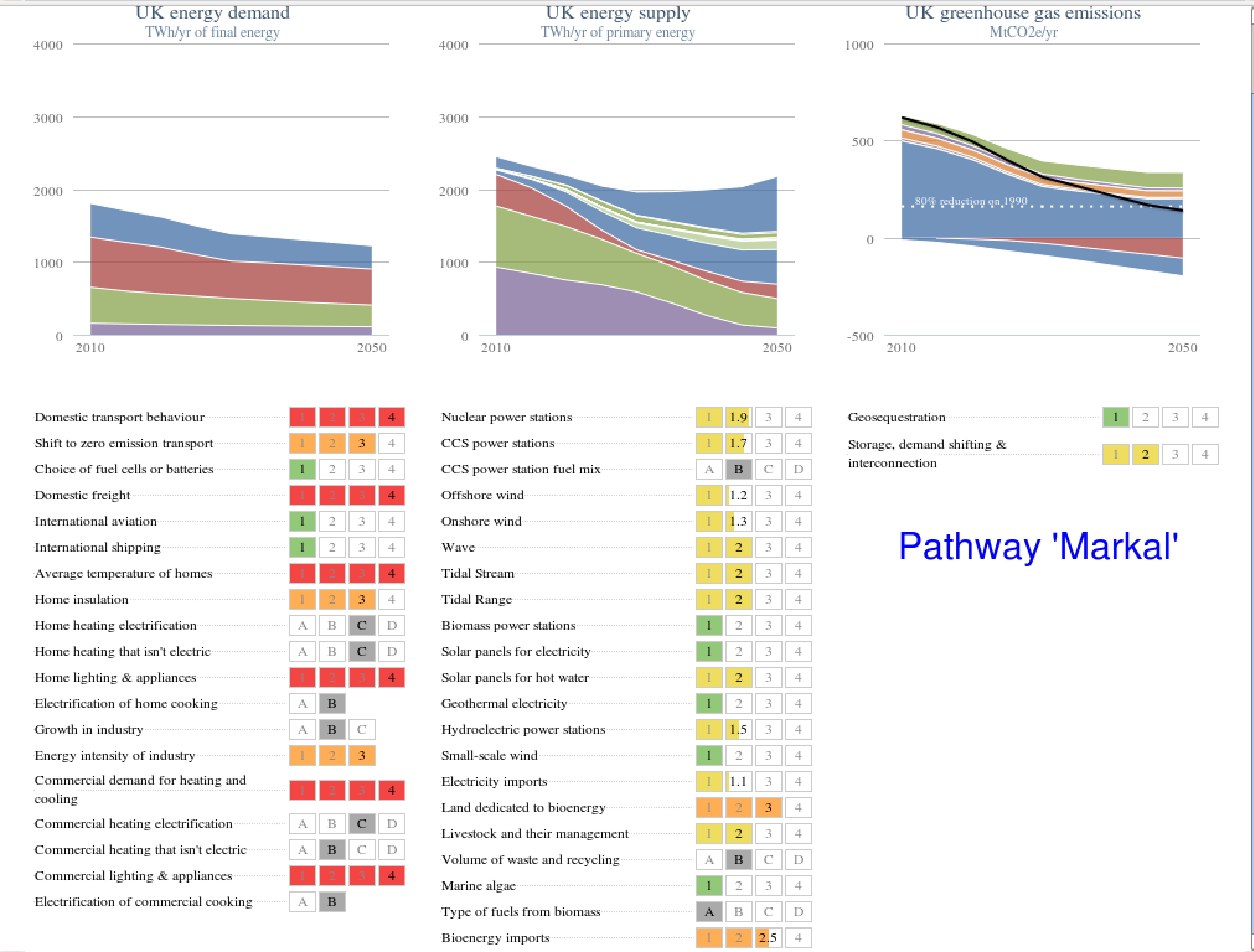
Domestic transport behaviour	1	2	3	**4**
Shift to zero emission transport	1	2	**3**	4
Choice of fuel cells or batteries	**1**	2	3	4
Domestic freight	1	2	3	**4**
International aviation	**1**	2	3	4
International shipping	**1**	2	3	4
Average temperature of homes	1	2	3	**4**
Home insulation	1	2	**3**	4
Home heating electrification	A	B	**C**	D
Home heating that isn't electric	A	B	**C**	D
Home lighting & appliances	1	2	3	**4**
Electrification of home cooking	A	**B**		
Growth in industry	A	**B**	C	
Energy intensity of industry	1	2	**3**	
Commercial demand for heating and cooling	1	2	3	**4**
Commercial heating electrification	A	B	**C**	D
Commercial heating that isn't electric	A	**B**	C	D
Commercial lighting & appliances	1	2	3	**4**

Nuclear power stations	1	**1.9**	3	4
CCS power stations	1	**1.7**	3	4
CCS power station fuel mix	A	**B**	C	D
Offshore wind	1	**1.2**	3	4
Onshore wind	1	**1.3**	3	4
Wave	1	**2**	3	4
Tidal Stream	1	**2**	3	4
Tidal Range	1	**2**	3	4
Biomass power stations	**1**	2	3	4
Solar panels for electricity	**1**	2	3	4
Solar panels for hot water	1	**2**	3	4
Geothermal electricity	**1**	2	3	4
Hydroelectric power stations	1	**1.5**	3	4
Small-scale wind	**1**	2	3	4
Electricity imports	1	**1.1**	3	4
Land dedicated to bioenergy	1	2	**3**	4
Livestock and their management	1	**2**	3	4
Volume of waste and recycling	A	**B**	C	D

Geosequestration	**1**	2	3	4
Storage, demand shifting & interconnection	1	**2**	3	4

2050 futures



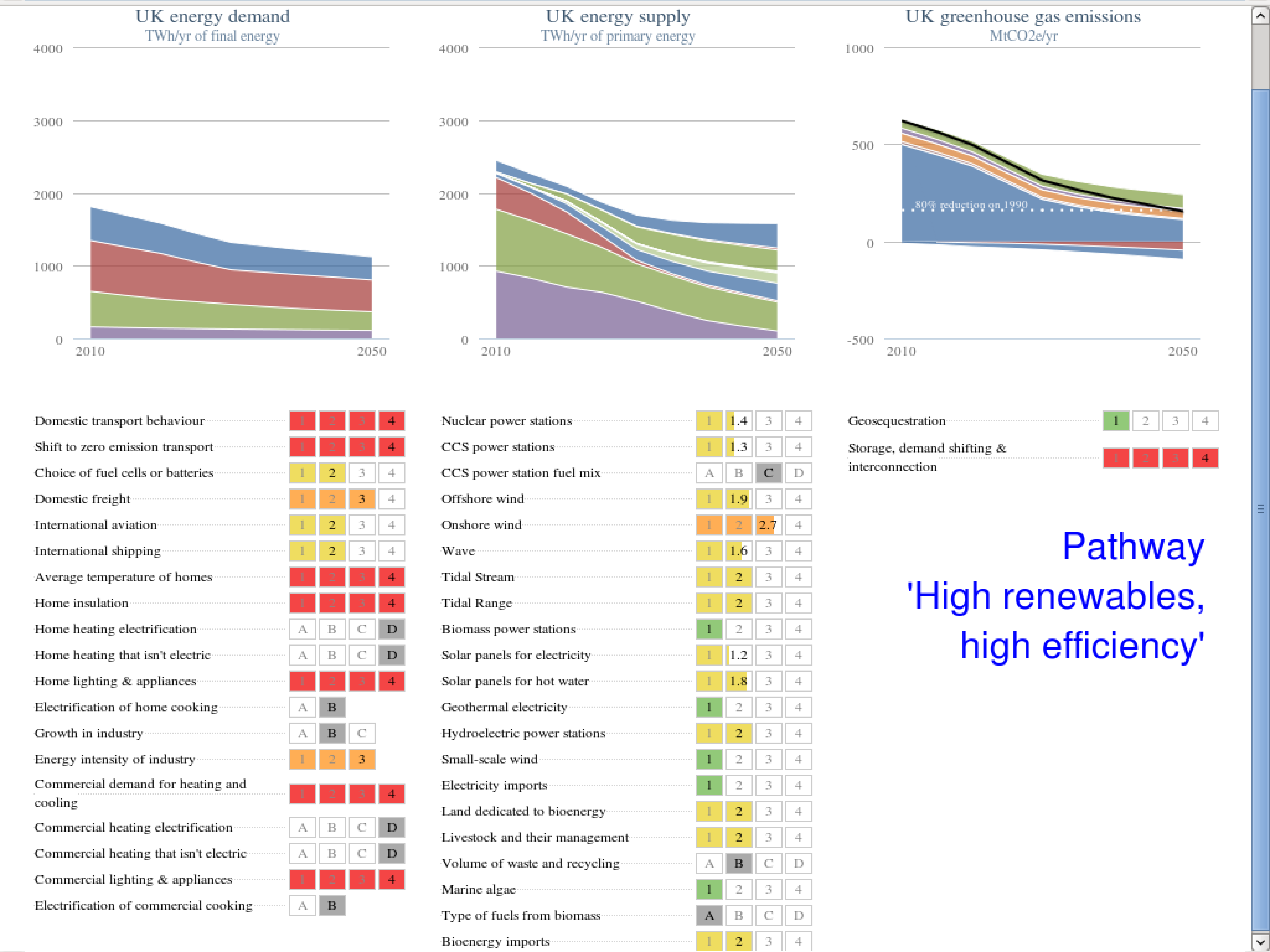


Domestic transport behaviour	1	2	3	**4**
Shift to zero emission transport	1	2	**3**	4
Choice of fuel cells or batteries	**1**	2	3	4
Domestic freight	1	2	3	**4**
International aviation	**1**	2	3	4
International shipping	**1**	2	3	4
Average temperature of homes	1	2	3	**4**
Home insulation	1	2	**3**	4
Home heating electrification	A	B	**C**	D
Home heating that isn't electric	A	B	**C**	D
Home lighting & appliances	1	2	3	**4**
Electrification of home cooking	A	**B**		
Growth in industry	A	**B**	C	
Energy intensity of industry	1	2	**3**	
Commercial demand for heating and cooling	1	2	3	**4**
Commercial heating electrification	A	B	**C**	D
Commercial heating that isn't electric	A	**B**	C	D
Commercial lighting & appliances	1	2	3	**4**
Electrification of commercial cooking	A	**B**		

Nuclear power stations	1	**1.9**	3	4
CCS power stations	1	**1.7**	3	4
CCS power station fuel mix	A	**B**	C	D
Offshore wind	1	**1.2**	3	4
Onshore wind	1	**1.3**	3	4
Wave	1	**2**	3	4
Tidal Stream	1	**2**	3	4
Tidal Range	1	**2**	3	4
Biomass power stations	**1**	2	3	4
Solar panels for electricity	**1**	2	3	4
Solar panels for hot water	1	**2**	3	4
Geothermal electricity	**1**	2	3	4
Hydroelectric power stations	1	**1.5**	3	4
Small-scale wind	**1**	2	3	4
Electricity imports	1	**1.1**	3	4
Land dedicated to bioenergy	1	2	**3**	4
Livestock and their management	1	**2**	3	4
Volume of waste and recycling	A	**B**	C	D
Marine algae	**1**	2	3	4
Type of fuels from biomass	**A**	B	C	D
Bioenergy imports	1	2	**2.5**	4

Geosequestration	**1**	2	3	4
Storage, demand shifting & interconnection	1	**2**	3	4

Pathway 'Markal'

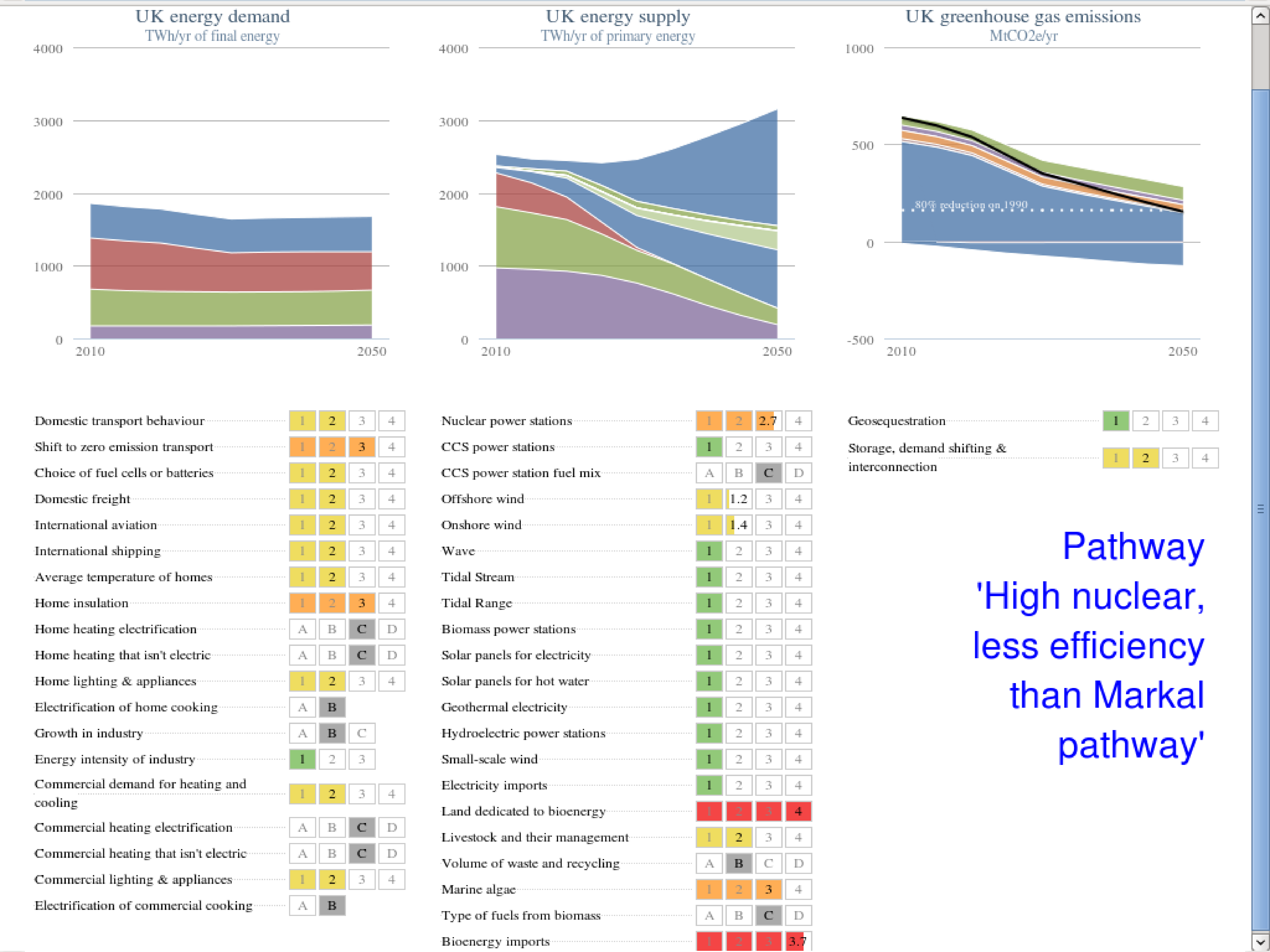


Domestic transport behaviour	1	2	3	**4**
Shift to zero emission transport	1	2	3	**4**
Choice of fuel cells or batteries	1	**2**	3	4
Domestic freight	1	2	**3**	4
International aviation	1	**2**	3	4
International shipping	1	**2**	3	4
Average temperature of homes	1	2	3	**4**
Home insulation	1	2	3	**4**
Home heating electrification	A	B	C	**D**
Home heating that isn't electric	A	B	C	**D**
Home lighting & appliances	1	2	3	**4**
Electrification of home cooking	A	**B**		
Growth in industry	A	**B**	C	
Energy intensity of industry	1	2	**3**	
Commercial demand for heating and cooling	1	2	3	**4**
Commercial heating electrification	A	B	C	**D**
Commercial heating that isn't electric	A	B	C	**D**
Commercial lighting & appliances	1	2	3	**4**
Electrification of commercial cooking	A	**B**		

Nuclear power stations	1	**1.4**	3	4
CCS power stations	1	**1.3**	3	4
CCS power station fuel mix	A	B	**C**	D
Offshore wind	1	**1.9**	3	4
Onshore wind	1	2	**2.7**	4
Wave	1	**1.6**	3	4
Tidal Stream	1	**2**	3	4
Tidal Range	1	**2**	3	4
Biomass power stations	**1**	2	3	4
Solar panels for electricity	1	**1.2**	3	4
Solar panels for hot water	1	**1.8**	3	4
Geothermal electricity	**1**	2	3	4
Hydroelectric power stations	1	**2**	3	4
Small-scale wind	**1**	2	3	4
Electricity imports	**1**	2	3	4
Land dedicated to bioenergy	1	**2**	3	4
Livestock and their management	1	**2**	3	4
Volume of waste and recycling	A	**B**	C	D
Marine algae	**1**	2	3	4
Type of fuels from biomass	**A**	B	C	D
Bioenergy imports	1	**2**	3	4

Geosequestration	**1**	2	3	4
Storage, demand shifting & interconnection	1	2	3	**4**

Pathway
'High renewables,
high efficiency'

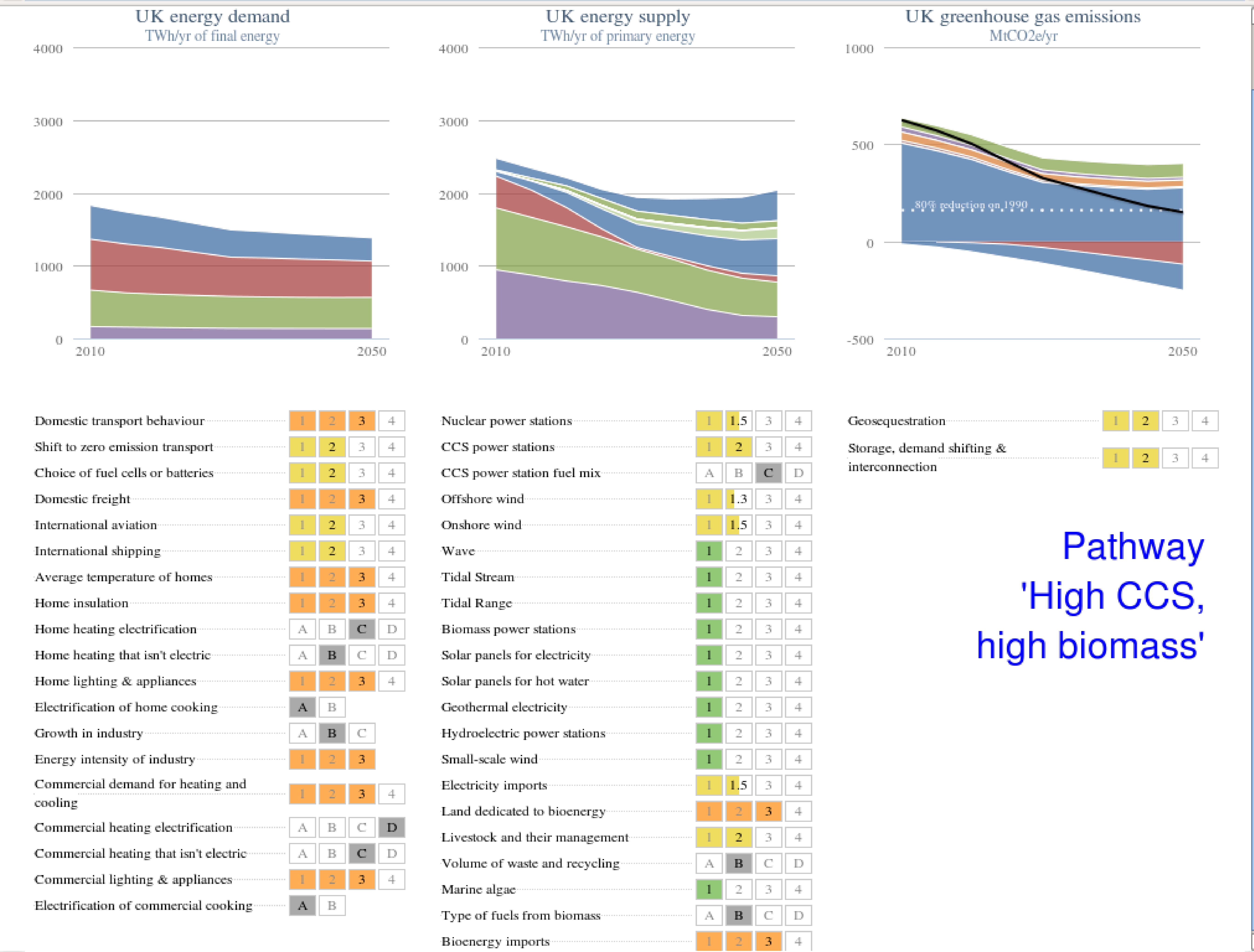


Domestic transport behaviour 1 **2** 3 4
Shift to zero emission transport 1 2 **3** 4
Choice of fuel cells or batteries 1 **2** 3 4
Domestic freight 1 **2** 3 4
International aviation 1 **2** 3 4
International shipping 1 **2** 3 4
Average temperature of homes 1 **2** 3 4
Home insulation 1 2 **3** 4
Home heating electrification A B **C** D
Home heating that isn't electric A B **C** D
Home lighting & appliances 1 **2** 3 4
Electrification of home cooking A **B**
Growth in industry A **B** C
Energy intensity of industry **1** 2 3
Commercial demand for heating and cooling 1 **2** 3 4
Commercial heating electrification A B **C** D
Commercial heating that isn't electric A B **C** D
Commercial lighting & appliances 1 **2** 3 4
Electrification of commercial cooking A **B**

Nuclear power stations 1 2 **2.7** 4
CCS power stations **1** 2 3 4
CCS power station fuel mix A B **C** D
Offshore wind 1 **1.2** 3 4
Onshore wind 1 **1.4** 3 4
Wave **1** 2 3 4
Tidal Stream **1** 2 3 4
Tidal Range **1** 2 3 4
Biomass power stations **1** 2 3 4
Solar panels for electricity **1** 2 3 4
Solar panels for hot water **1** 2 3 4
Geothermal electricity **1** 2 3 4
Hydroelectric power stations **1** 2 3 4
Small-scale wind **1** 2 3 4
Electricity imports **1** 2 3 4
Land dedicated to bioenergy 1 2 3 **4**
Livestock and their management 1 **2** 3 4
Volume of waste and recycling A **B** C D
Marine algae 1 2 **3** 4
Type of fuels from biomass A B **C** D
Bioenergy imports 1 2 3 **3.7**

Geosequestration **1** 2 3 4
Storage, demand shifting & interconnection 1 **2** 3 4

Pathway 'High nuclear, less efficiency than Markal pathway'



Domestic transport behaviour: 1 2 [✓ 3] 4
Shift to zero emission transport: 1 [✓ 2] 3 4
Choice of fuel cells or batteries: 1 [✓ 2] 3 4
Domestic freight: 1 2 [✓ 3] 4
International aviation: 1 [✓ 2] 3 4
International shipping: 1 [✓ 2] 3 4
Average temperature of homes: 1 2 [✓ 3] 4
Home insulation: 1 2 [✓ 3] 4
Home heating electrification: A B [✓ C] D
Home heating that isn't electric: A [✓ B] C D
Home lighting & appliances: 1 2 [✓ 3] 4
Electrification of home cooking: [✓ A] B
Growth in industry: A [✓ B] C
Energy intensity of industry: 1 2 [✓ 3]
Commercial demand for heating and cooling: 1 2 [✓ 3] 4
Commercial heating electrification: A B C [✓ D]
Commercial heating that isn't electric: A B [✓ C] D
Commercial lighting & appliances: 1 2 [✓ 3] 4
Electrification of commercial cooking: [✓ A] B

Nuclear power stations: 1 [✓ 1.5] 3 4
CCS power stations: 1 [✓ 2] 3 4
CCS power station fuel mix: A B [✓ C] D
Offshore wind: 1 [✓ 1.3] 3 4
Onshore wind: 1 [✓ 1.5] 3 4
Wave: [✓ 1] 2 3 4
Tidal Stream: [✓ 1] 2 3 4
Tidal Range: [✓ 1] 2 3 4
Biomass power stations: [✓ 1] 2 3 4
Solar panels for electricity: [✓ 1] 2 3 4
Solar panels for hot water: [✓ 1] 2 3 4
Geothermal electricity: [✓ 1] 2 3 4
Hydroelectric power stations: [✓ 1] 2 3 4
Small-scale wind: [✓ 1] 2 3 4
Electricity imports: 1 [✓ 1.5] 3 4
Land dedicated to bioenergy: 1 2 [✓ 3] 4
Livestock and their management: 1 [✓ 2] 3 4
Volume of waste and recycling: A [✓ B] C D
Marine algae: [✓ 1] 2 3 4
Type of fuels from biomass: A [✓ B] C D
Bioenergy imports: 1 2 [✓ 3] 4

Geosequestration: 1 [✓ 2] 3 4
Storage, demand shifting & interconnection: 1 [✓ 2] 3 4

Pathway 'High CCS, high biomass'

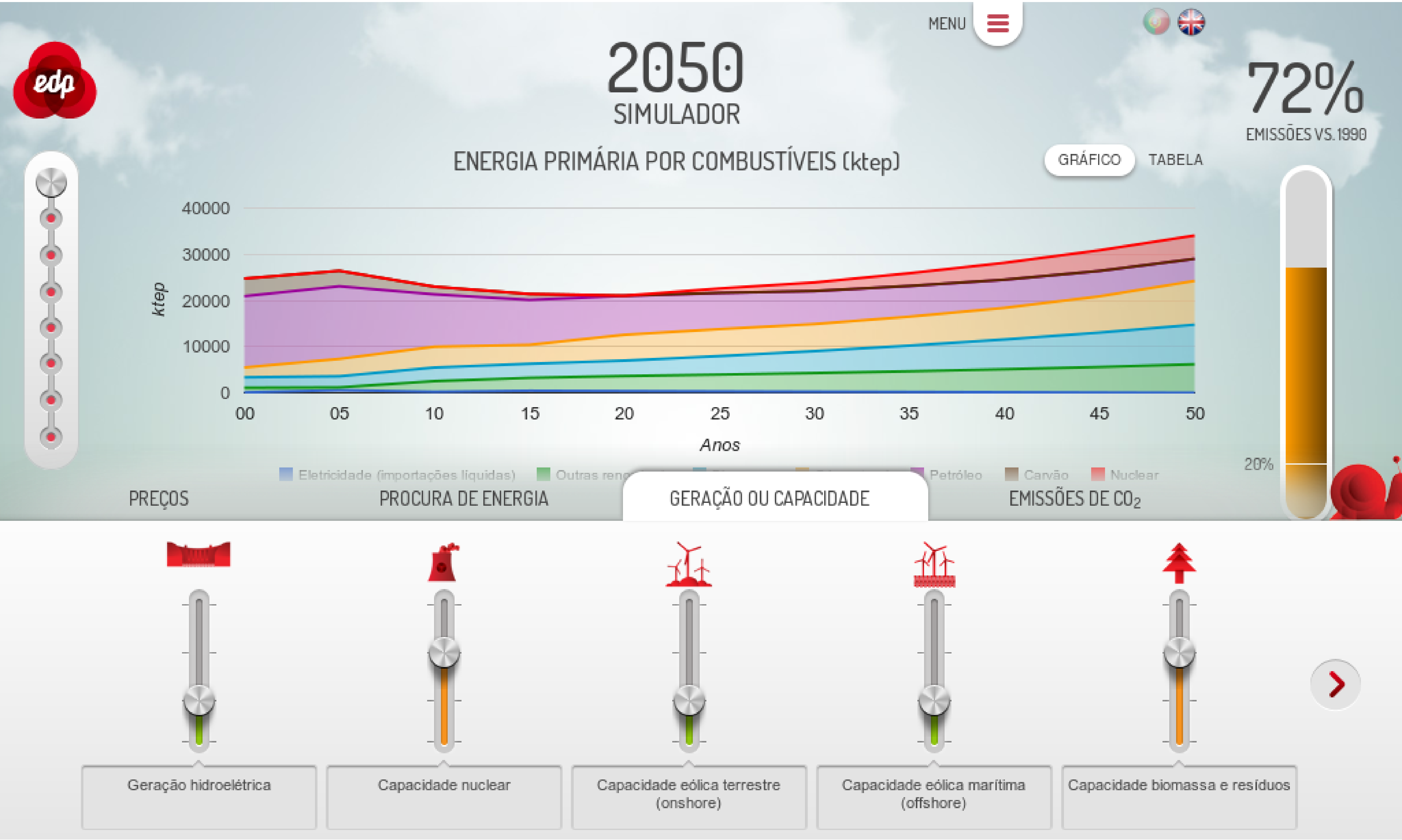
Impacts

- Bioenergy strategy
- Nuclear strategy
- Electricity Market reform
- Heat strategy

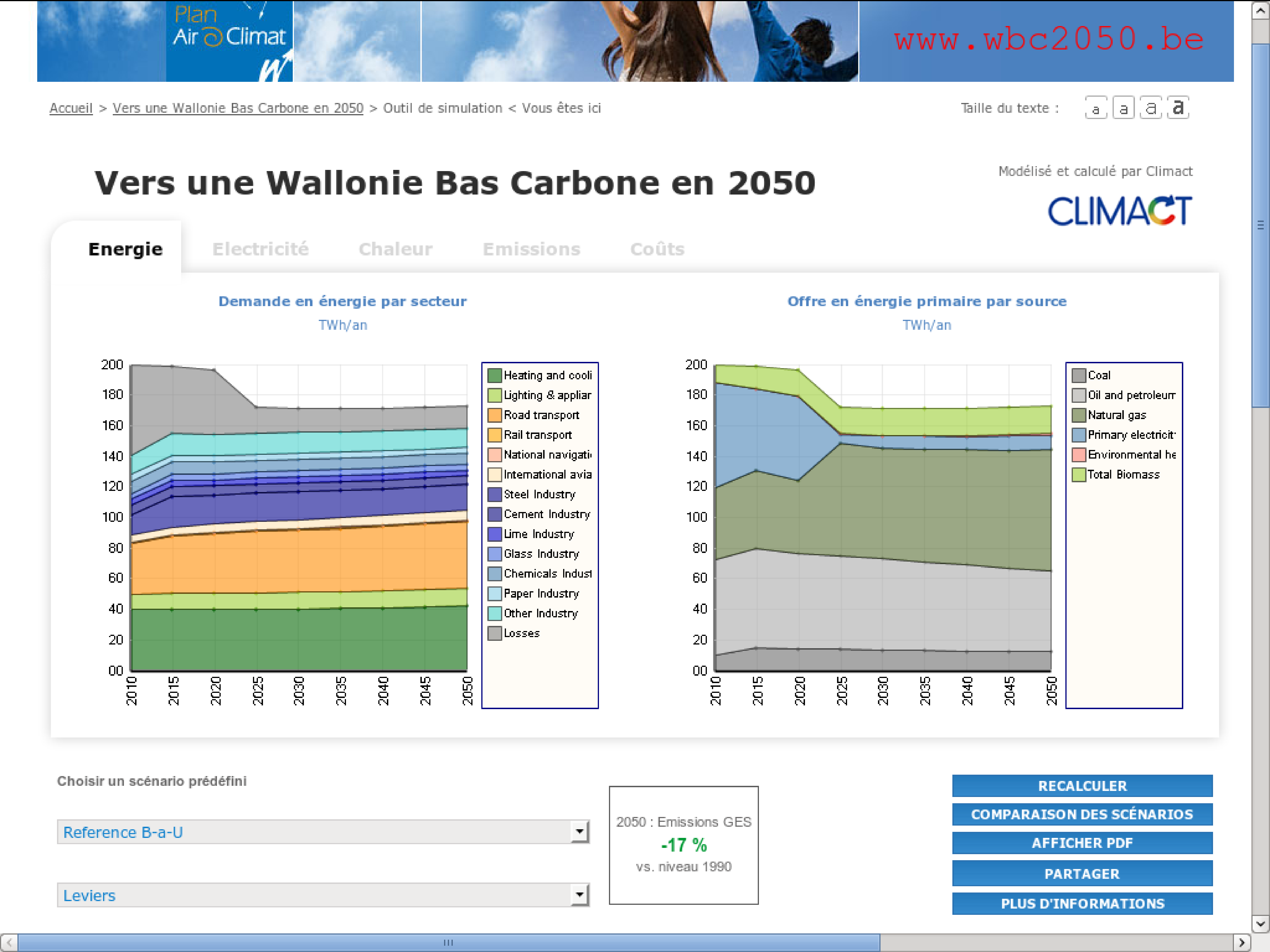
DEPARTMENT OF ENERGY & CLIMATE CHANGE

The Future of Heating:
A strategic framework for
low carbon heat in the UK

March 2012


MENU
2050
SIMULADOR
72%
EMISSÕES VS. 1990
ENERGIA PRIMÁRIA POR COMBUSTÍVEIS (ktep)
GRÁFICO
TABELA
40000
30000
20000
10000
0
ktep
00
05
10
15
20
25
30
35
40
45
50
Anos
Eletricidade (importações líquidas)
Outras reno
Petróleo
Carvão
Nuclear
20%
PREÇOS
PROCURA DE ENERGIA
GERAÇÃO OU CAPACIDADE
EMISSÕES DE CO2
Geração hidroelétrica
Capacidade nuclear
Capacidade eólica terrestre (onshore)
Capacidade eólica marítima (offshore)
Capacidade biomassa e resíduos

2050.edp.pt



Accueil > Vers une Wallonie Bas Carbone en 2050 > Outil de simulation < Vous êtes ici

Vers une Wallonie Bas Carbone en 2050

Modélisé et calculé par Climact

CLIMACT

Demande en énergie par secteur

TWh/an

Offre en énergie primaire par source

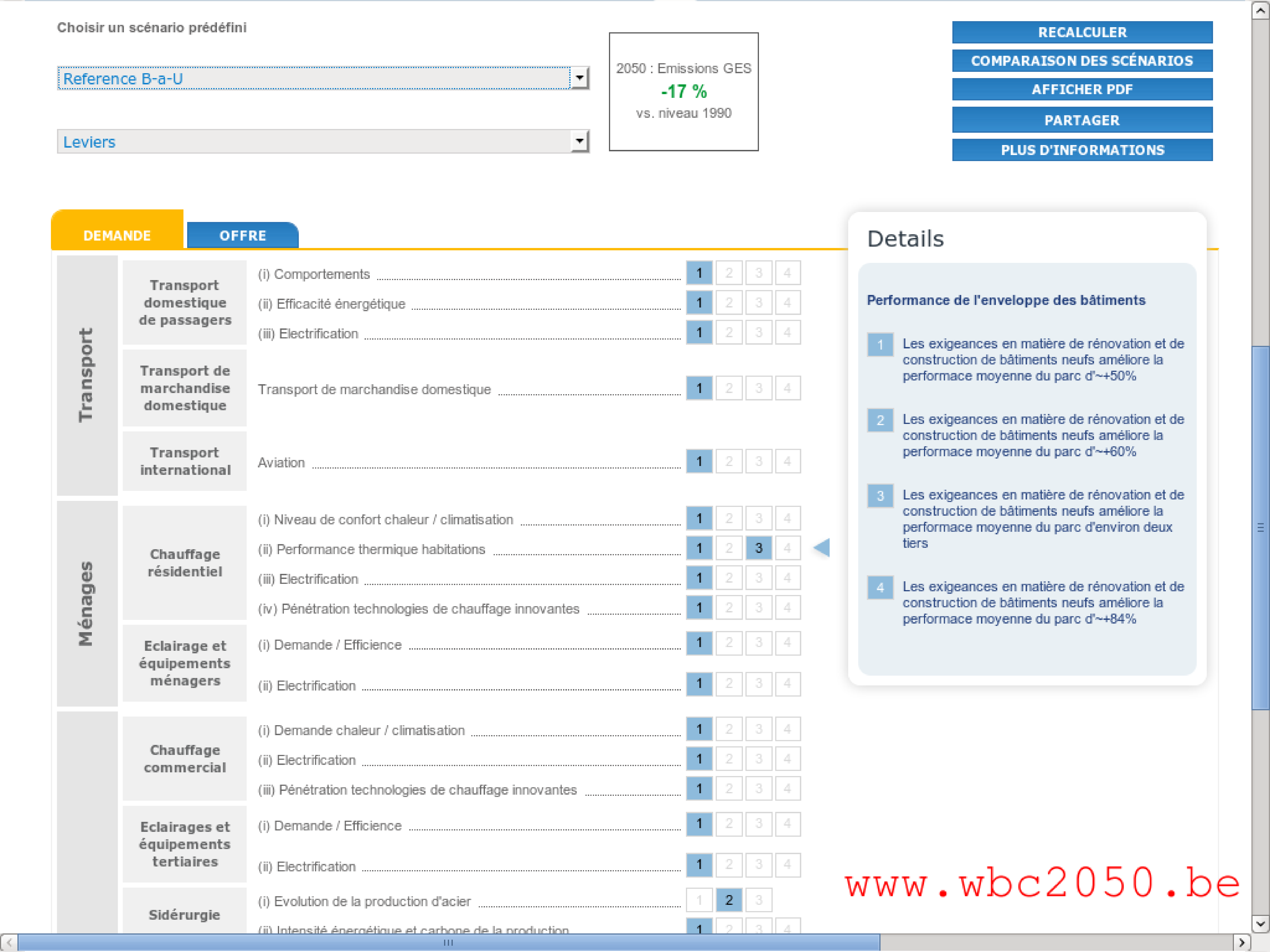
TWh/an

Choisir un scénario prédéfini

Reference B-a-U

Leviers

2050 : Emissions GES
-17 %
vs. niveau 1990



Choisir un scénario prédéfini

Reference B-a-U

Leviers

2050 : Emissions GES
-17 %
vs. niveau 1990

Transport	Transport domestique de passagers	(i) Comportements	[✓ 1] 2 3 4
		(ii) Efficacité énergétique	[✓ 1] 2 3 4
		(iii) Electrification	[✓ 1] 2 3 4
	Transport de marchandise domestique	Transport de marchandise domestique	[✓ 1] 2 3 4
	Transport international	Aviation	[✓ 1] 2 3 4
Ménages	Chauffage résidentiel	(i) Niveau de confort chaleur / climatisation	[✓ 1] 2 3 4
		(ii) Performance thermique habitations	1 2 [✓ 3] 4
		(iii) Electrification	[✓ 1] 2 3 4
		(iv) Pénétration technologies de chauffage innovantes	[✓ 1] 2 3 4
	Eclairage et équipements ménagers	(i) Demande / Efficience	[✓ 1] 2 3 4
		(ii) Electrification	[✓ 1] 2 3 4
	Chauffage commercial	(i) Demande chaleur / climatisation	[✓ 1] 2 3 4
		(ii) Electrification	[✓ 1] 2 3 4
		(iii) Pénétration technologies de chauffage innovantes	[✓ 1] 2 3 4
	Eclairages et équipements tertiaires	(i) Demande / Efficience	[✓ 1] 2 3 4
		(ii) Electrification	[✓ 1] 2 3 4
	Sidérurgie	(i) Evolution de la production d'acier	1 [✓ 2] 3
		(ii) Intensité énergétique et carbone de la production	[✓ 1] 2 3 4

Details

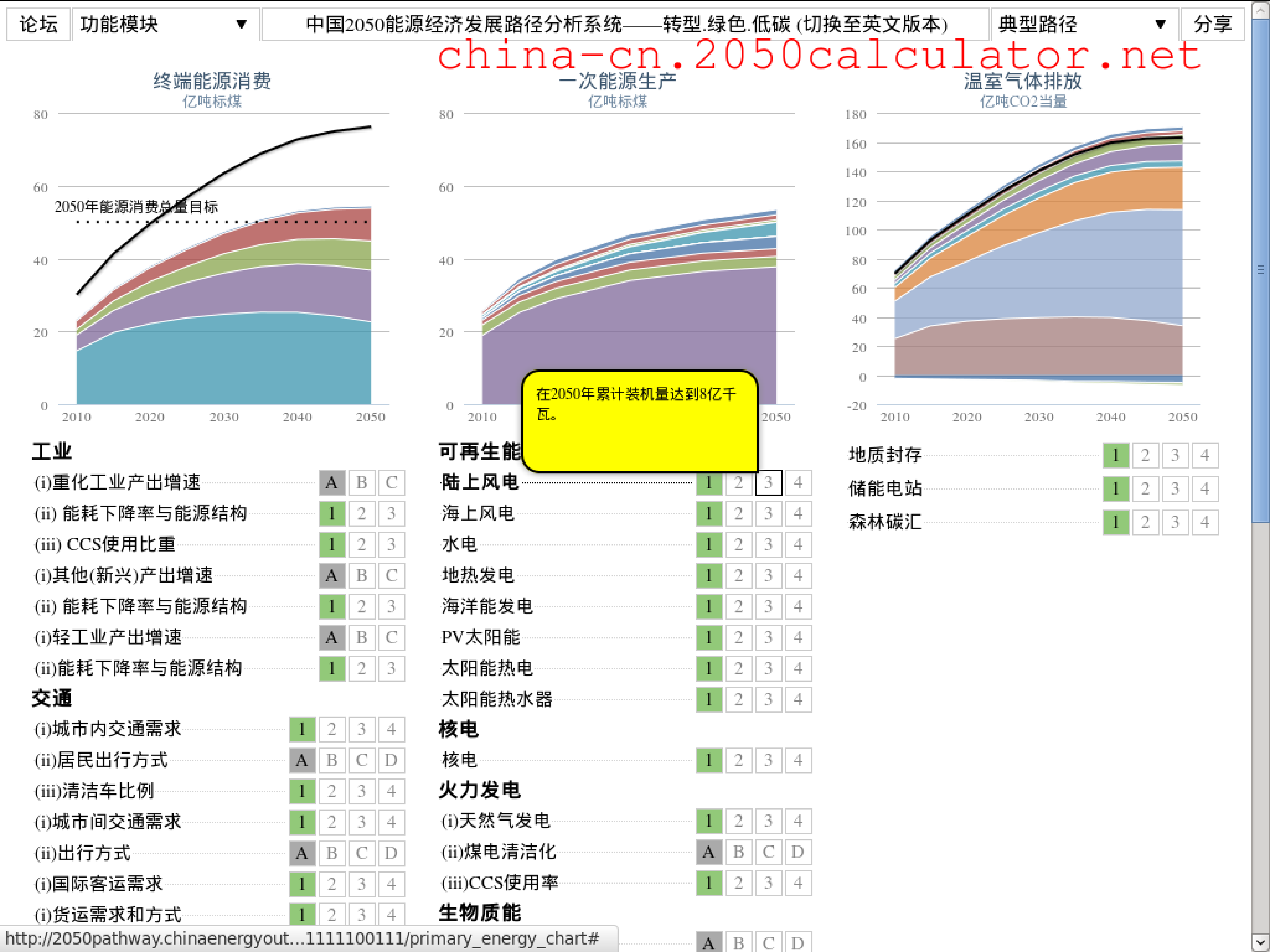
Performance de l'enveloppe des bâtiments

1 Les exigeances en matière de rénovation et de construction de bâtiments neufs améliore la performace moyenne du parc d'~+50%

2 Les exigeances en matière de rénovation et de construction de bâtiments neufs améliore la performace moyenne du parc d'~+60%

3 Les exigeances en matière de rénovation et de construction de bâtiments neufs améliore la performace moyenne du parc d'environ deux tiers

4 Les exigeances en matière de rénovation et de construction de bâtiments neufs améliore la performace moyenne du parc d'~+84%



中国2050能源经济发展路径分析系统——转型.绿色.低碳 (切换至英文版本)

china-cn.2050calculator.net

在2050年累计装机量达到8亿千瓦。

工业

(i)重化工业产出增速 [✓ A] B C

(ii) 能耗下降率与能源结构 [✓ 1] 2 3

(iii) CCS使用比重 [✓ 1] 2 3

(i)其他(新兴)产出增速 [✓ A] B C

(ii) 能耗下降率与能源结构 [✓ 1] 2 3

(i)轻工业产出增速 [✓ A] B C

(ii)能耗下降率与能源结构 [✓ 1] 2 3

交通

(i)城市内交通需求 [✓ 1] 2 3 4

(ii)居民出行方式 [✓ A] B C D

(iii)清洁车比例 [✓ 1] 2 3 4

(i)城市间交通需求 [✓ 1] 2 3 4

(ii)出行方式 [✓ A] B C D

(i)国际客运需求 [✓ 1] 2 3 4

(i)货运需求和方式 [✓ 1] 2 3 4

可再生能

陆上风电 [✓ 1] 2 3 4

海上风电 [✓ 1] 2 3 4

水电 [✓ 1] 2 3 4

地热发电 [✓ 1] 2 3 4

海洋能发电 [✓ 1] 2 3 4

PV太阳能 [✓ 1] 2 3 4

太阳能热电 [✓ 1] 2 3 4

太阳能热水器 [✓ 1] 2 3 4

核电

核电 [✓ 1] 2 3 4

火力发电

(i)天然气发电 [✓ 1] 2 3 4

(ii)煤电清洁化 [✓ A] B C D

(iii)CCS使用率 [✓ 1] 2 3 4

生物质能

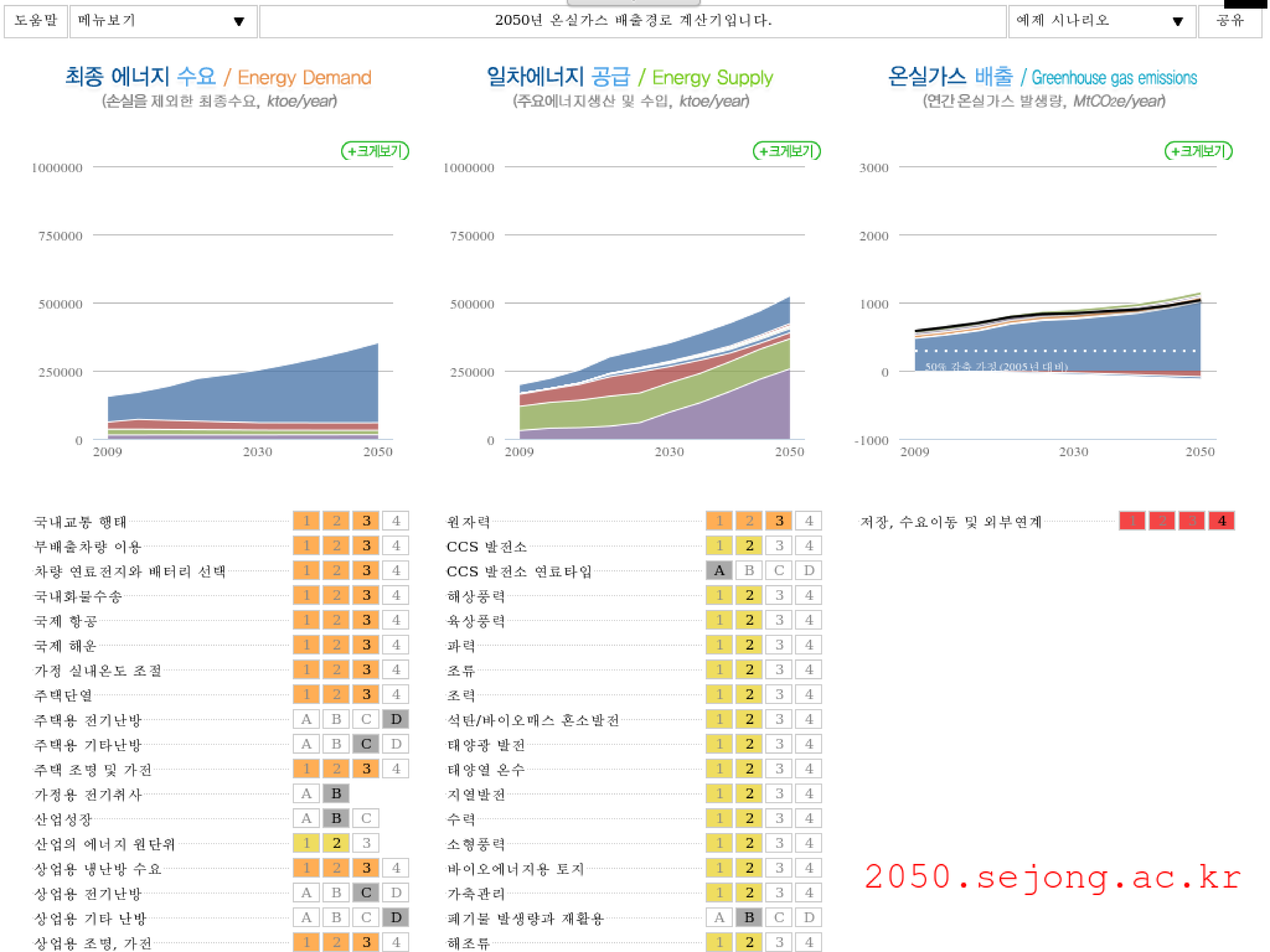
[✓ A] B C D

地质封存 [✓ 1] 2 3 4

储能电站 [✓ 1] 2 3 4

森林碳汇 [✓ 1] 2 3 4

http://2050pathway.chinaenergyout...1111100111/primary_energy_chart#



2050년 온실가스 배출경로 계산기입니다.

최종 에너지 수요 / Energy Demand
(손실을 제외한 최종수요, *ktoe/year*)

일차에너지 공급 / Energy Supply
(주요에너지생산 및 수입, *ktoe/year*)

온실가스 배출 / Greenhouse gas emissions
(연간온실가스 발생량, *MtCO₂e/year*)

국내교통 행태	1 2 [✓ 3] 4
부배출차량 이용	1 2 [✓ 3] 4
차량 연료전지와 배터리 선택	1 2 [✓ 3] 4
국내화물수송	1 2 [✓ 3] 4
국제 항공	1 2 [✓ 3] 4
국제 해운	1 2 [✓ 3] 4
가정 실내온도 조절	1 2 [✓ 3] 4
주택단열	1 2 [✓ 3] 4
주택용 전기난방	A B C [✓ D]
주택용 기타난방	A B [✓ C] D
주택 조명 및 가전	1 2 [✓ 3] 4
가정용 전기취사	A [✓ B]
산업성장	A [✓ B] C
산업의 에너지 원단위	1 [✓ 2] 3
상업용 냉난방 수요	1 2 [✓ 3] 4
상업용 전기난방	A B [✓ C] D
상업용 기타 난방	A B C [✓ D]
상업용 조명, 가전	1 2 [✓ 3] 4

원자력	1 2 [✓ 3] 4
CCS 발전소	1 [✓ 2] 3 4
CCS 발전소 연료타입	[✓ A] B C D
해상풍력	1 [✓ 2] 3 4
육상풍력	1 [✓ 2] 3 4
파력	1 [✓ 2] 3 4
조류	1 [✓ 2] 3 4
조력	1 [✓ 2] 3 4
석탄/바이오매스 혼소발전	1 [✓ 2] 3 4
태양광 발전	1 [✓ 2] 3 4
태양열 온수	1 [✓ 2] 3 4
지열발전	1 [✓ 2] 3 4
수력	1 [✓ 2] 3 4
소형풍력	1 [✓ 2] 3 4
바이오에너지용 토지	1 [✓ 2] 3 4
가축관리	1 [✓ 2] 3 4
폐기물 발생량과 재활용	A [✓ B] C D
해조류	1 [✓ 2] 3 4

저장, 수요이동 및 외부연계	1 2 3 [✓ 4]

2050.sejong.ac.kr

भारत ऊर्जा सुरक्षा परिदृश्य 2047

INDIA ENERGY SECURITY SCENARIOS 2047

TOWARDS ENERGY INDEPENDENCE

Design your own energy pathway for India till 2047

The India Energy Security Scenarios, 2047

The IESS, 2047 is housed in the Energy and Research Division of the Planning Commission; and has been developed as an energy scenario building tool. The guiding ambition of this is to develop energy pathways leading up to the year 2047, exploring a range of potential future energy scenarios for India, across energy supply sectors such as renewable energy, oil, gas, coal, and nuclear, and energy demand sectors such as transport, industry, agriculture, cooking, lighting and appliances, etc. The outcomes of this model also evaluate carbon dioxide emissions, and land-use implications for different energy scenarios.

Get the Downloadable Excel Model

Explore the Interactive Web Version

Quick Links

The IESS, 2047 enables the user to reflect on the implications of his chosen pathway on carbon dioxide emissions, as well as land-use and energy security

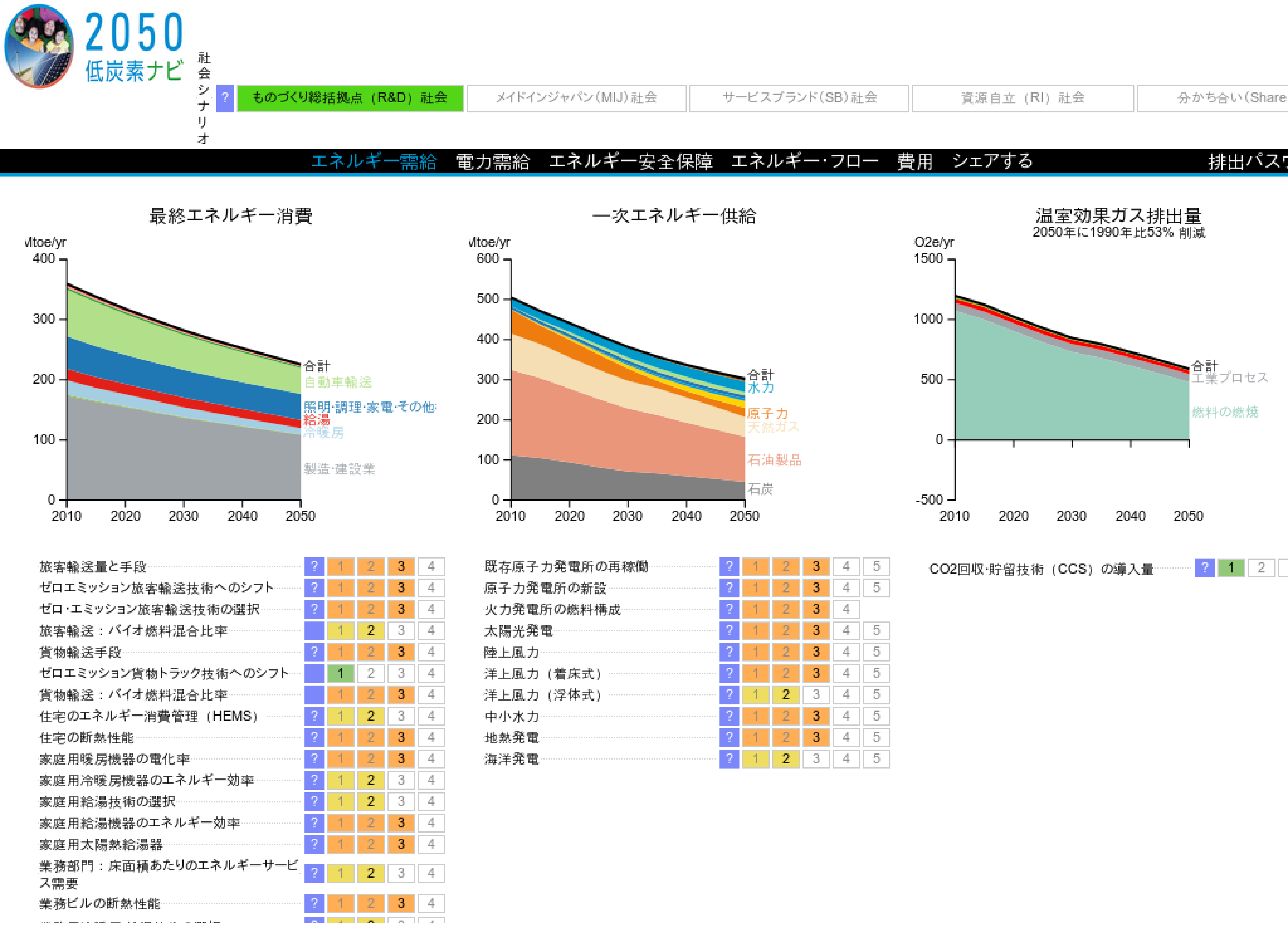
... Read more >>

Take a deeper look into the components of the IESS, 2047.

... Read more >>

The IESS, 2047 allows the user to pick from a variety of supply options in order to meet his/her chosen levels of demand.

... Read more >>



旅客輸送量と手段	?	1	2	**3**	4
ゼロエミッション旅客輸送技術へのシフト	?	1	2	**3**	4
ゼロ·エミッション旅客輸送技術の選択	?	1	2	**3**	4
旅客輸送：バイオ燃料混合比率		1	**2**	3	4
貨物輸送手段	?	1	2	**3**	4
ゼロエミッション貨物トラック技術へのシフト		**1**	2	3	4
貨物輸送：バイオ燃料混合比率		1	2	**3**	4
住宅のエネルギー消費管理（HEMS）	?	1	**2**	3	4
住宅の断熱性能	?	1	2	**3**	4
家庭用暖房機器の電化率	?	1	2	**3**	4
家庭用冷暖房機器のエネルギー効率	?	1	**2**	3	4
家庭用給湯技術の選択	?	1	**2**	3	4
家庭用給湯機器のエネルギー効率	?	1	2	**3**	4
家庭用太陽熱給湯器	?	1	2	**3**	4
業務部門：床面積あたりのエネルギーサービス需要	?	1	**2**	3	4
業務ビルの断熱性能	?	1	2	**3**	4

既存原子力発電所の再稼働	?	1	2	**3**	4	5
原子力発電所の新設	?	1	2	**3**	4	5
火力発電所の燃料構成	?	1	2	**3**	4	
太陽光発電	?	1	2	**3**	4	5
陸上風力	?	1	2	**3**	4	5
洋上風力（着床式）	?	1	2	**3**	4	5
洋上風力（浮体式）	?	1	**2**	3	4	5
中小水力	?	1	2	**3**	4	5
地熱発電	?	1	2	**3**	4	5
海洋発電	?	1	**2**	3	4	5

CO2回収·貯留技術（CCS）の導入量	?	**1**	2

Keep emissions below the line to maintain a 50% chance of meeting the UNFCCC 2°C target!

Choose an example pathway or create your own pathway by selecting effort level 1 to 4 for each lever.

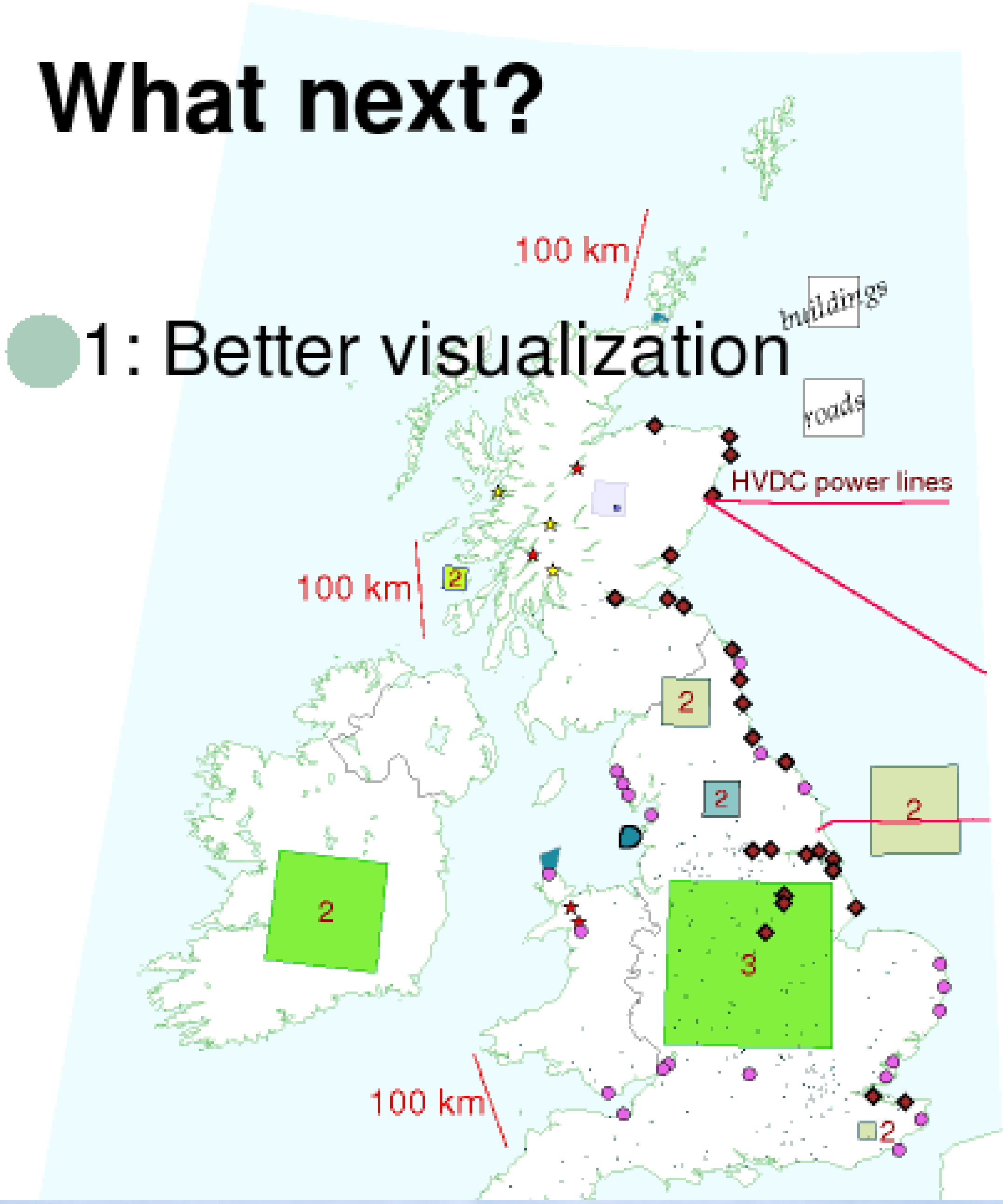
Selected pathway: IEA 6DS (approx.)

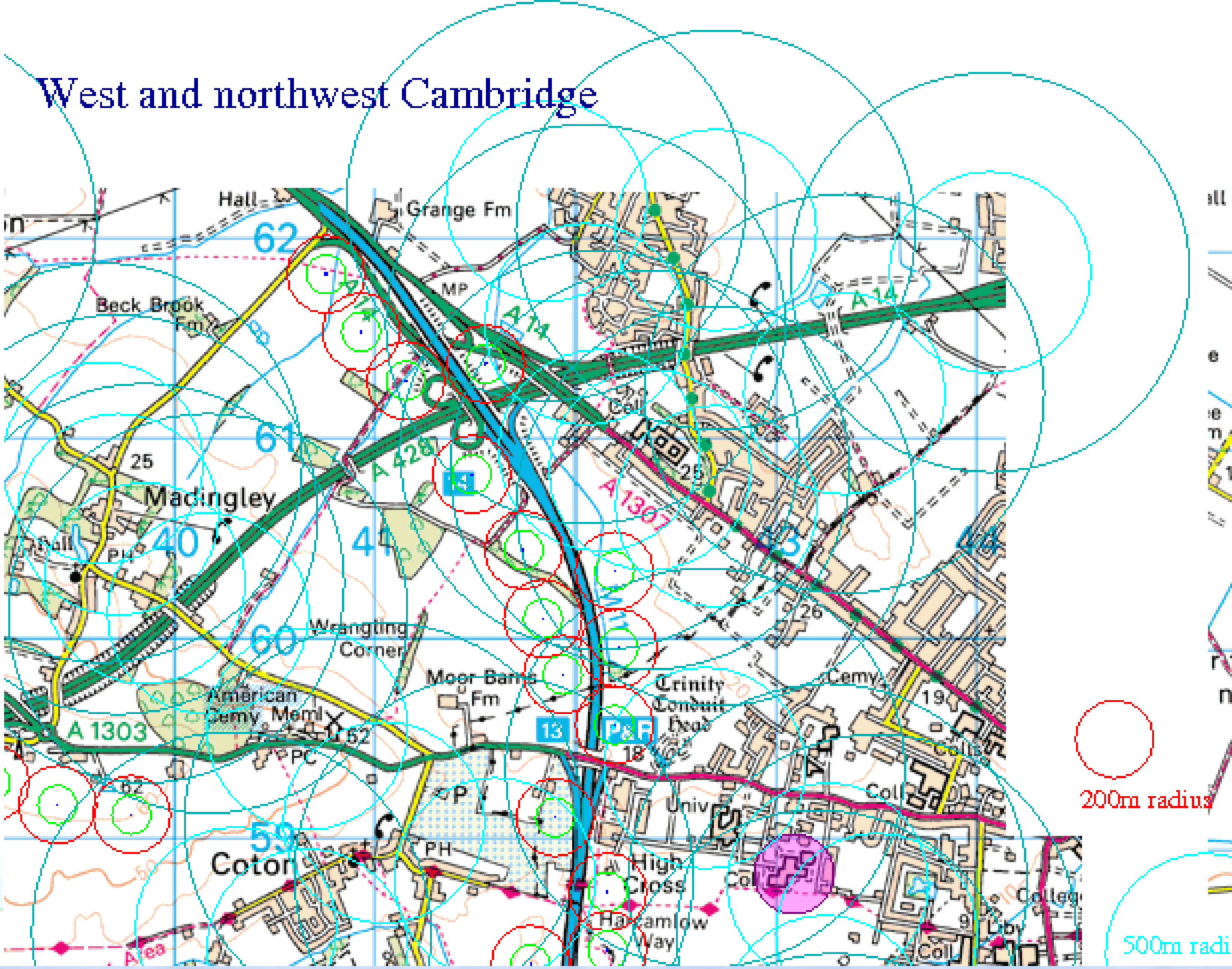
By using the Global Calculator you are agreeing to be bound to its **conditions of use**.

Based on spreadsheet v.3.99.0 **v.3.99.0**.

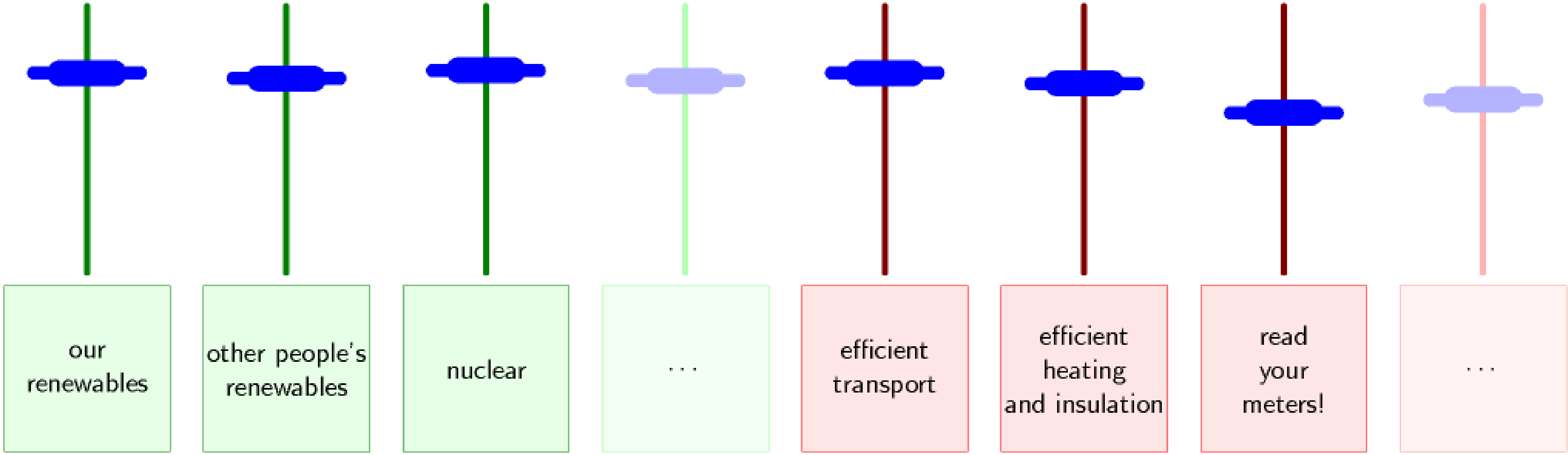
What next?

- 1: Better visualization





2: We need a plan that adds up -



our renewables

other people's renewables

nuclear

. . .

efficient transport

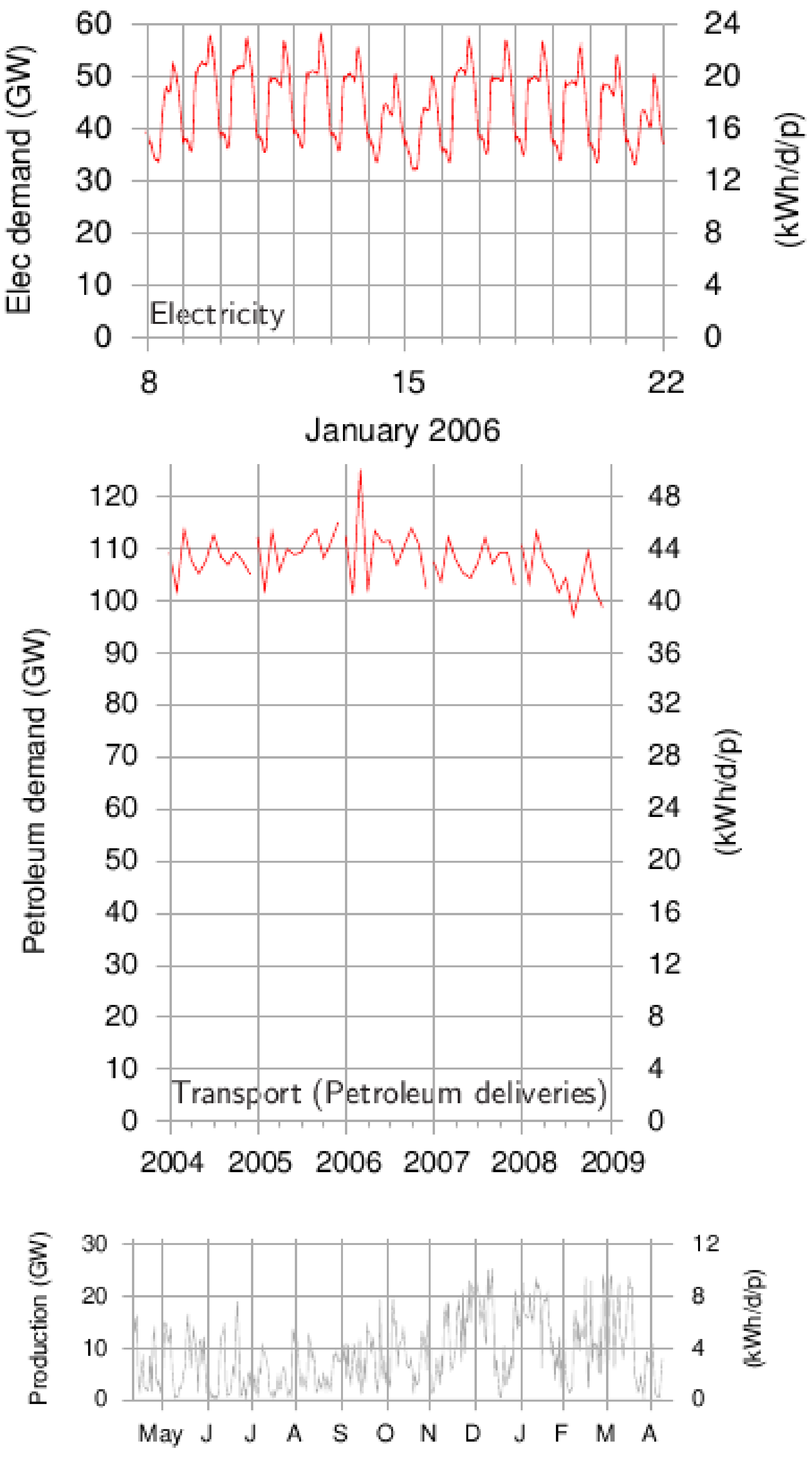
efficient heating and insulation

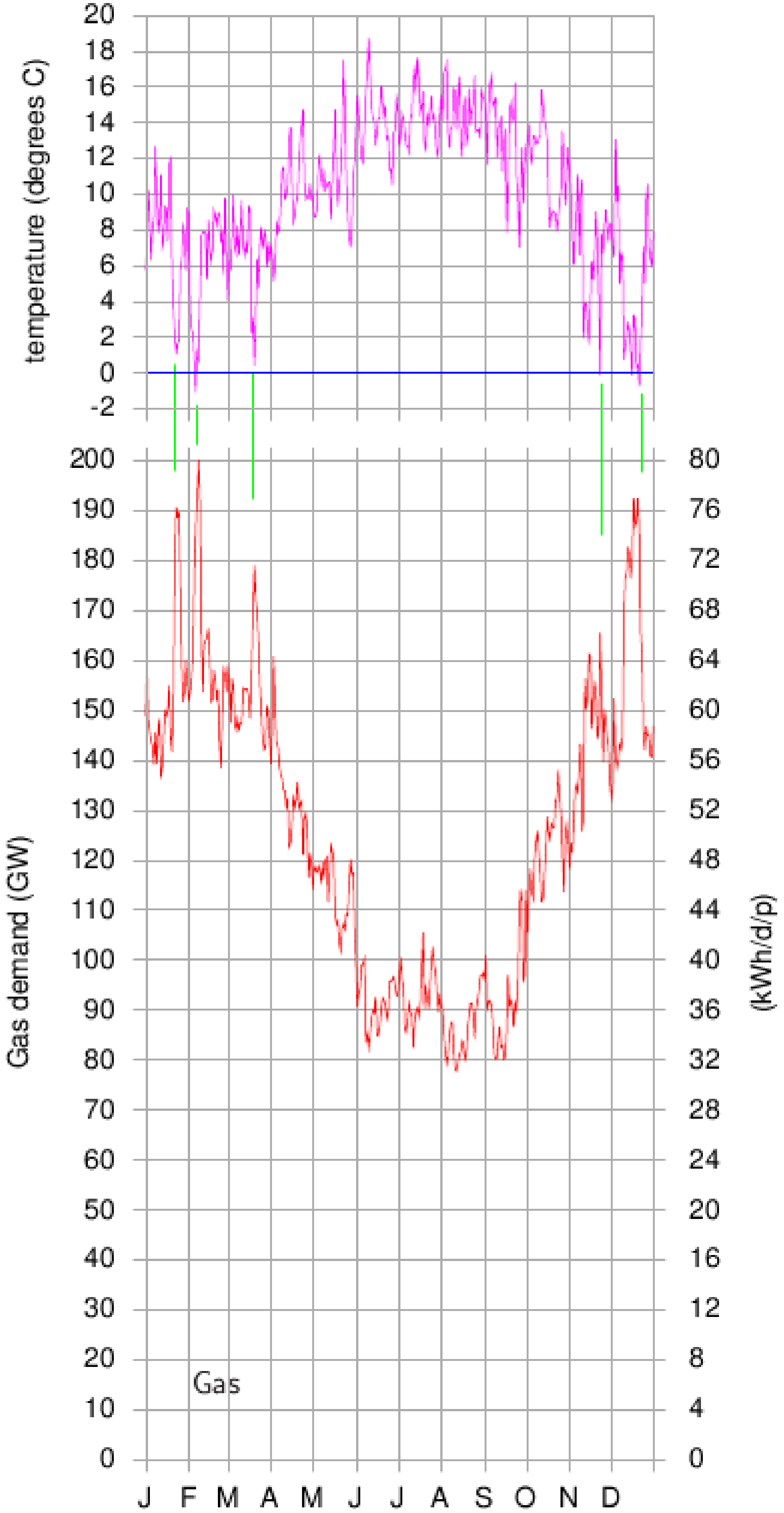
read your meters!

. . .

... every month, every day, and every hour!

Transport, heating, electricity; wind





Electricity, gas, and transport demand; and fictional wind (assuming 33 GW of capacity), all on the same vertical scale.

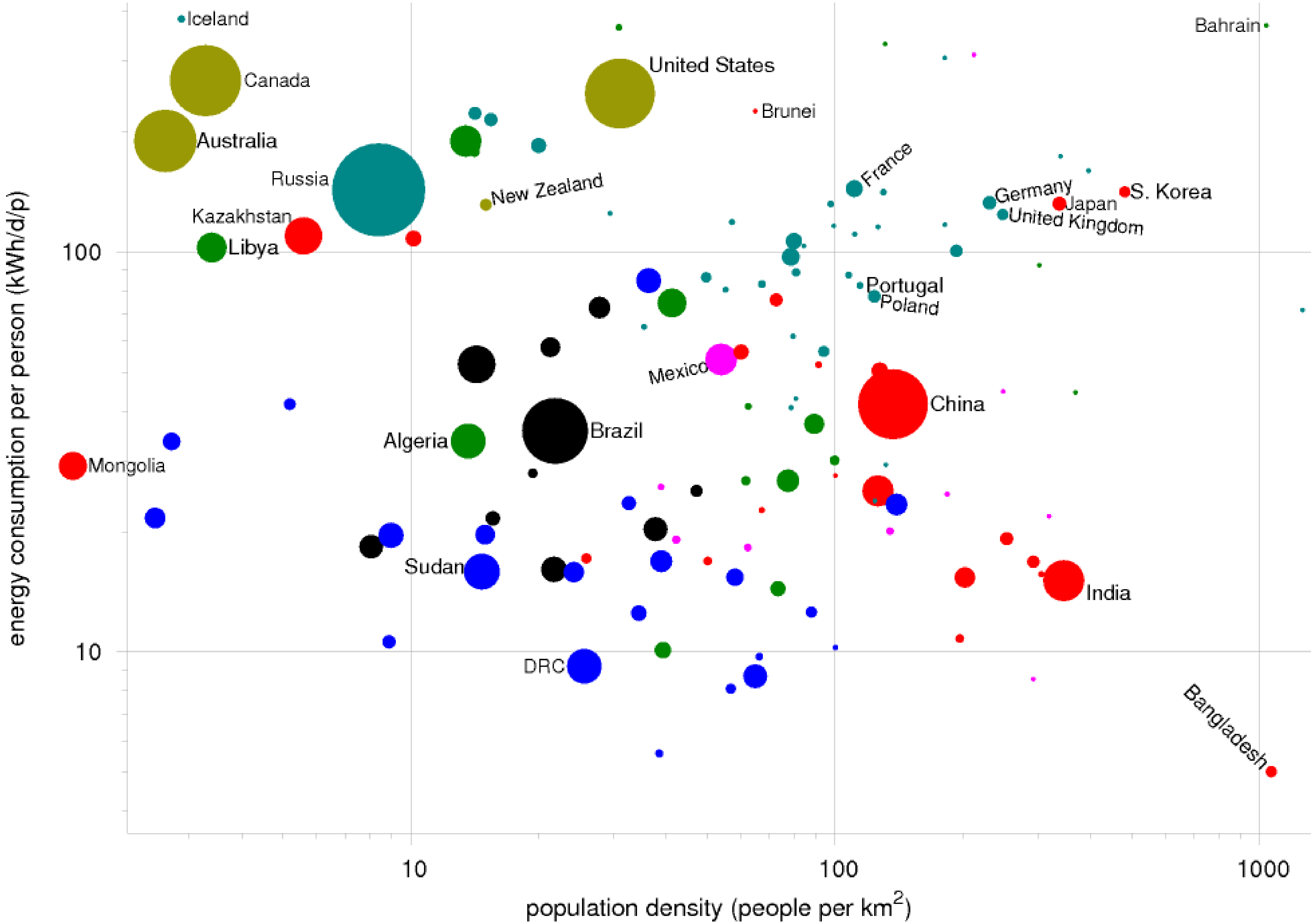
Ups and Downs of the 2050 Calculator

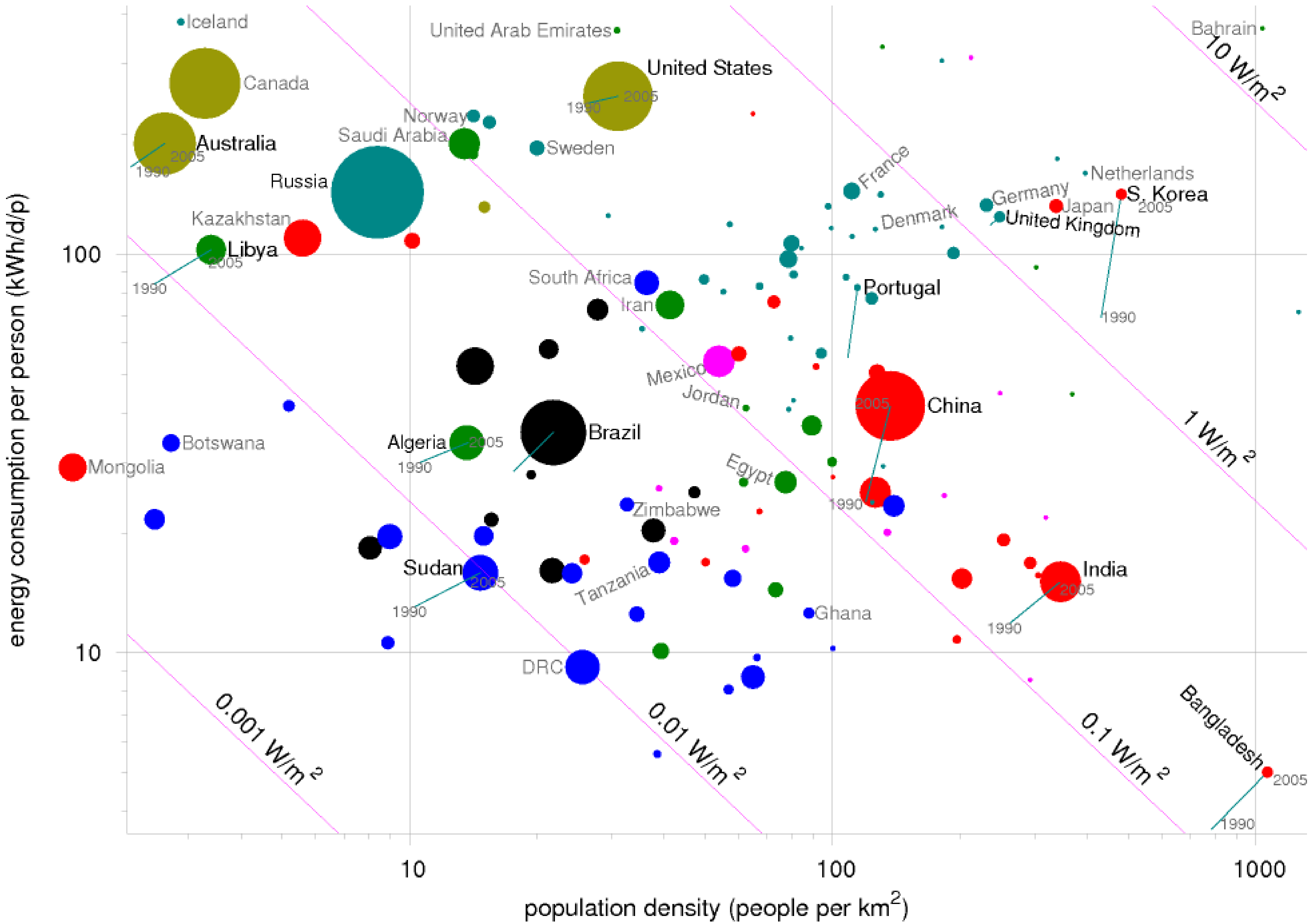
2050 Community Conference   Taipei February 2015

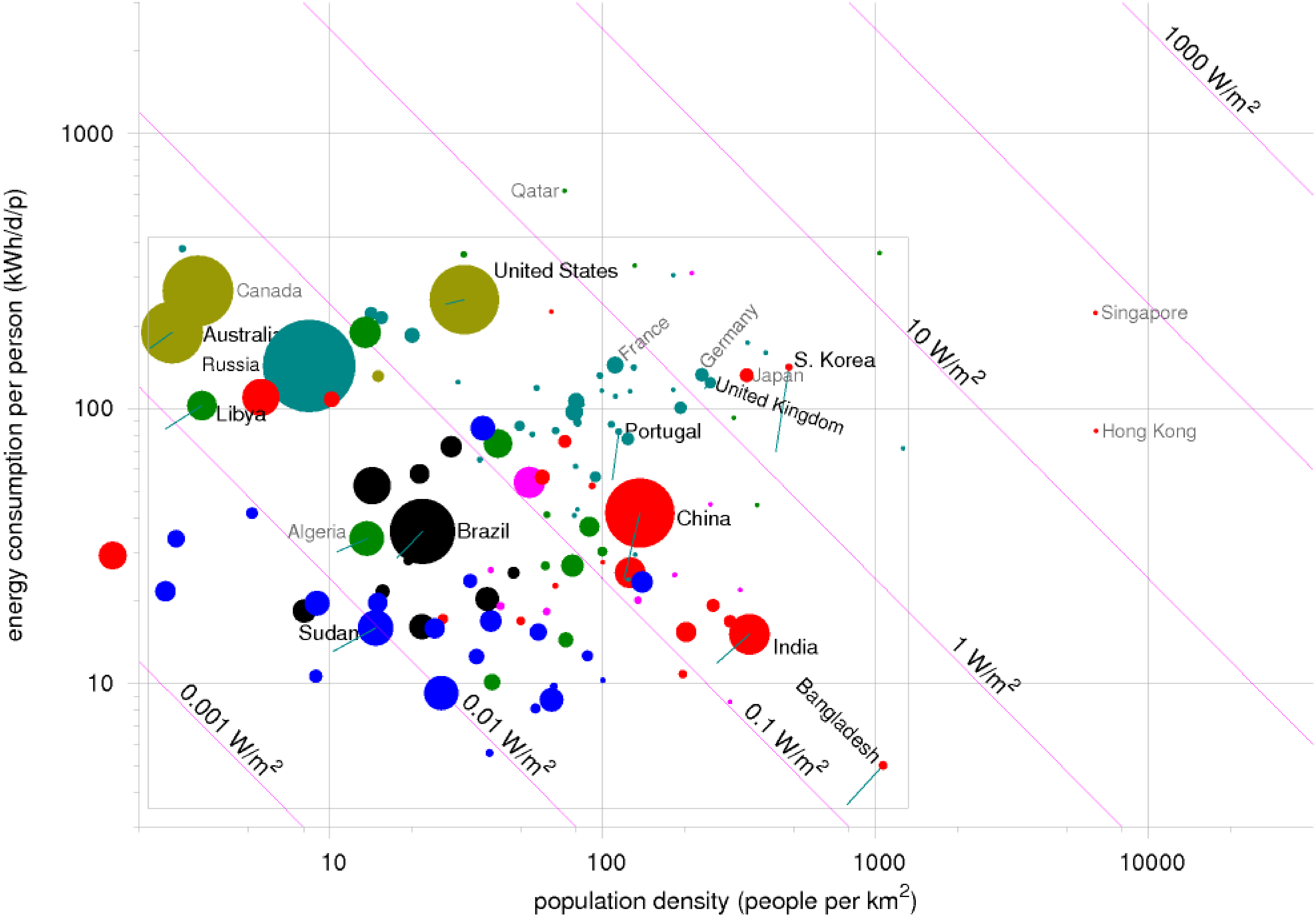
David MacKay FRS

Department of Engineering, University of Cambridge

Former Chief Scientific Advisor, Department of Energy and Climate Change, UK Government


Iceland
Canada
United States
Brunei
Australia
Russia
New Zealand
France
Germany
Japan
S. Korea
United Kingdom
Bahrain
Kazakhstan
Libya
Portugal
Poland
Mexico
China
Brazil
Algeria
Mongolia
Sudan
India
DRC
Bangladesh
energy consumption per person (kWh/d/p)
100
10
10
100
1000
population density (people per km^2)


Iceland
United Arab Emirates
Bahrain
10 W/m^2
Canada
United States
1990
2005
Norway
Saudi Arabia
Australia
2005
1990
Sweden
Russia
France
Netherlands
Germany
S. Korea
Japan
2005
Kazakhstan
Denmark
United Kingdom
Libya
2005
1990
100
South Africa
1990
Iran
Portugal
Mexico
Jordan
China
2005
1 W/m^2
Botswana
Algeria
2005
Brazil
Mongolia
1990
Egypt
1990
Zimbabwe
Sudan
2005
India
Tanzania
2005
1990
Ghana
1990
10
DRC
0.001 W/m^2
0.01 W/m^2
0.1 W/m^2
Bangladesh
2005
1990
10
100
1000
energy consumption per person (kWh/d/p)
population density (people per km^2)


energy consumption per person (kWh/d/p)
1000
100
10
population density (people per km^2)
10
100
1000
10000
0.001 W/m²
0.01 W/m²
0.1 W/m²
1 W/m²
10 W/m²
1000 W/m²
Qatar
United States
Canada
Australia
Russia
Libya
Algeria
Brazil
Sudan
France
Germany
S. Korea
Japan
United Kingdom
Portugal
China
India
Bangladesh
Singapore
Hong Kong

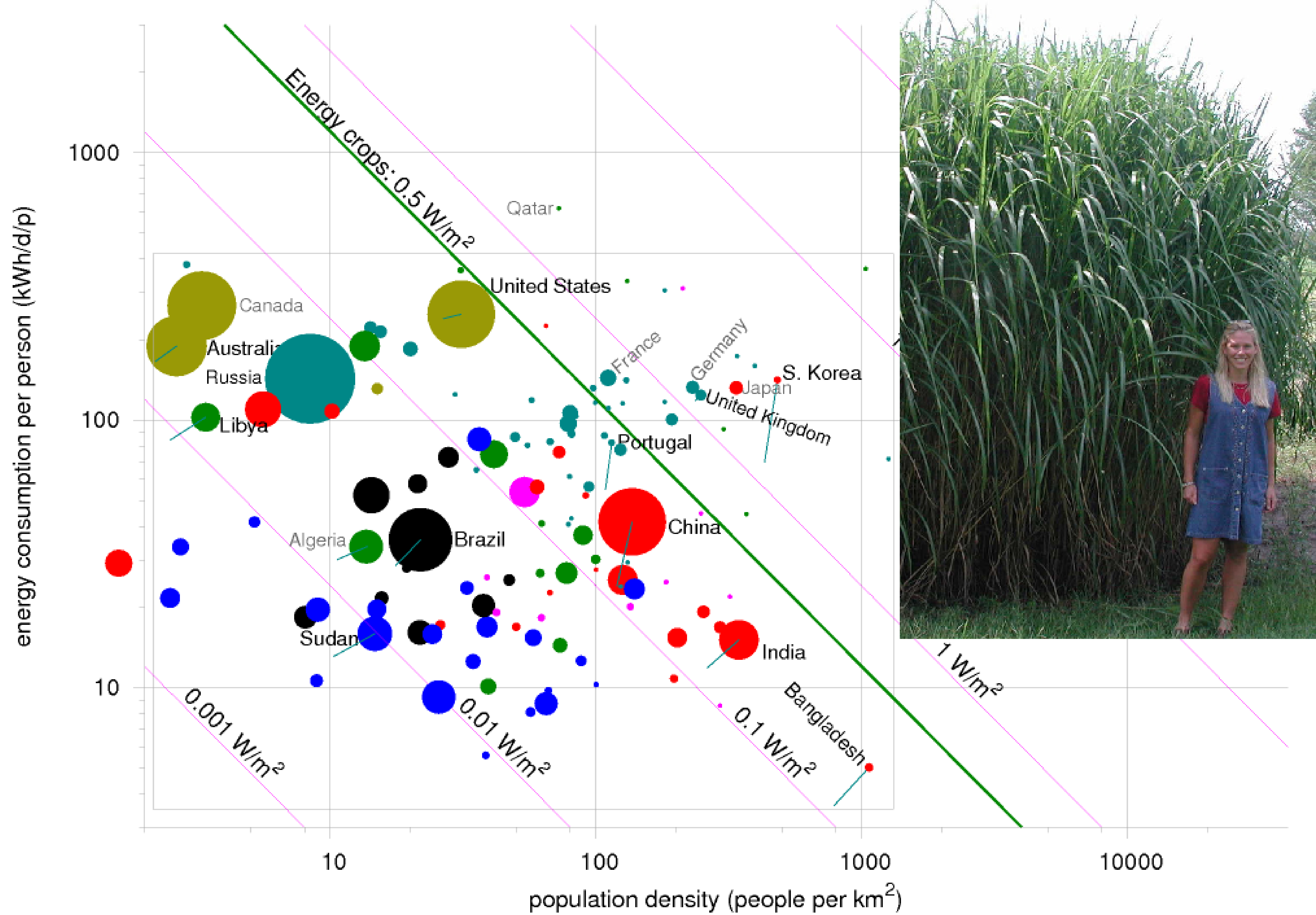
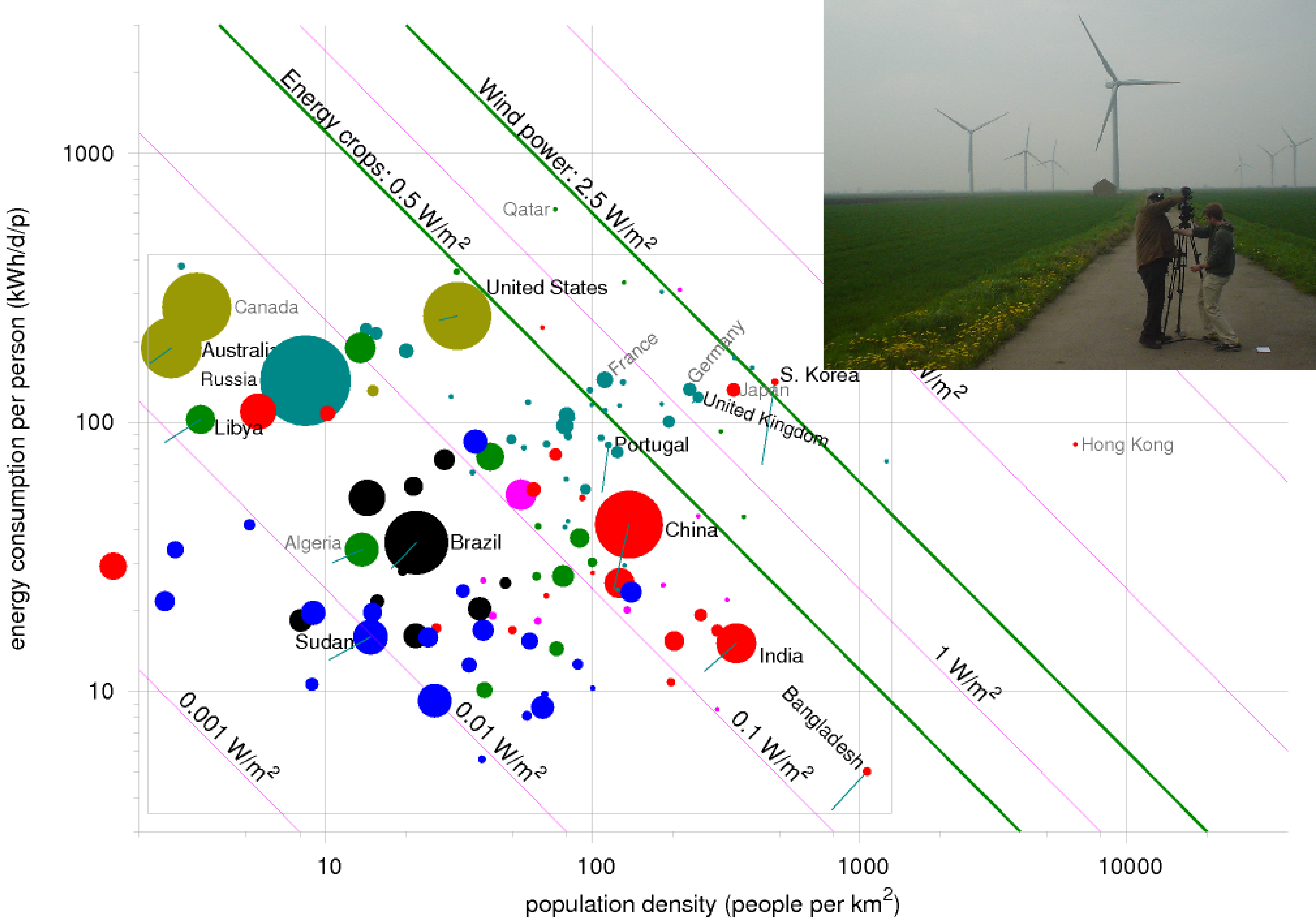
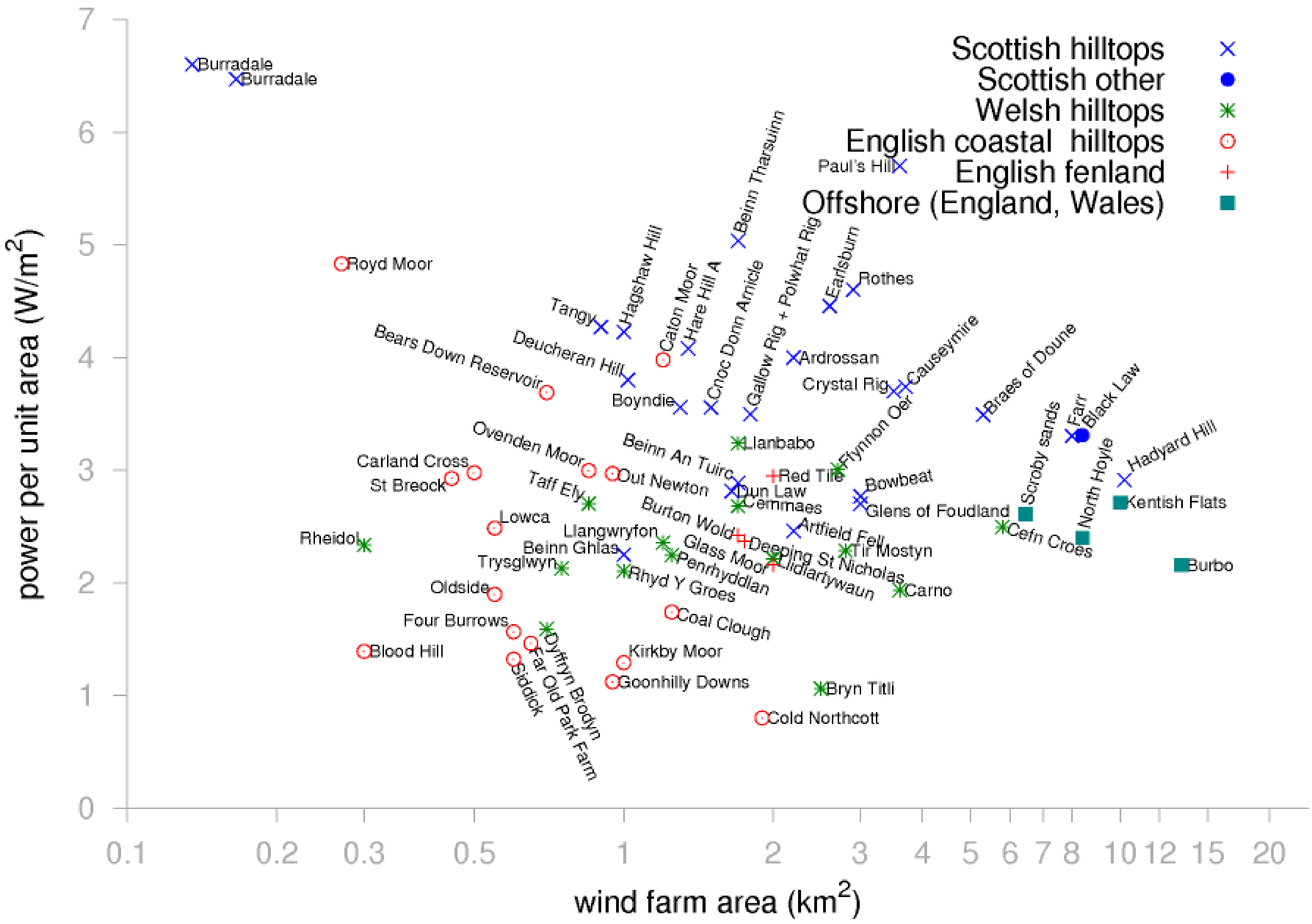
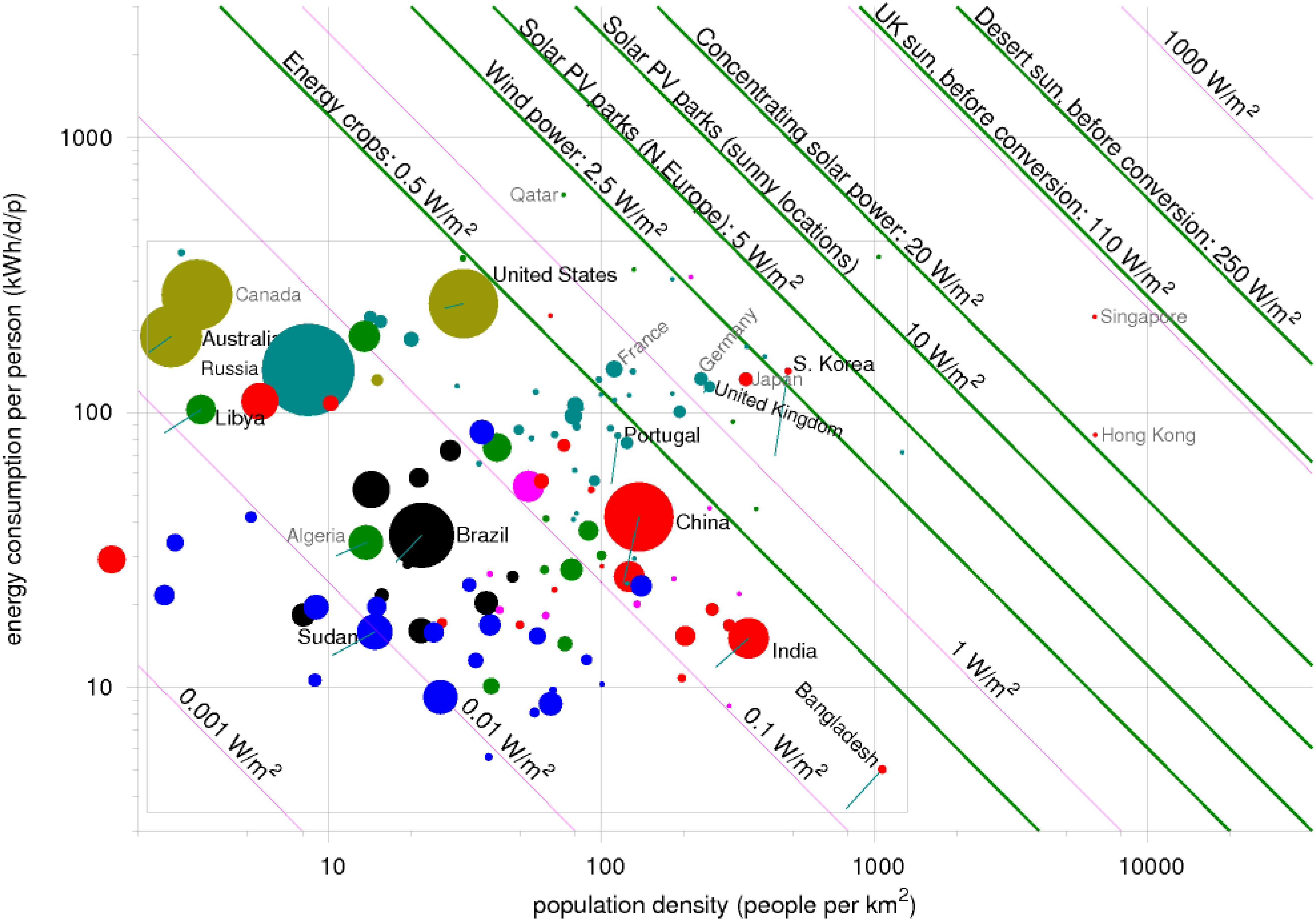


Photo provided by the University of Illinois

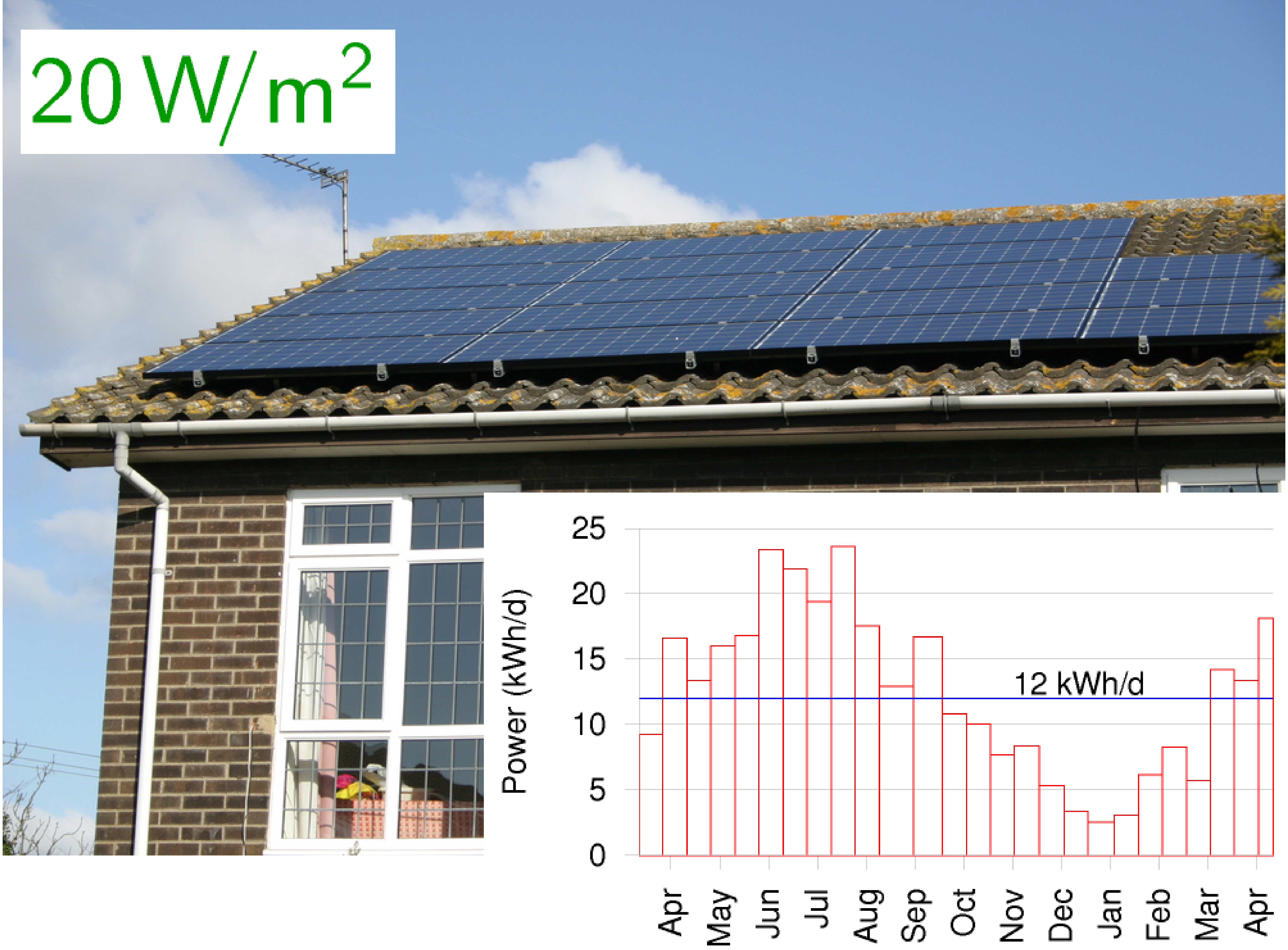

energy consumption per person (kWh/d/p)
1000
100
10
population density (people per km^2)
10
100
1000
10000
Energy crops: 0.5 W/m²
Wind power: 2.5 W/m²
W/m²
1 W/m²
0.1 W/m²
0.01 W/m²
0.001 W/m²
Qatar
United States
Canada
Australi
Russia
Libya
France
Germany
Japan
S. Korea
United Kingdom
Portugal
Hong Kong
Algeria
Brazil
China
Sudan
India
Bangladesh

Powers per unit area of British wind farms, v farm size




Energy crops: 0.5 W/m²
Wind power: 2.5 W/m²
Solar PV parks (N.Europe): 5 W/m²
Solar PV parks (sunny locations)
Concentrating solar power: 20 W/m²
UK sun, before conversion: 110 W/m²
Desert sun, before conversion: 250 W/m²
1000 W/m²
10 W/m²
1 W/m²
0.1 W/m²
0.01 W/m²
0.001 W/m²
Qatar
United States
Canada
Australia
Russia
Libya
France
Germany
S. Korea
Japan
United Kingdom
Portugal
Singapore
Hong Kong
China
Algeria
Brazil
Sudan
India
Bangladesh
1000
100
10
10
100
1000
10000
energy consumption per person (kWh/d/p)
population density (people per km^2)

$20\ \mathrm{W/m^2}$



Data and photo by Jonathan Kimmitt - 25 sq m of panels

$5\,W/m^2$

www.powerlight.com

$3.8\,\mathrm{W/m^2}$

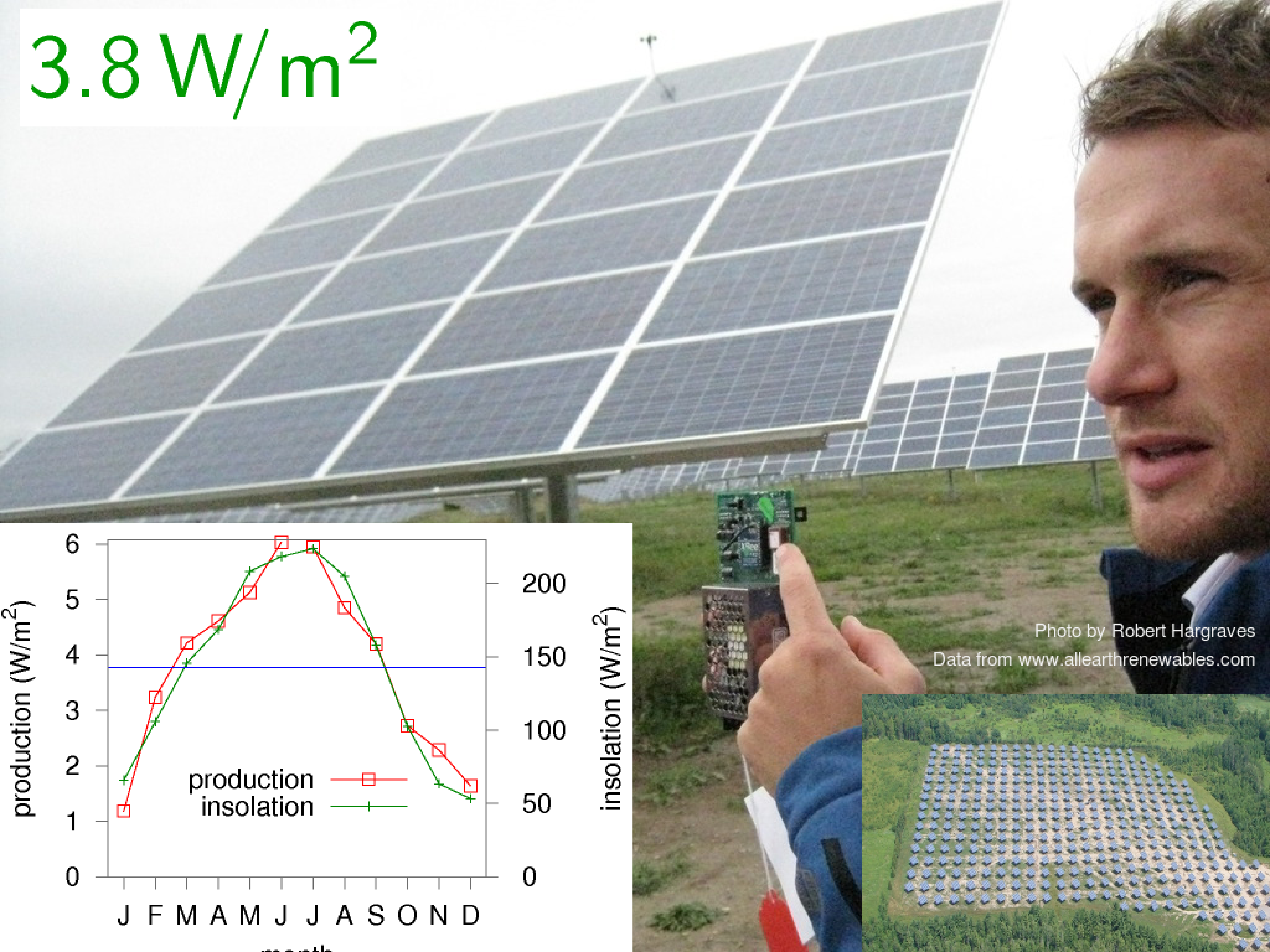
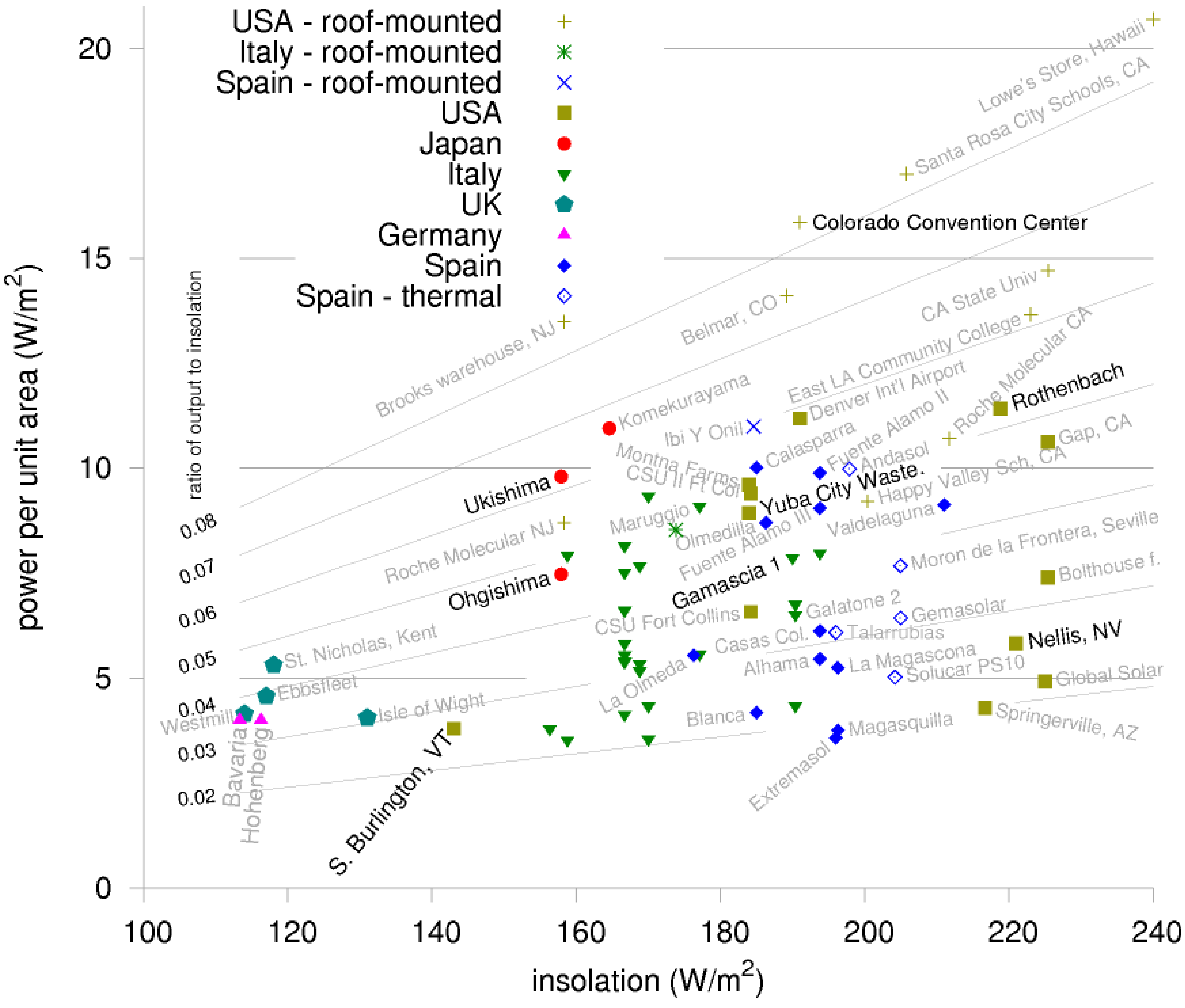
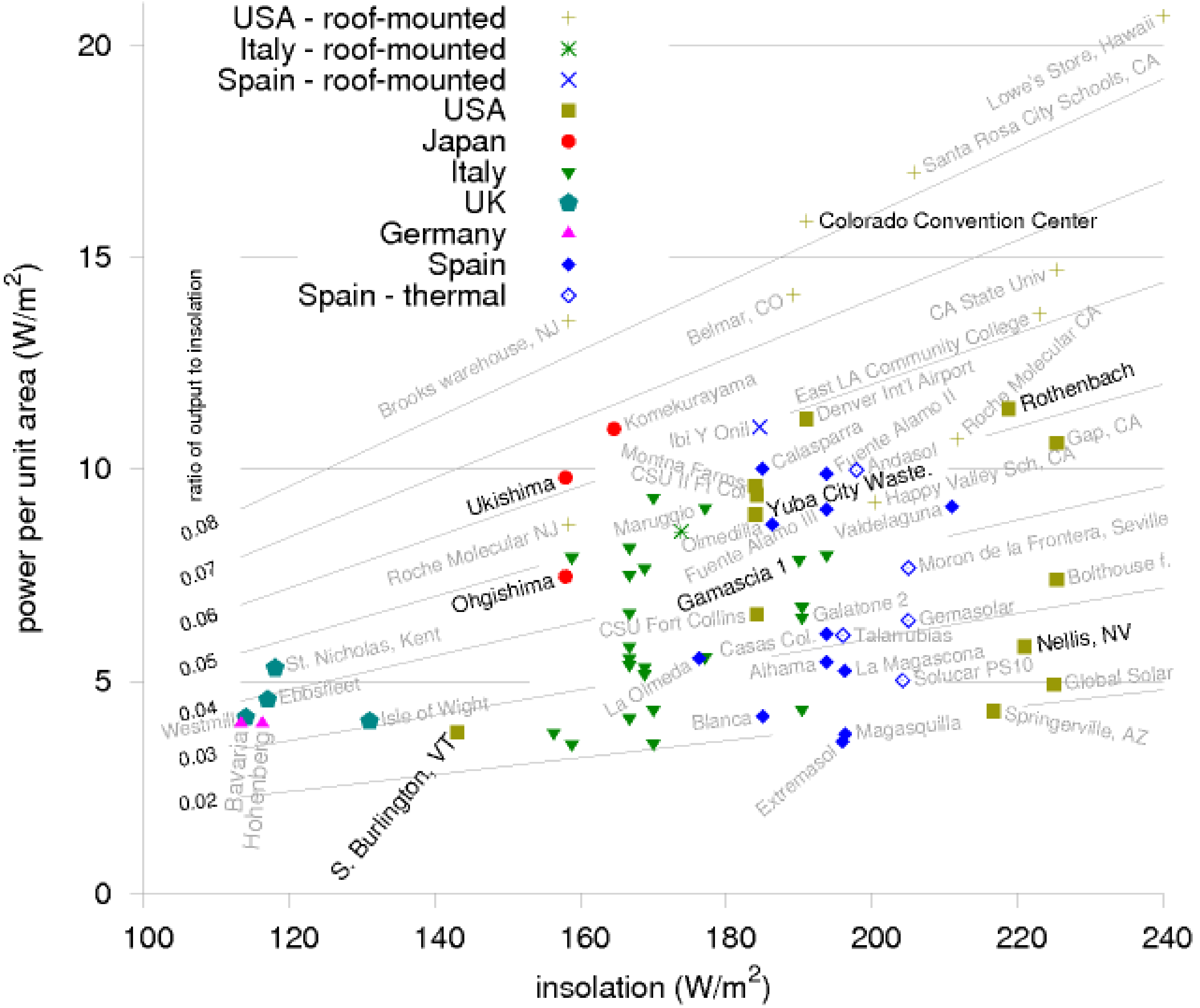


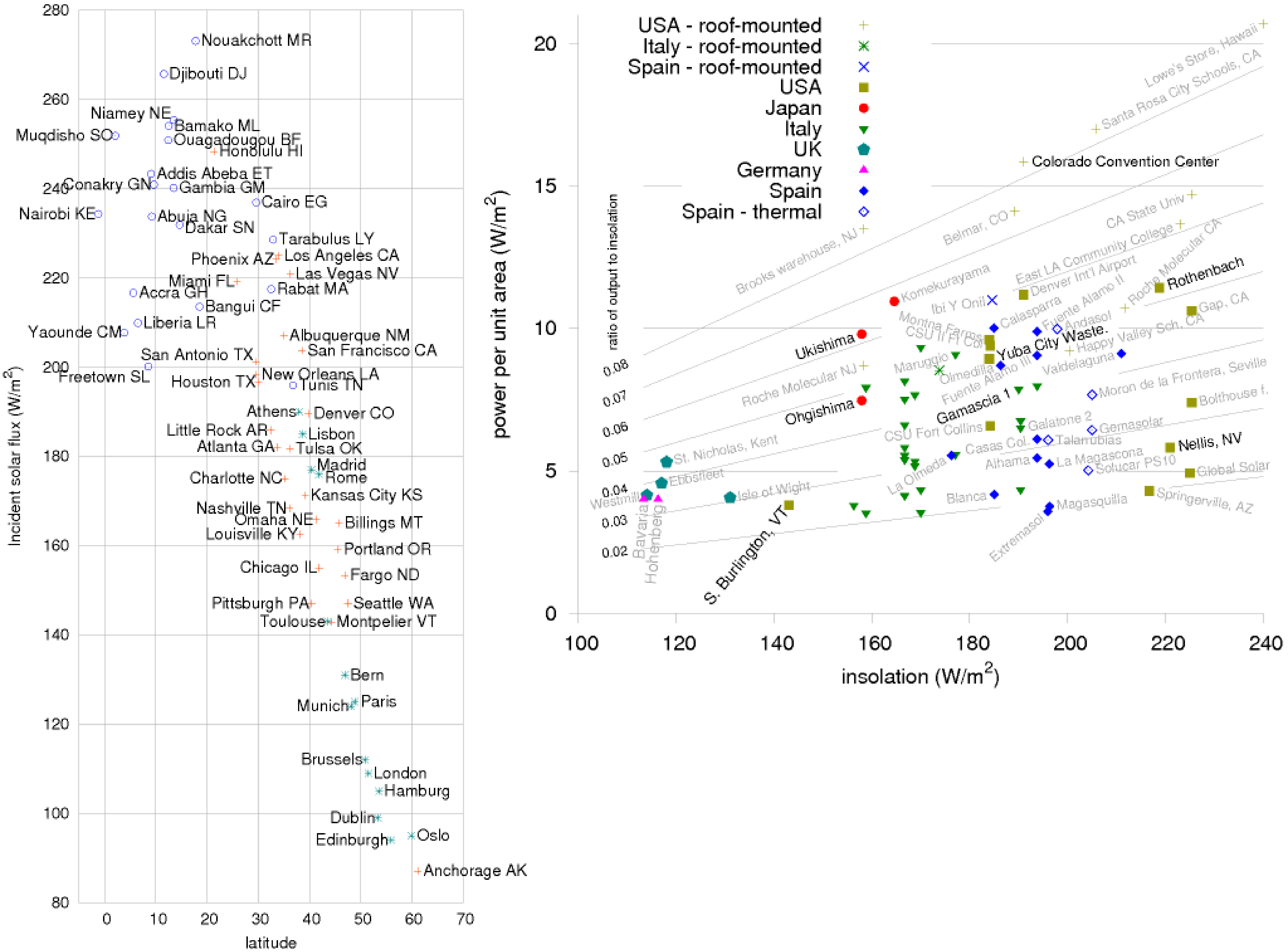
Photo by Robert Hargraves

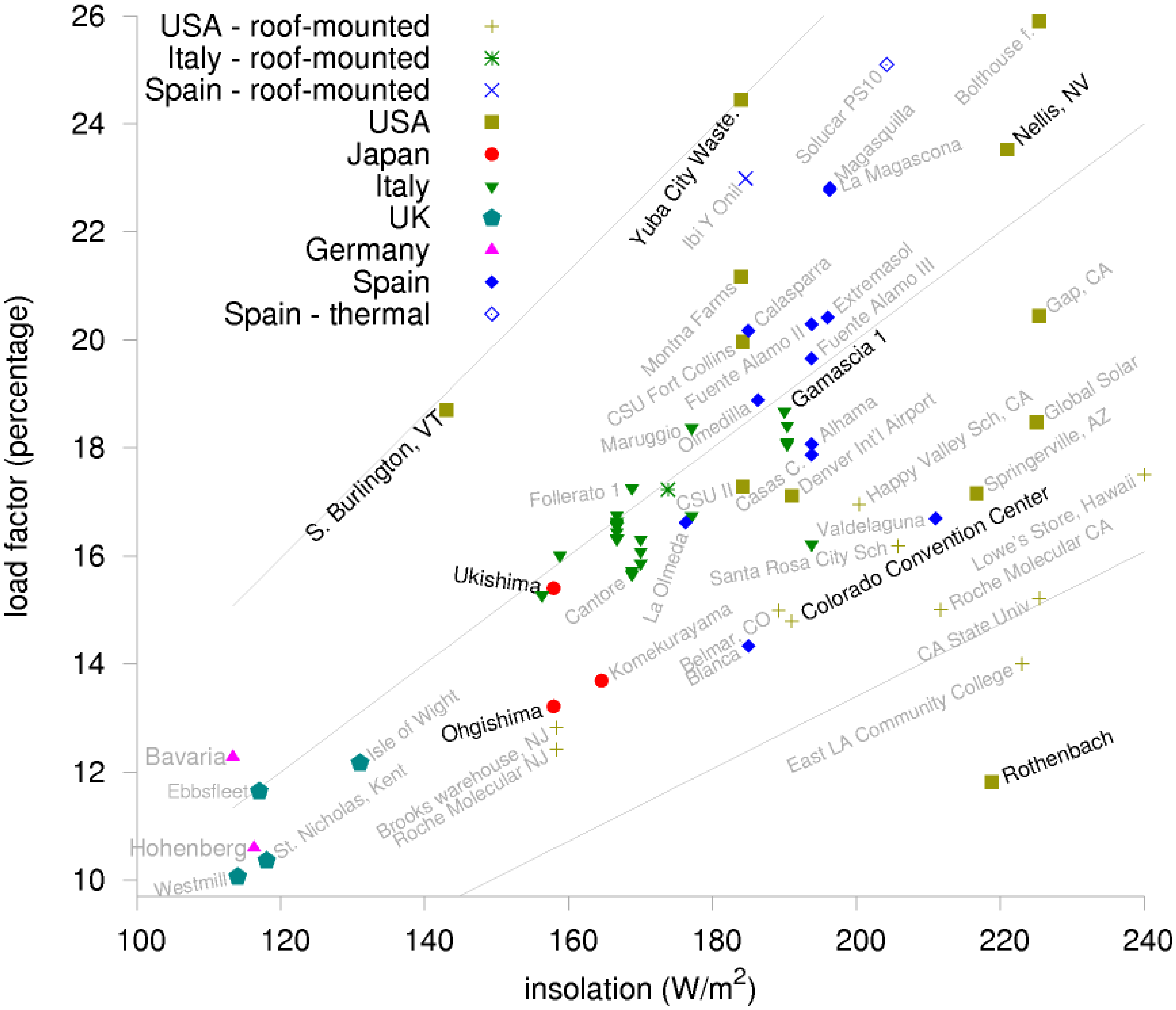
Data from www.allearthrenewables.com

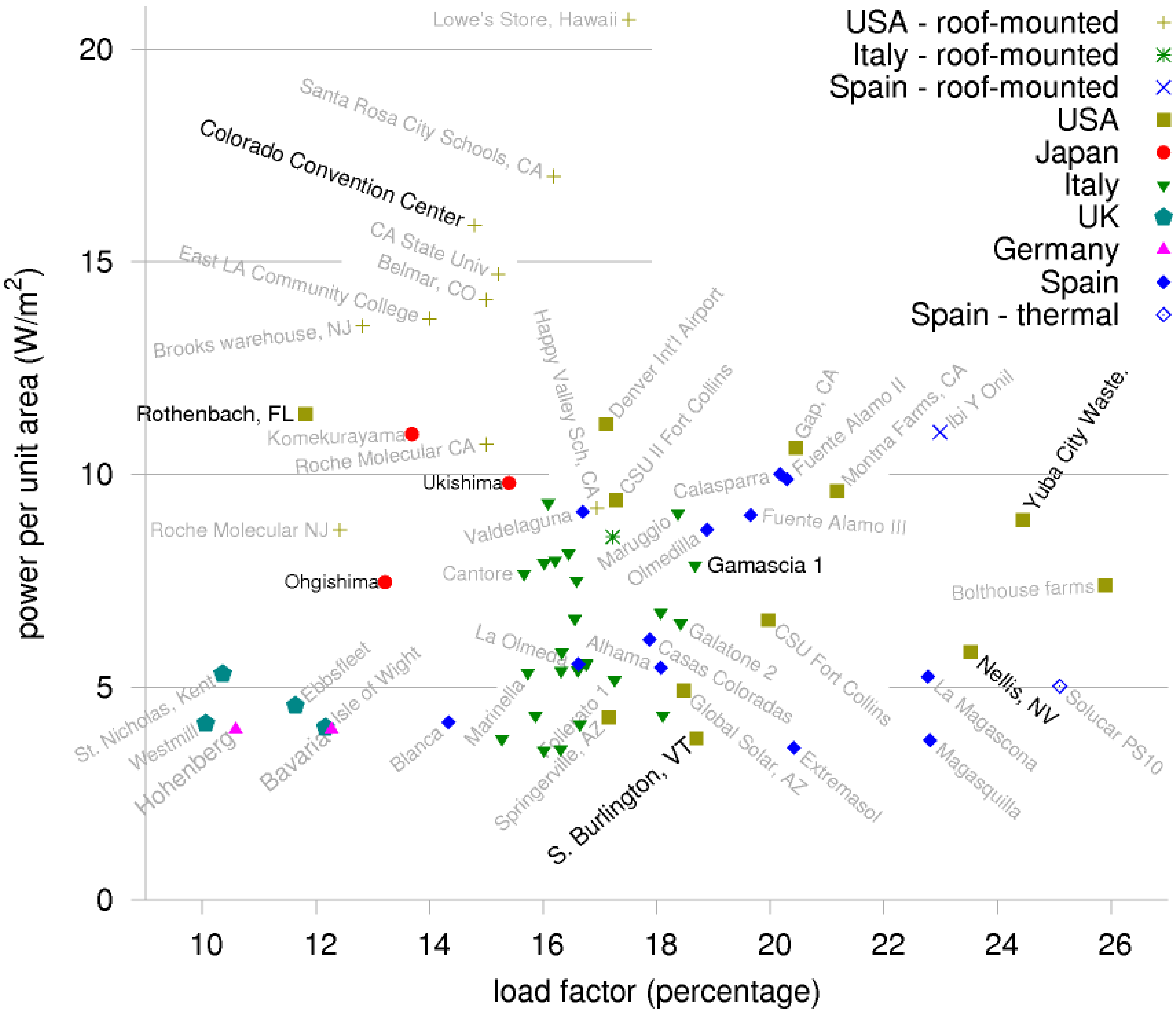

USA - roof-mounted
Italy - roof-mounted
Spain - roof-mounted
USA
Japan
Italy
UK
Germany
Spain
Spain - thermal
power per unit area (W/m²)
insolation (W/m²)
ratio of output to insolation
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0
5
10
15
20
100
120
140
160
180
200
220
240
Lowe's Store, Hawaii
Santa Rosa City Schools, CA
Colorado Convention Center
Belmar, CO
Brooks warehouse, NJ
CA State Univ
East LA Community College
Denver Int'l Airport
Roche Molecular CA
Rothenbach
Gap, CA
Komekurayama
Ibi Y Onil
Calasparra
Fuente Alamo II
Andasol
Happy Valley Sch, CA
Montna Farms
CSU II Ft Col
Yuba City Waste.
Valdelaguna
Ukishima
Maruggio
Olmedilla
Fuente Alamo III
Roche Molecular NJ
Moron de la Frontera, Seville
Bolthouse f.
Ohgishima
Gamascia 1
CSU Fort Collins
Galatone 2
Gemasolar
Talarrubias
Nellis, NV
Casas Col.
St. Nicholas, Kent
Alhama
La Magascona
Solucar PS10
Global Solar
Ebbsfleet
La Olmeda
Isle of Wight
Westmill
Bavaria
Hohenberg
Blanca
Springerville, AZ
Magasquilla
Extremasol
S. Burlington, VT

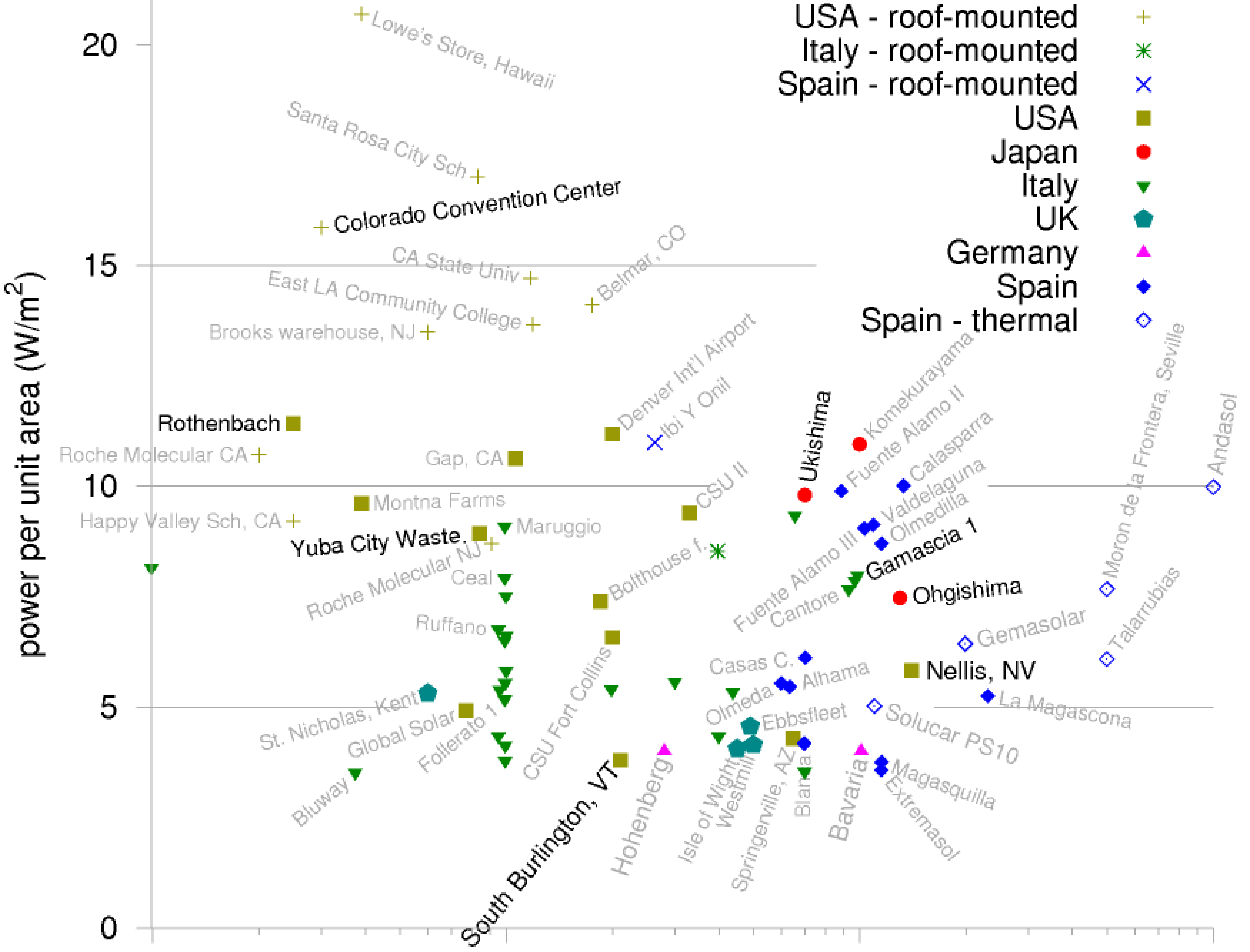
U.S. Air Force photo by
Airman 1st Class Nadine Y. Barclay



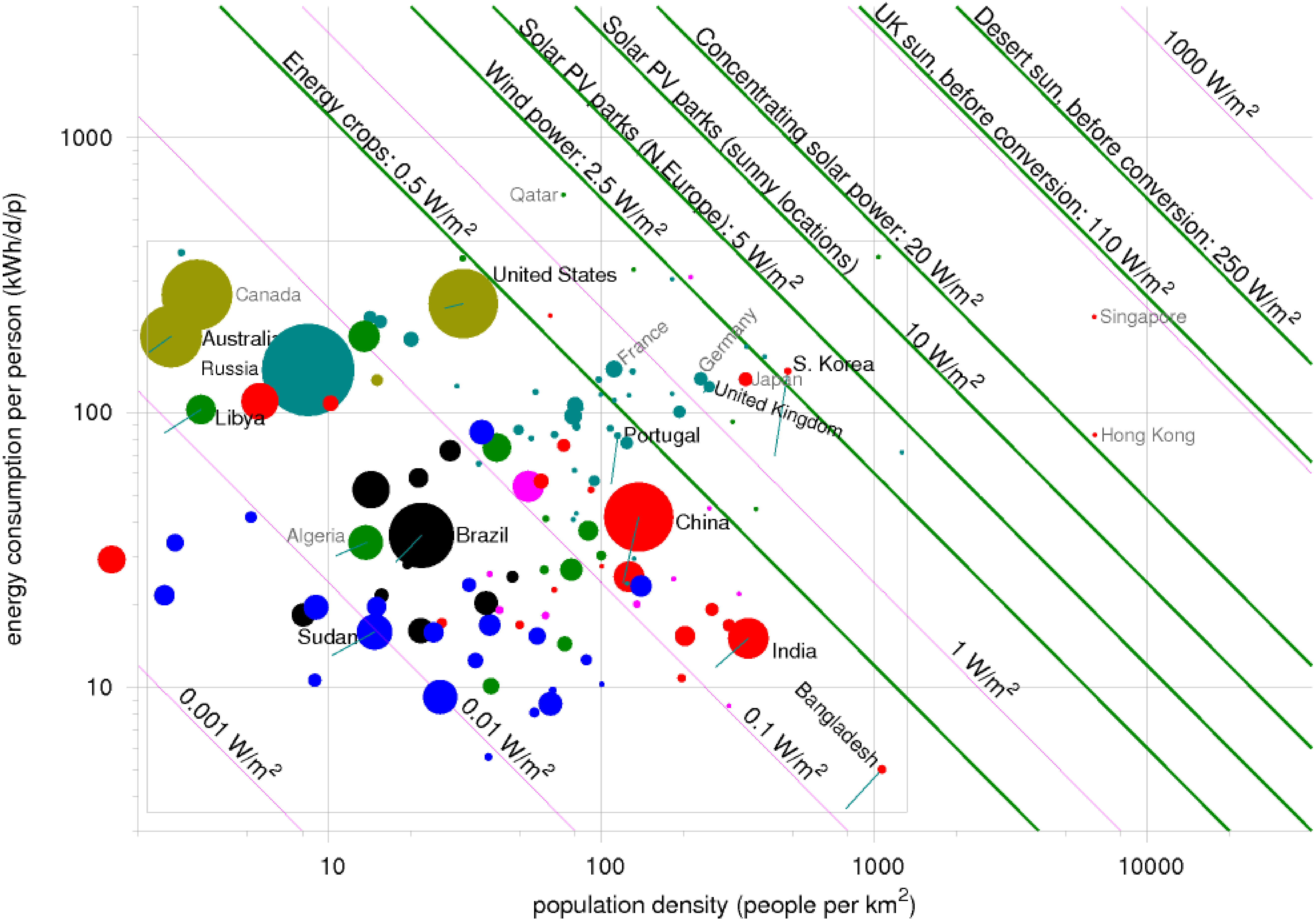

Incident solar flux (W/m²)
latitude
280
260
240
220
200
180
160
140
120
100
80
0
10
20
30
40
50
60
70
Nouakchott MR
Djibouti DJ
Niamey NE
Bamako ML
Muqdisho SO
Ouagadougou BF
Honolulu HI
Addis Abeba ET
Conakry GN
Gambia GM
Cairo EG
Nairobi KE
Abuja NG
Dakar SN
Tarabulus LY
Phoenix AZ
Los Angeles CA
Las Vegas NV
Miami FL
Accra GH
Rabat MA
Bangui CF
Liberia LR
Yaounde CM
Albuquerque NM
San Francisco CA
San Antonio TX
Freetown SL
New Orleans LA
Houston TX
Tunis TN
Athens
Denver CO
Little Rock AR
Lisbon
Atlanta GA
Tulsa OK
Madrid
Rome
Charlotte NC
Kansas City KS
Nashville TN
Omaha NE
Billings MT
Louisville KY
Portland OR
Chicago IL
Fargo ND
Pittsburgh PA
Seattle WA
Toulouse
Montpelier VT
Bern
Munich
Paris
Brussels
London
Hamburg
Dublin
Oslo
Edinburgh
Anchorage AK
power per unit area (W/m²)
insolation (W/m²)
ratio of output to insolation
USA - roof-mounted
Italy - roof-mounted
Spain - roof-mounted
USA
Japan
Italy
UK
Germany
Spain
Spain - thermal
0
5
10
15
20
100
120
140
160
180
200
220
240
0.08
0.07
0.06
0.05
0.04
0.03
0.02
Lowe's Store, Hawaii
Santa Rosa City Schools, CA
Colorado Convention Center
CA State Univ
Belmar, CO
Brooks warehouse, NJ
East LA Community College
Denver Int'l Airport
Roche Molecular CA
Rothenbach
Komekurayama
Ibi Y Onil
Calasparra
Fuente Alamo II
Andasol
Gap, CA
Montna Farms
CSU II Ft Col
Yuba City Waste.
Happy Valley Sch. CA
Ukishima
Maruggio
Olmedilla
Fuente Alamo III
Valdelaguna
Roche Molecular NJ
Gamascia 1
Moron de la Frontera, Seville
Bolthouse f.
Ohgishima
CSU Fort Collins
Galatone 2
Gemasolar
Casas Col.
Talarrubias
Nellis, NV
St. Nicholas, Kent
Alhama
La Magascona
Solucar PS10
Global Solar
Ebbsfleet
La Olmeda
Isle of Wight
Westmill
Blanca
Magasquilla
Springerville, AZ
Bavaria
Hohenberg
S. Burlington, VT
Extremasol


USA - roof-mounted
Italy - roof-mounted
Spain - roof-mounted
USA
Japan
Italy
UK
Germany
Spain
Spain - thermal
load factor (percentage)
insolation (W/m²)
26
24
22
20
18
16
14
12
10
100
120
140
160
180
200
220
240
Yuba City Waste.
Solucar PS10
Bolthouse f.
Nellis, NV
Magasquilla
La Magascona
Ibi Y Onil
S. Burlington, VT
Montna Farms
Calasparra
Extremasol
Fuente Alamo III
Gap, CA
CSU Fort Collins
Fuente Alamo II
Fuente Alamo III
Gamascia 1
Maruggio
Olmedilla
Alhama
Denver Int'l Airport
Happy Valley Sch, CA
Global Solar
Springerville, AZ
Follerato 1
CSU II
Casas C.
Valdelaguna
Lowe's Store, Hawaii
Colorado Convention Center
Santa Rosa City Sch
Roche Molecular CA
Ukishima
Cantore
La Olmeda
Komekurayama
Belmar, CO
Blanca
CA State Univ
East LA Community College
Ohgishima
Isle of Wight
Brooks warehouse, NJ
Roche Molecular NJ
St. Nicholas, Kent
Bavaria
Ebbsfleet
Hohenberg
Westmill
Rothenbach


USA - roof-mounted
Italy - roof-mounted
Spain - roof-mounted
USA
Japan
Italy
UK
Germany
Spain
Spain - thermal
power per unit area (W/m^2)
load factor (percentage)
0
5
10
15
20
10
12
14
16
18
20
22
24
26
Lowe's Store, Hawaii
Santa Rosa City Schools, CA
Colorado Convention Center
CA State Univ
Belmar, CO
East LA Community College
Brooks warehouse, NJ
Happy Valley Sch, CA
Denver Int'l Airport
CSU II Fort Collins
Gap, CA
Fuente Alamo II
Montna Farms, CA
Ibi Y Onil
Yuba City Waste.
Rothenbach, FL
Komekurayama
Roche Molecular CA
Ukishima
Calasparra
Valdelaguna
Fuente Alamo III
Maruggio
Olmedilla
Roche Molecular NJ
Gamascia 1
Cantore
Ohgishima
Bolthouse farms
La Olmeda
Galatone 2
CSU Fort Collins
Alhama
Casas Coloradas
Nellis, NV
St. Nicholas, Kent
Ebbsfleet
Isle of Wight
Westmill
Hohenberg
Bavaria
Blanca
Marinella
Follerato 1
Springerville, AZ
S. Burlington, VT
Global Solar, AZ
Extremasol
La Magascona
Magasquilla
Solucar PS10



power per unit area (W/m2)
capacity (MW)
0
5
10
15
20
0.1
1
10
100
USA - roof-mounted
Italy - roof-mounted
Spain - roof-mounted
USA
Japan
Italy
UK
Germany
Spain
Spain - thermal
Lowe's Store, Hawaii
Santa Rosa City Sch
Colorado Convention Center
CA State Univ
Belmar, CO
East LA Community College
Brooks warehouse, NJ
Denver Int'l Airport
Ibi Y Onil
Rothenbach
Roche Molecular CA
Gap, CA
Ukishima
Komekurayama
Fuente Alamo II
Calasparra
Valdelaguna
Olmedilla
CSU II
Montna Farms
Happy Valley Sch, CA
Maruggio
Yuba City Waste.
Roche Molecular NJ
Bolthouse f.
Fuente Alamo III
Gamascia 1
Ceal
Cantore
Ohgishima
Moron de la Frontera, Seville
Andasol
Talarrubias
Gemasolar
Ruffano
CSU Fort Collins
Casas C.
Alhama
Nellis, NV
Olmeda
La Magascona
St. Nicholas, Kent
Global Solar
Follerato 1
Ebbsfleet
Solucar PS10
Bluway
South Burlington, VT
Hohenberg
Isle of Wight
Westmill
Springerville, AZ
Blanca
Bavaria
Magasquilla
Extremasol



energy consumption per person (kWh/d/p)
1000
100
10
population density (people per km^2)
10
100
1000
10000
Energy crops: 0.5 W/m^2
Wind power: 2.5 W/m^2
Solar PV parks (N.Europe): 5 W/m^2
Solar PV parks (sunny locations)
Concentrating solar power: 20 W/m^2
UK sun, before conversion: 110 W/m^2
Desert sun, before conversion: 250 W/m^2
1000 W/m^2
10 W/m^2
1 W/m^2
0.1 W/m^2
0.01 W/m^2
0.001 W/m^2
Qatar
United States
Canada
Australia
Russia
Libya
France
Germany
S. Korea
Japan
United Kingdom
Portugal
Singapore
Hong Kong
Algeria
Brazil
China
Sudan
India
Bangladesh

14 W/m^2

www.stirlingenergy.com

Andasol, Spain

10 W/m^2

PS10, Solucar

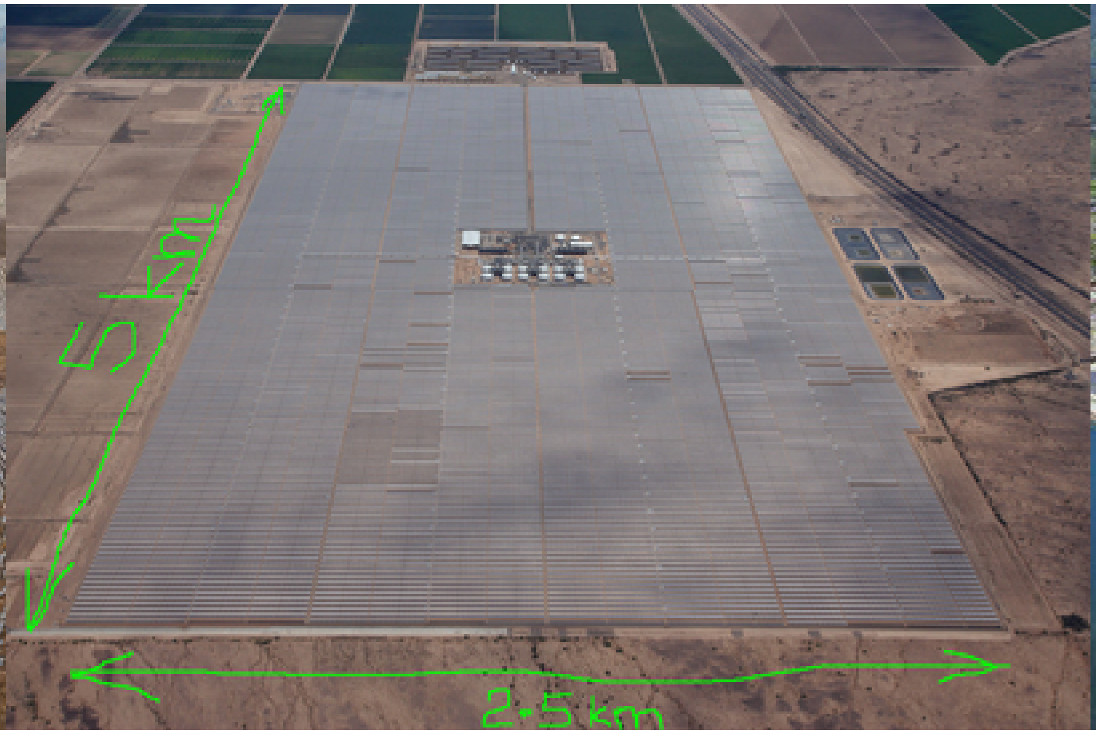
$5\,\mathrm{W/m^2}$


Photo by afloresm

Ivanpah CA: 377 MW capacity

1079 GWh/y (123 MW)
from 14.2 km^2 of land

Power per unit area: 8.7 W/m^2



Solana AZ: 280 MW capacity

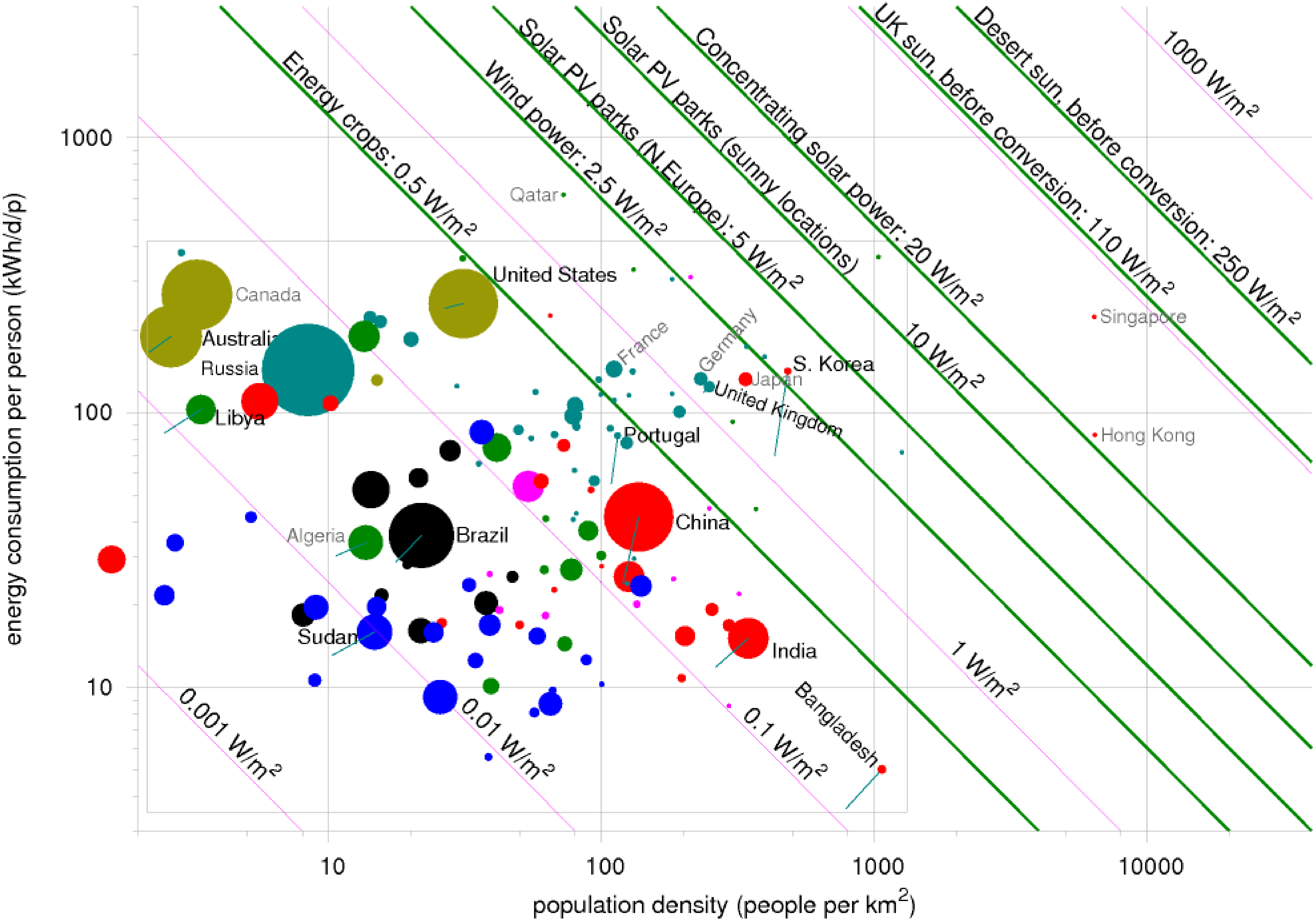
944 GWh/year (108 MW)
from 12.6 km^2 of land

Power per unit area: 8.6 W/m^2

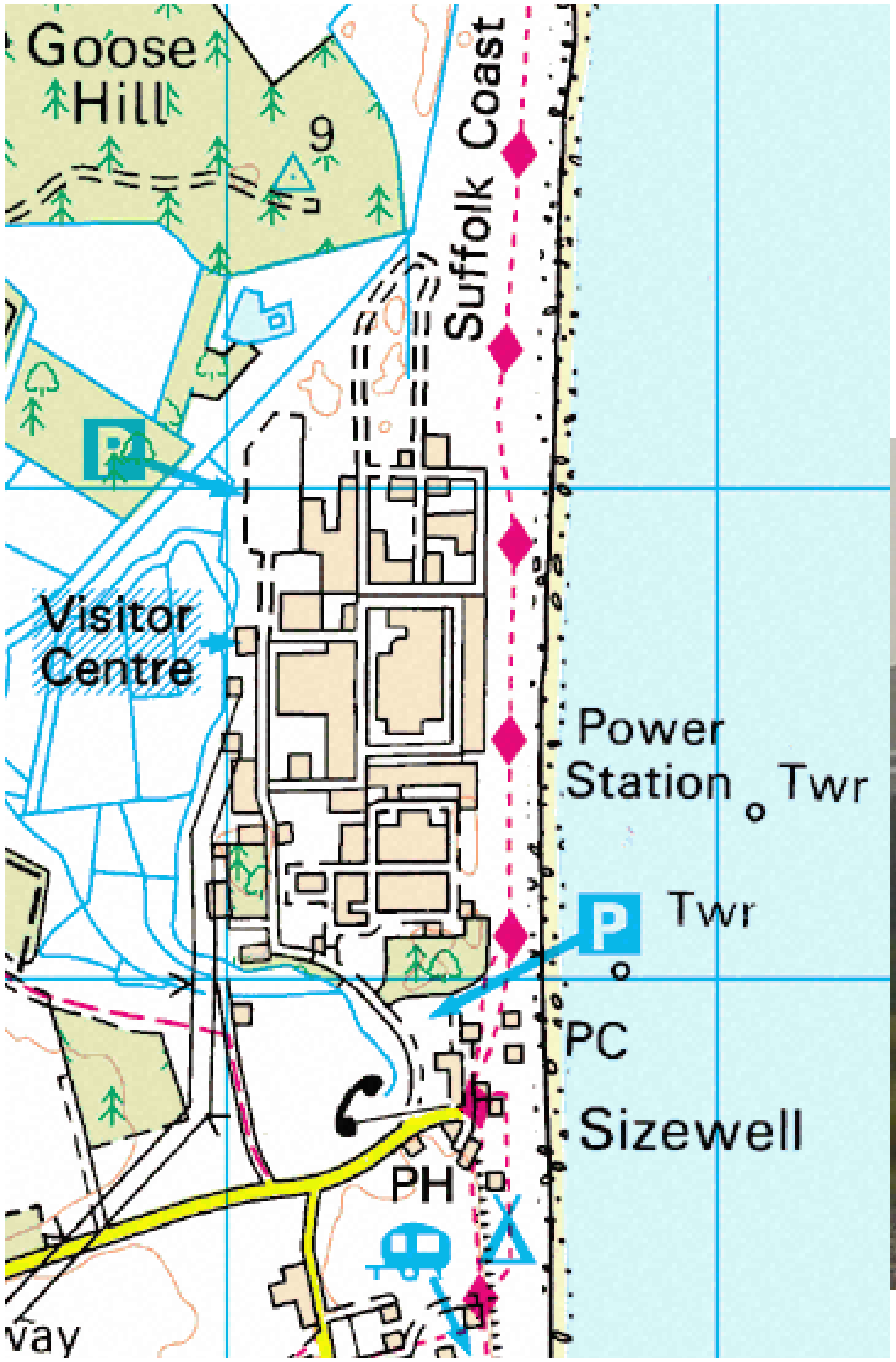
Kagoshima: 70 MW capacity

expected load factor 12.8%
1.04 km^2 of land

Power per unit area: 8.6 W/m^2


Energy crops: 0.5 W/m²
Wind power: 2.5 W/m²
Solar PV parks (N.Europe): 5 W/m²
Solar PV parks (sunny locations)
Concentrating solar power: 20 W/m²
UK sun, before conversion: 110 W/m²
Desert sun, before conversion: 250 W/m²
1000 W/m²
10 W/m²
1 W/m²
0.1 W/m²
0.01 W/m²
0.001 W/m²
Qatar
United States
Canada
Australia
Russia
Libya
France
Germany
S. Korea
Japan
United Kingdom
Portugal
Singapore
Hong Kong
China
Algeria
Brazil
Sudan
India
Bangladesh
1000
100
10
energy consumption per person (kWh/d/p)
10
100
1000
10000
population density (people per km²)

Wind	$2.5\,\mathrm{W/m^2}$
Plants	$0.5\,\mathrm{W/m^2}$
Solar PV panels	$5\text{–}20\,\mathrm{W/m^2}$
Tidal pools	$3\,\mathrm{W/m^2}$
Tidal stream	$8\,\mathrm{W/m^2}$
Rain-water (highlands)	$0.24\,\mathrm{W/m^2}$
Concentrating solar power (desert)	$15\text{–}20\,\mathrm{W/m^2}$


Goose Hill
9
Suffolk Coast
Visitor Centre
Power Station
Twr
P
Twr
PC
Sizewell
PH
vay

$1000\,W/m^2$

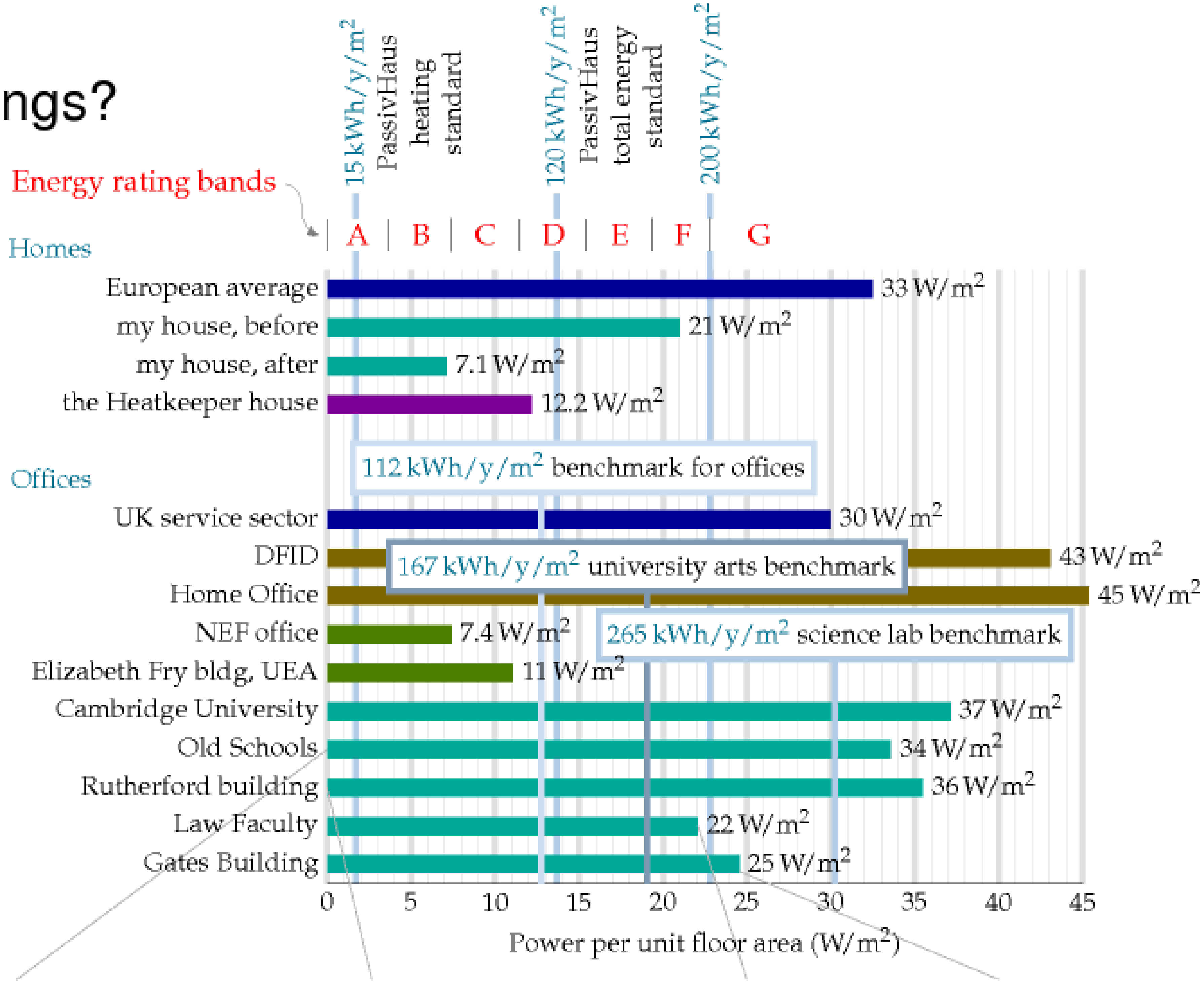
Power consumption of suburbia

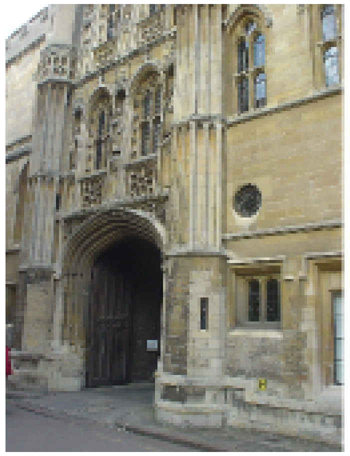
6750 m² / 0.6750 hectares / 0.006750 km² / 7.265e+4 ft² / 1.668 acres / 0.002606 mile²

$$\frac{60\,\mathrm{kWh/d}}{44\,\mathrm{m}^2} = 54\,\mathrm{W/m}^2 \qquad \frac{60\,\mathrm{kWh/d}}{420\,\mathrm{m}^2} = 5.7\,\mathrm{W/m}^2$$

$$\frac{13\,\mathrm{kWh/d}}{44\,\mathrm{m}^2} = 12\,\mathrm{W/m}^2 \qquad \frac{13\,\mathrm{kWh/d}}{420\,\mathrm{m}^2} = 1.2\,\mathrm{W/m}^2$$

Energy-efficient, award-winning buildings?




Old Schools


Rutherford building


Law faculty


Gates building

Every little helps

10f

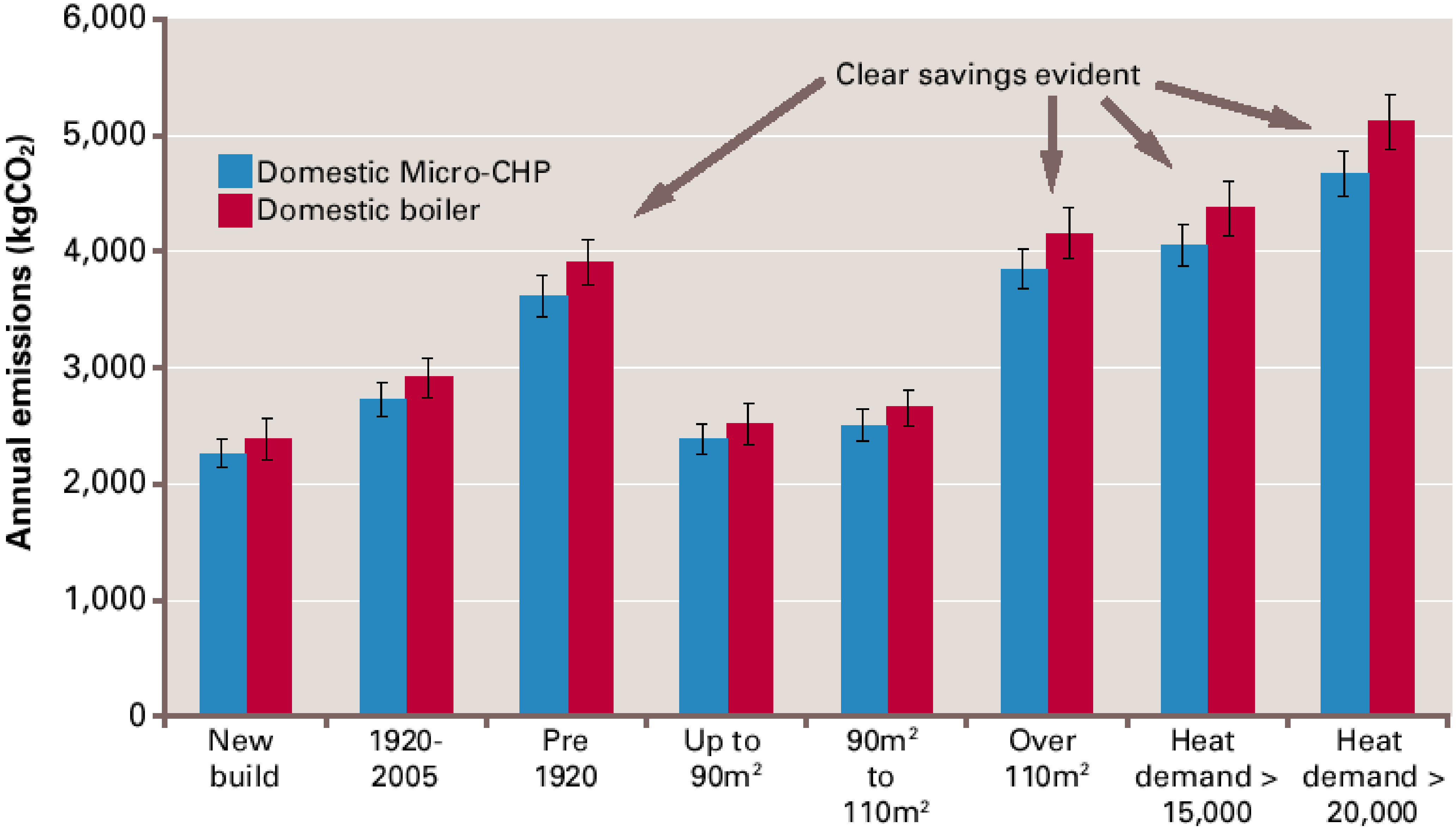
**If everyone does a little,
you'll get a little**

Carbon Trust on Micro-CHP

(combined heat and power) (cogeneration)

"Micro-CHP is an emerging set of technologies with the potential to provide carbon savings in both commercial and domestic environments."

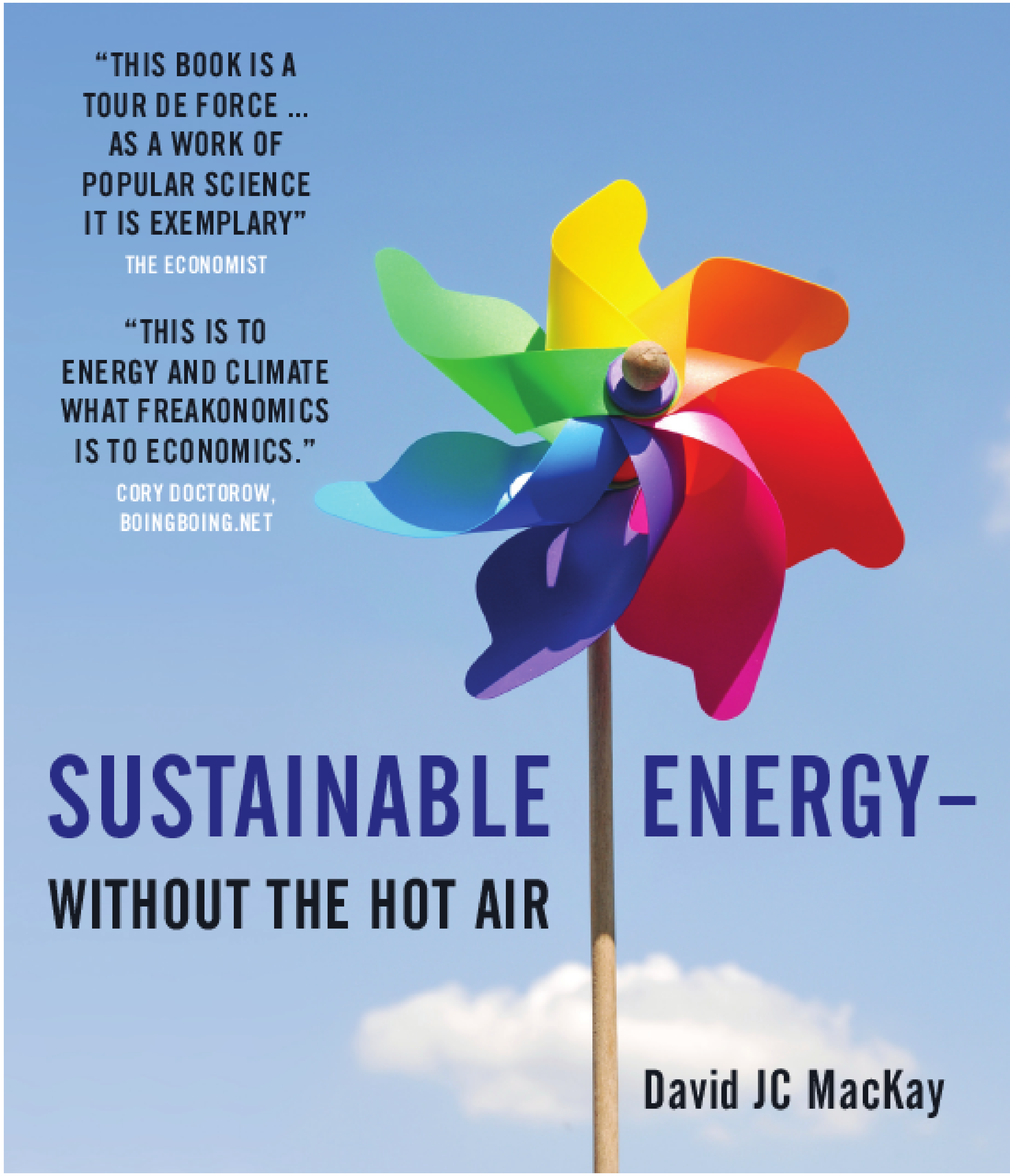
Figure 50 *Annual Micro-CHP and boiler emissions for cluster scenarios*



Something must be done!

Photos by Chris Jordan

This book is free online



"THIS BOOK IS A TOUR DE FORCE ... AS A WORK OF POPULAR SCIENCE IT IS EXEMPLARY"
THE ECONOMIST

"THIS IS TO ENERGY AND CLIMATE WHAT FREAKONOMICS IS TO ECONOMICS."
CORY DOCTOROW,
BOINGBOING.NET

SUSTAINABLE ENERGY–
WITHOUT THE HOT AIR

David JC MacKay

www.withouthotair.com