2050 Pathways

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DEPARTMENT OF ENERGY & CLIMATE CHANGE

2050-calculator-tool.decc.gov.uk

http://tinyurl.com/2050decc

http://tinyurl.com/2050decc2

The 2050 Pathways Approach

- For each demand sector, and each supply sector
  - lay out the range of what's technically possible
    - or what might be technically possible
  - four trajectories, 'level 1' to 'level 4'
- Build a model of the energy system
  - - a calculator that computes the consequences of any set of choices ('pathway')
- Explore which pathways meet goals of
  - energy security
  - carbon emissions reductions
- It's challenging ... but it is possible!

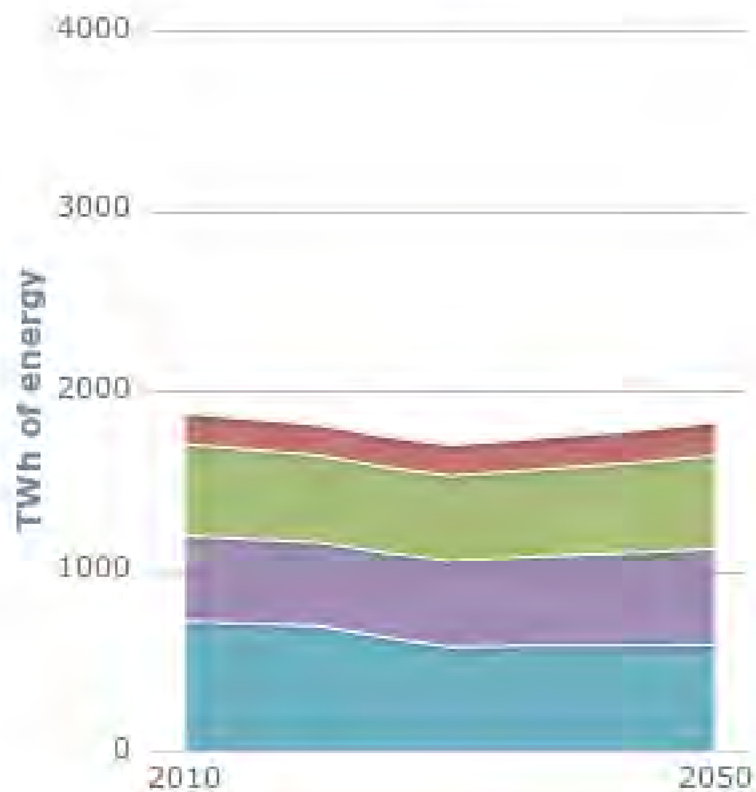
Sector trajectories

- Level 1
  - No effort towards security of supply, energy saving, or climate change
- Level 2
  - Effort likely to be viewed as achievable by most or all stakeholders
- Level 3
  - Effort that is unlikely to happen without significant change from current systems
- Level 4
  - Effort at the extreme upper end of the believable scale:

    heroic without being physically impossible

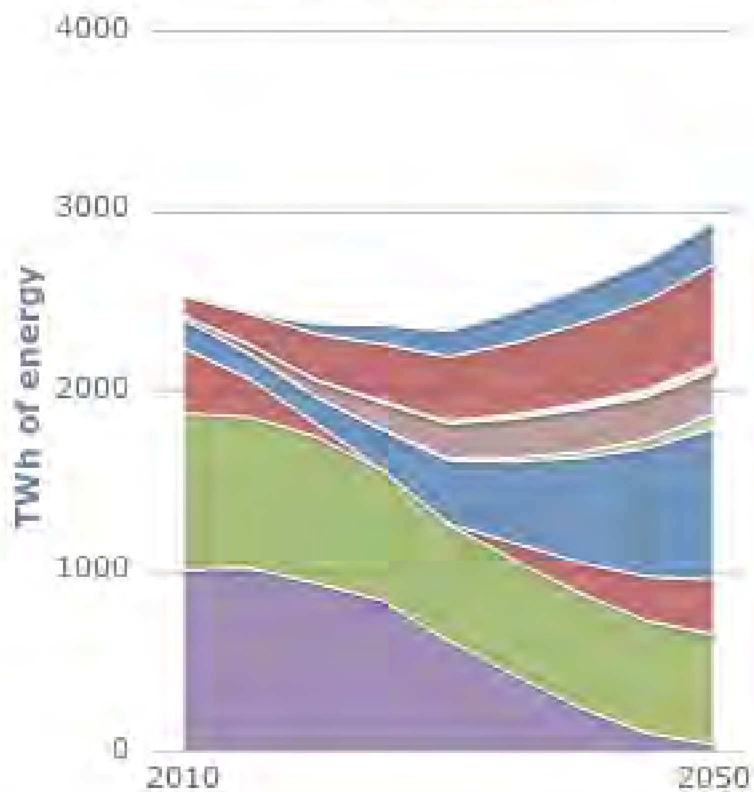
Very high levels of behaviour change. Any technology that is physically possible and might be developed + deployed before 2050. A level of build effort commensurate with that pursued during World War II or the American efforts for a manned moon landing

UK demand for energy

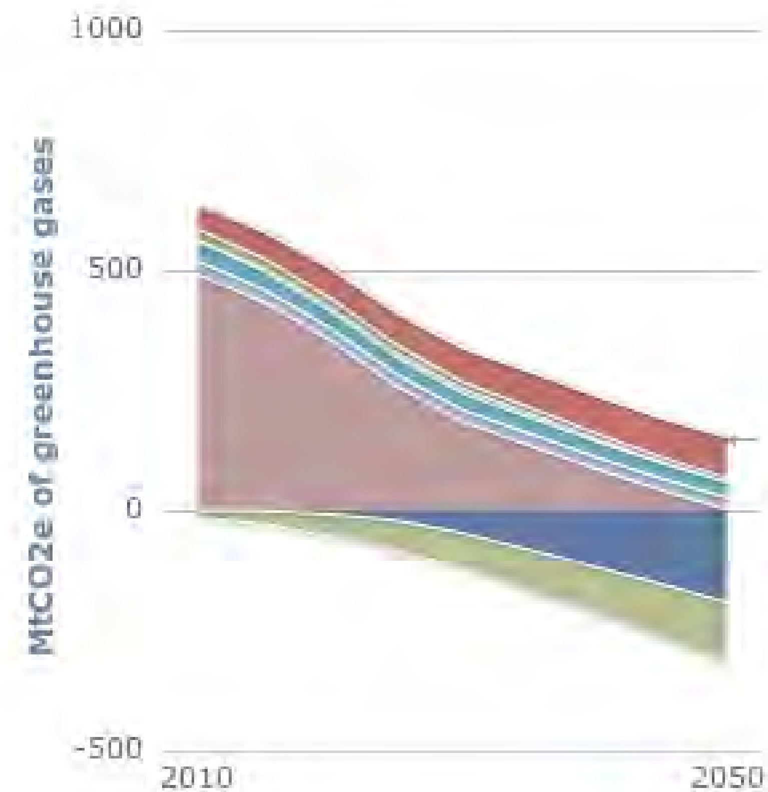


UK supply of primary energy

Switch to chart showing just electricity



Net UK Greenhouse gas emissions



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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
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2020 energy imports	35%	of primary energy
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2050 5 still winter days	100%	of electricity reserves used
and	2	GW of standby generation required
Difficulty	74	Lowest: 35. Highest: 140

Demand-side options - heating

options for energy-saving:

- Reduce temperature difference
  - Turn the thermostat down
- Reduce leakiness
- Increase CoP of heat-creation

$$\underset{(\text{kWh/d})}{\boxed{\text{Heat loss}}} = \underset{(\text{kWh/d/°C})}{\text{Leakiness}} \times \underset{(\text{°C})}{\text{Average temperature difference}}$$

$$\text{Power required} = \boxed{\text{Heat loss}} \Big/ \begin{array}{c}\text{Coefficient of performance}\\ \text{of heat-creation}\end{array}$$

Reduce leakiness

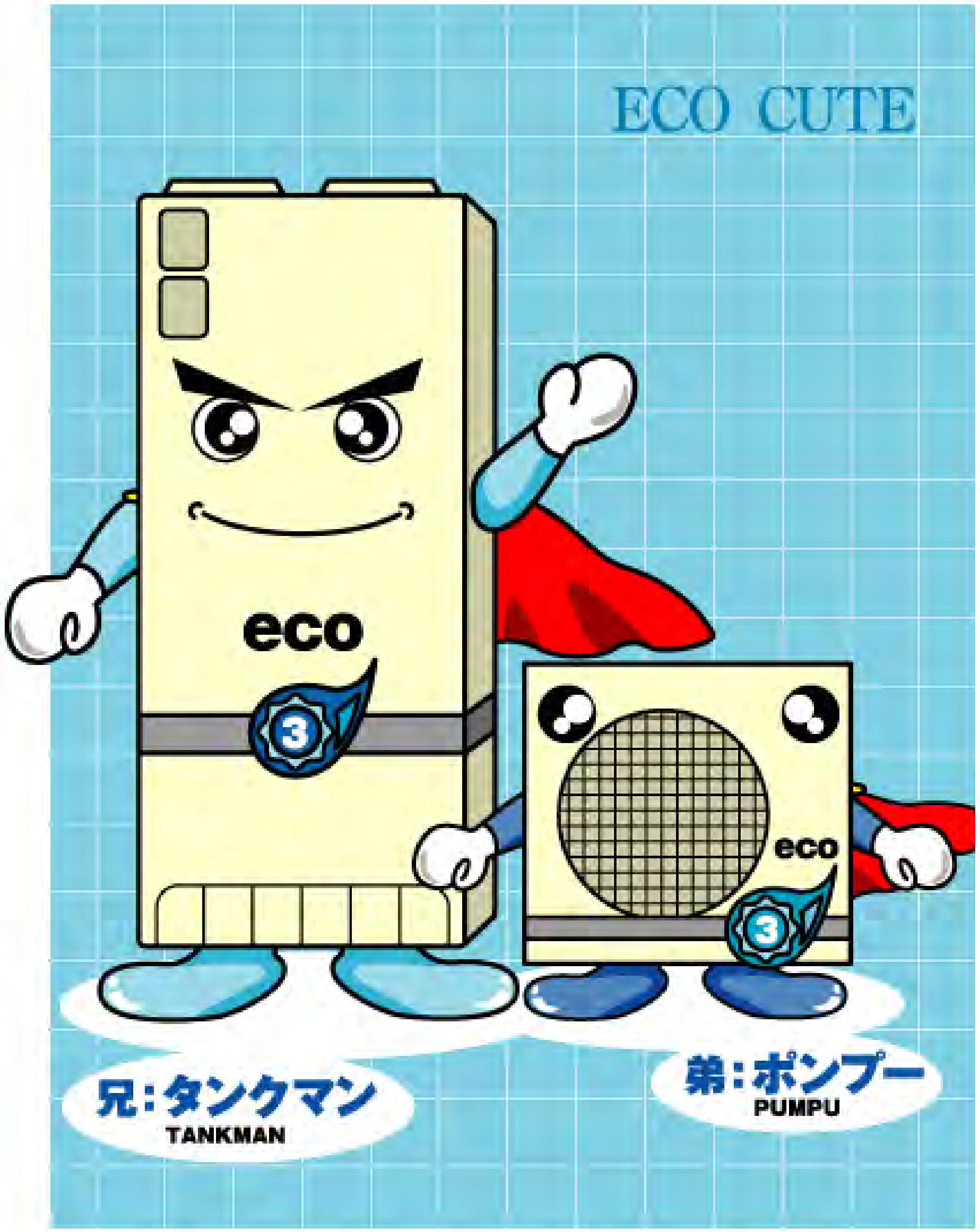
⟵ Leakiness: 8 kWh/d/°C

New leakiness: 6 kWh/d/°C

German insulation retrofit

photos by pollok-gonzalo.de

Increase coefficient of performance - use Heat pumps



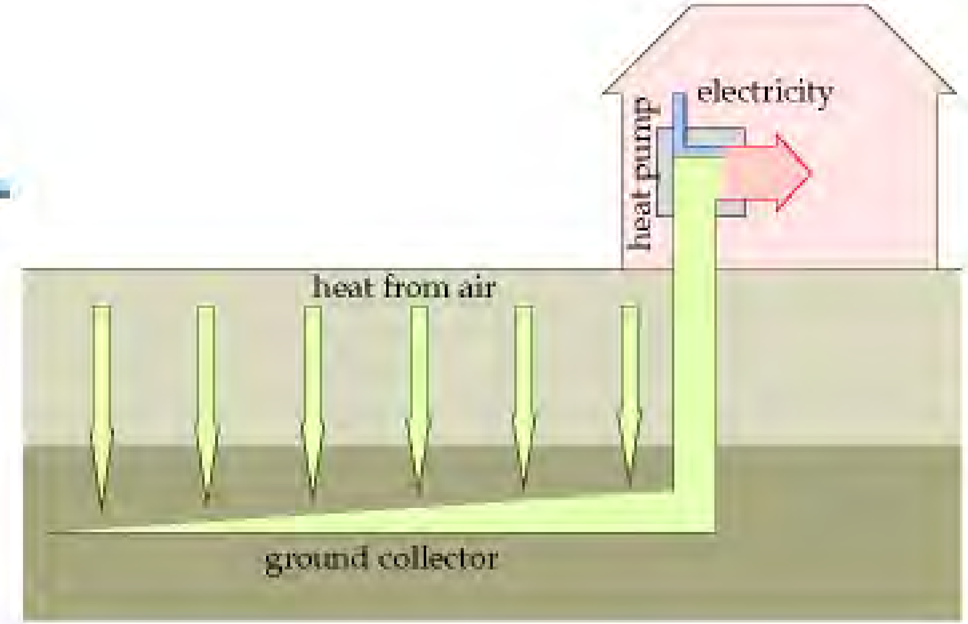
http://www.ecosystem-japan.com/

EcoCute water heater - CoP = 4.9!

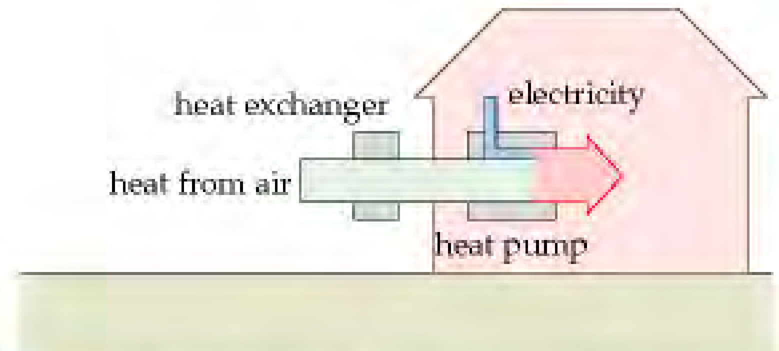
$$\text{Power required} = \boxed{\text{Heat loss}} \Big/ \begin{array}{c}\text{Coefficient of performance}\\ \text{of heat-creation}\end{array}$$

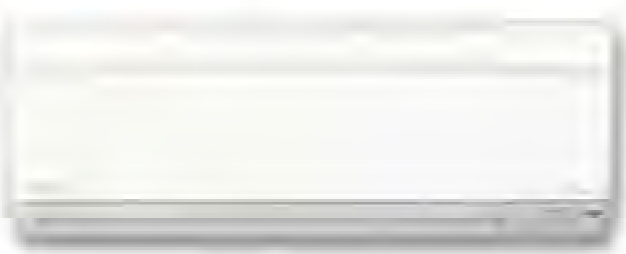
Heating without fossil fuels

- Heat pumps, powered by electricity
  - Ground-source heat pumps



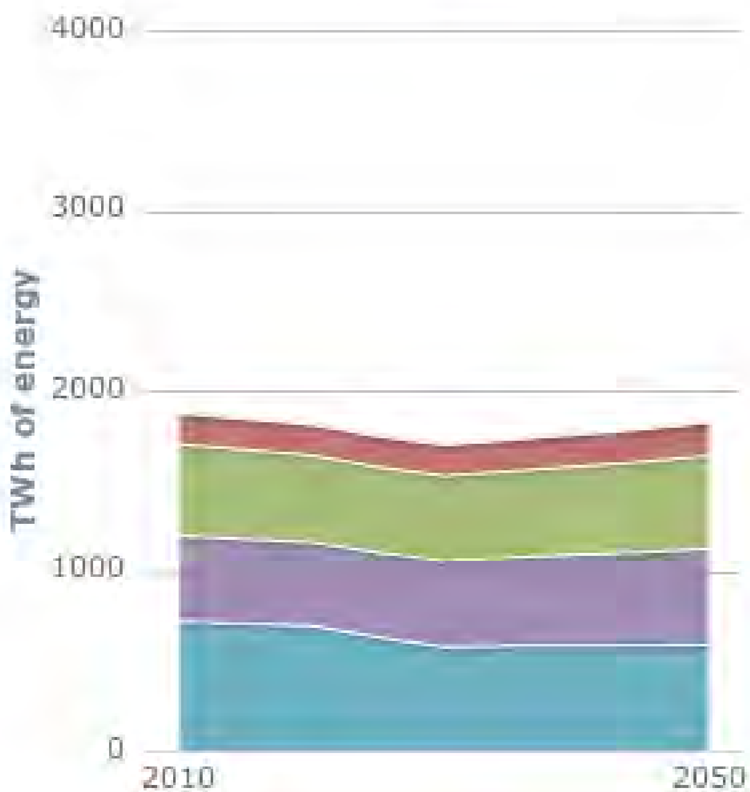
  - Air-source heat pumps





4 times more efficient than ordinary electric heating

UK demand for energy



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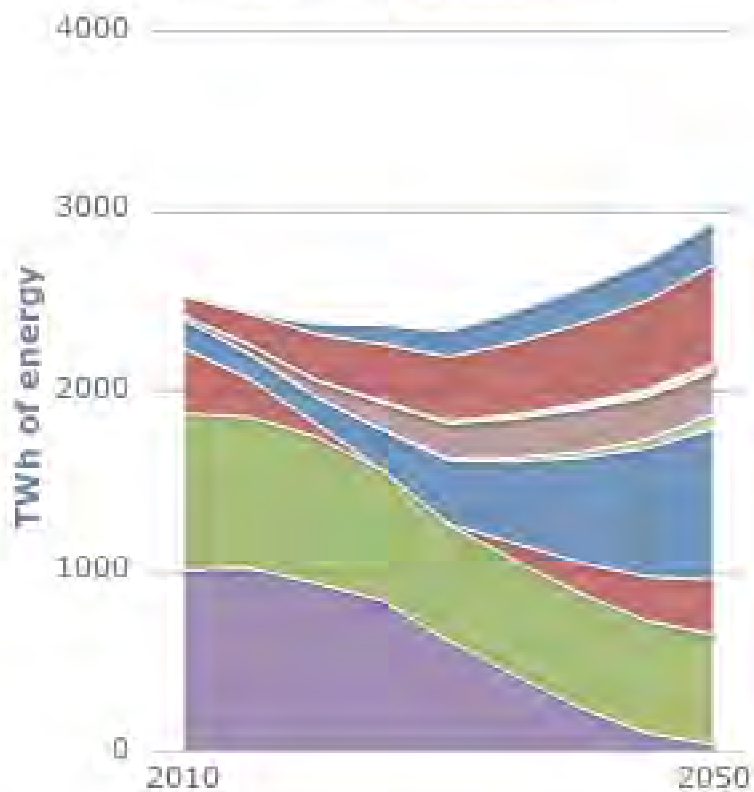

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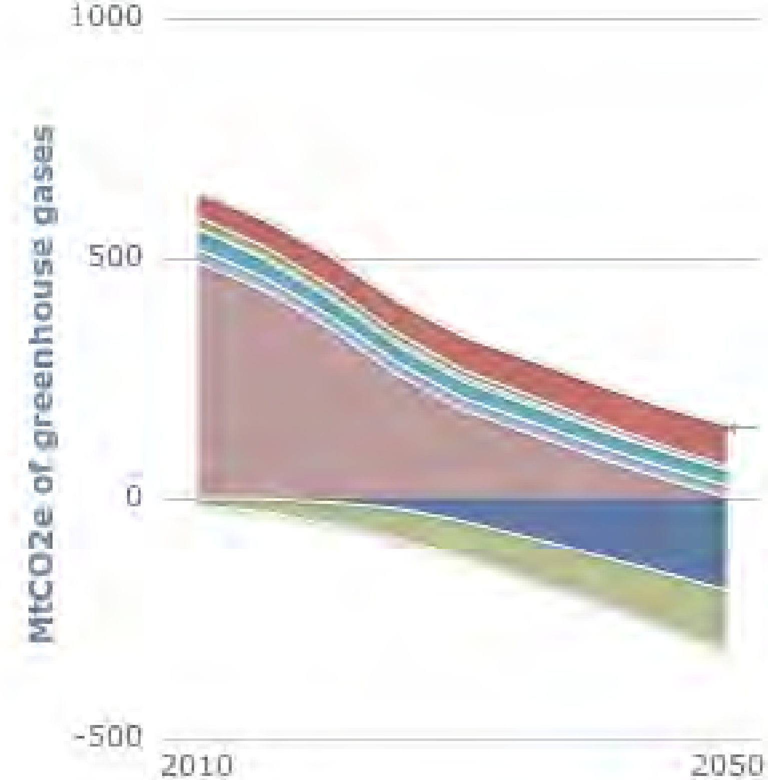

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Efficient transport

Have small frontal area per person

Have small weight per person

Go slowly

Go steadily

Convert energy
efficiently

Average UK car uses
80 kWh per 100 person-km (1 person)

1 kWh per 100 person-km (3 people)

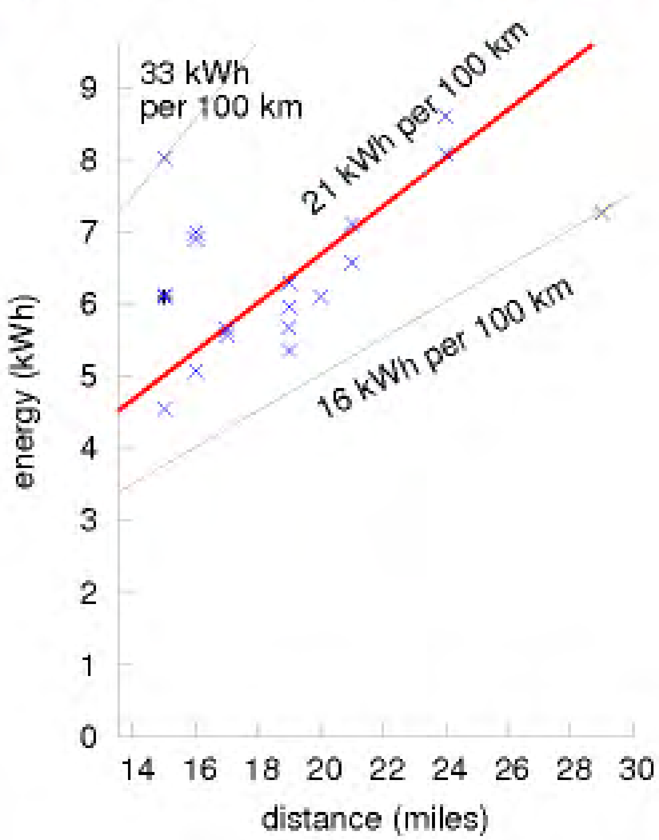
How can this consumption be reduced?

6 kWh per 100 person-km average (electric)
3 kWh per 100 person-km (electric) if full

Electric cars

G-Wiz

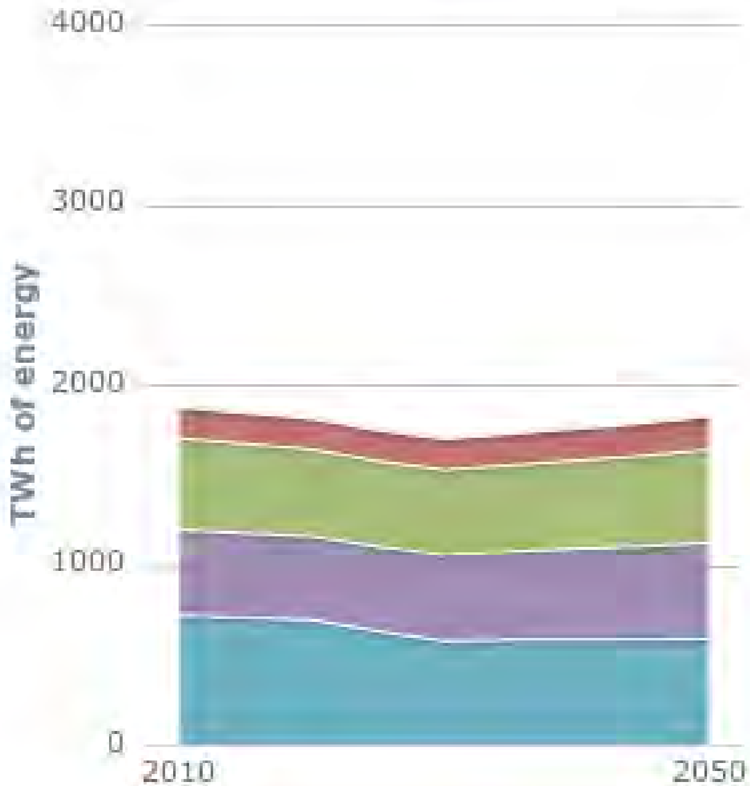
- 21 kWh per 100 km (solo)
  - equivalent to 125 miles per gallon



data from Kele Baker

6 kWh per 100 km

UK demand for energy



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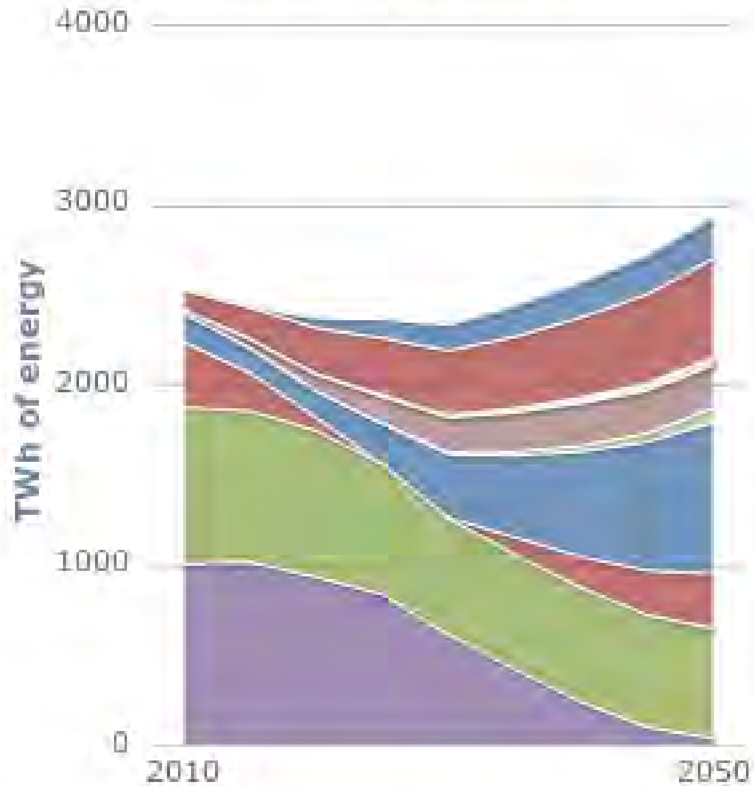

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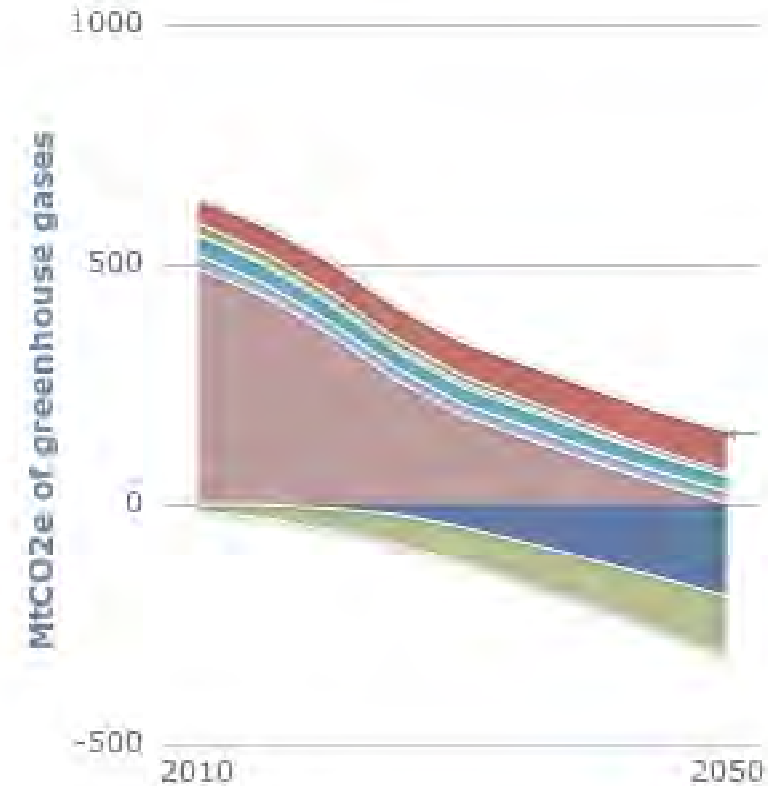

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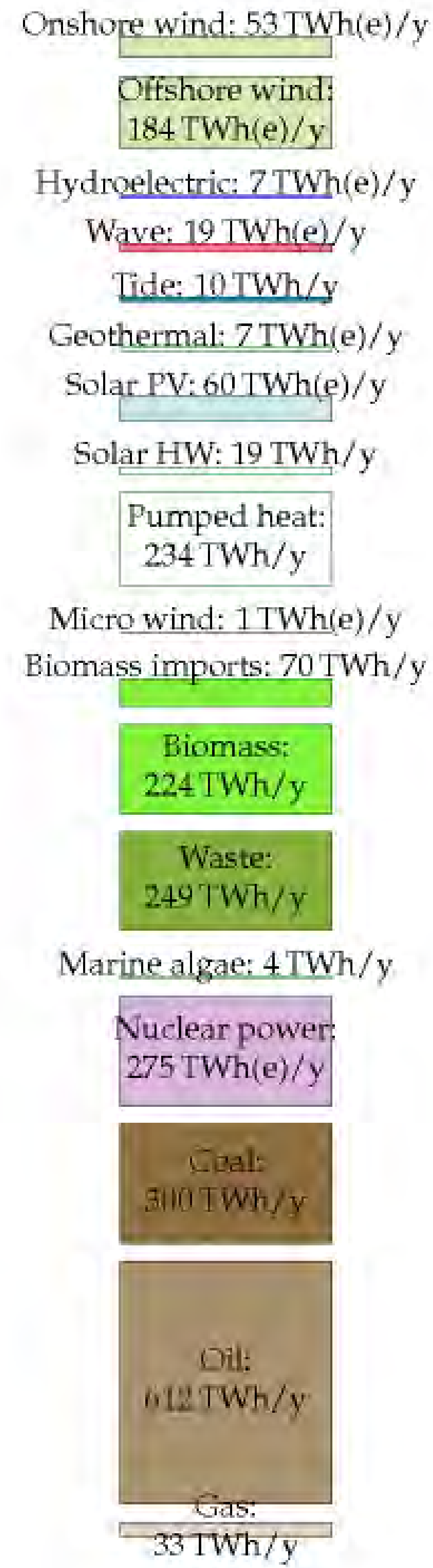
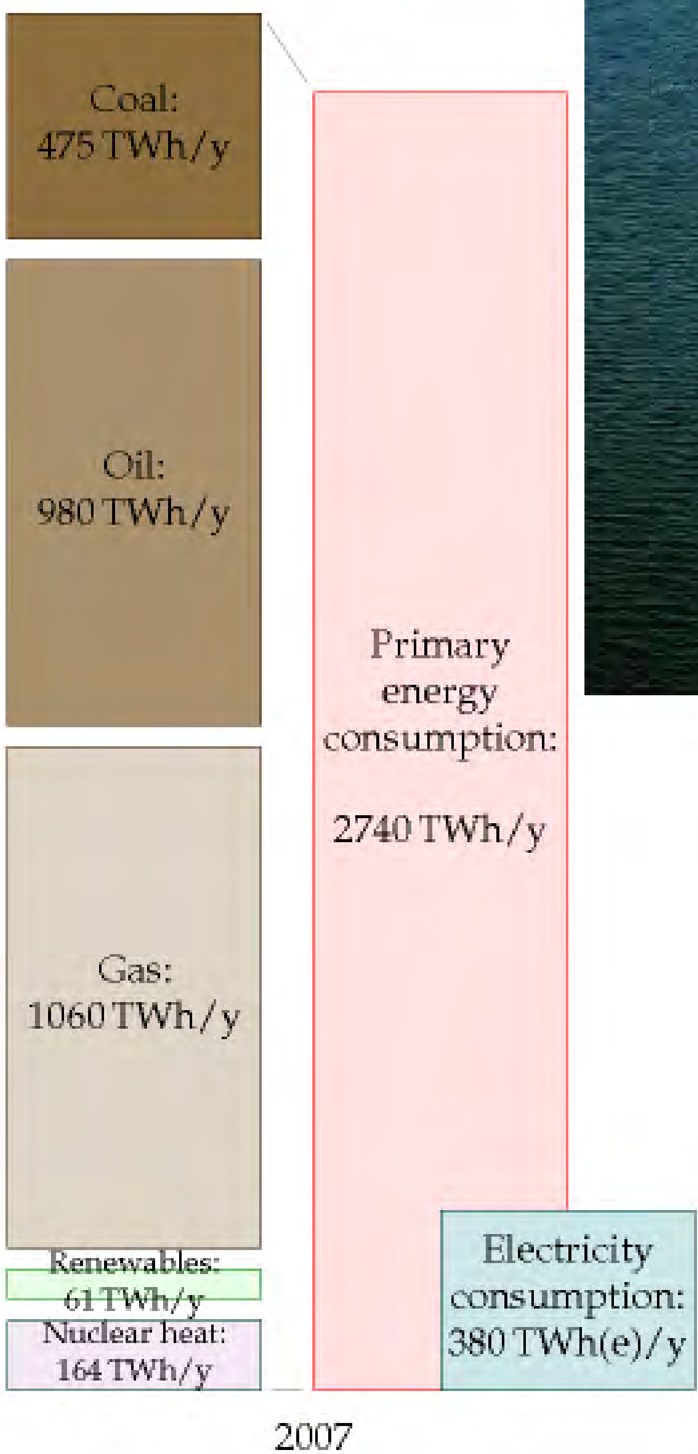
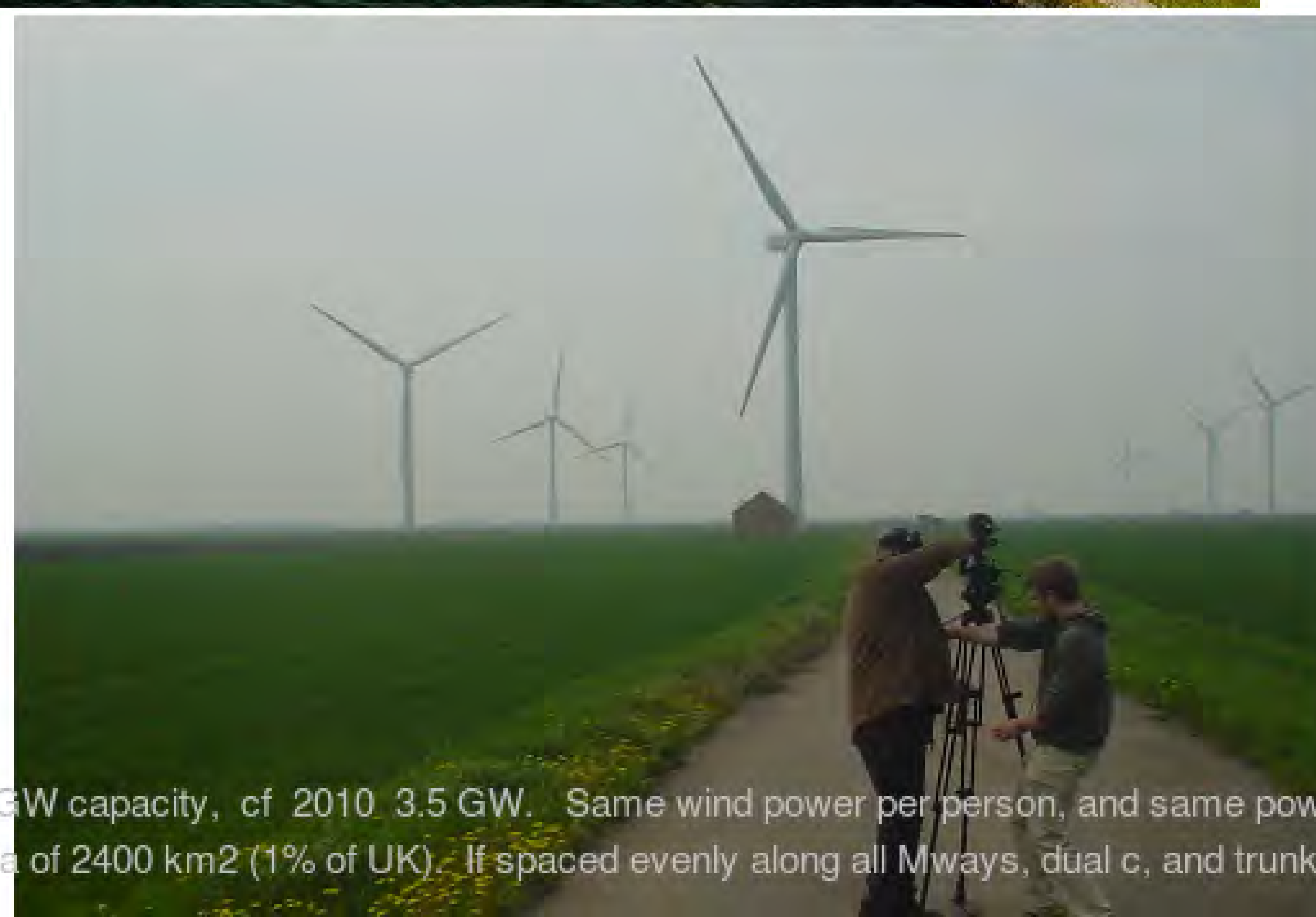
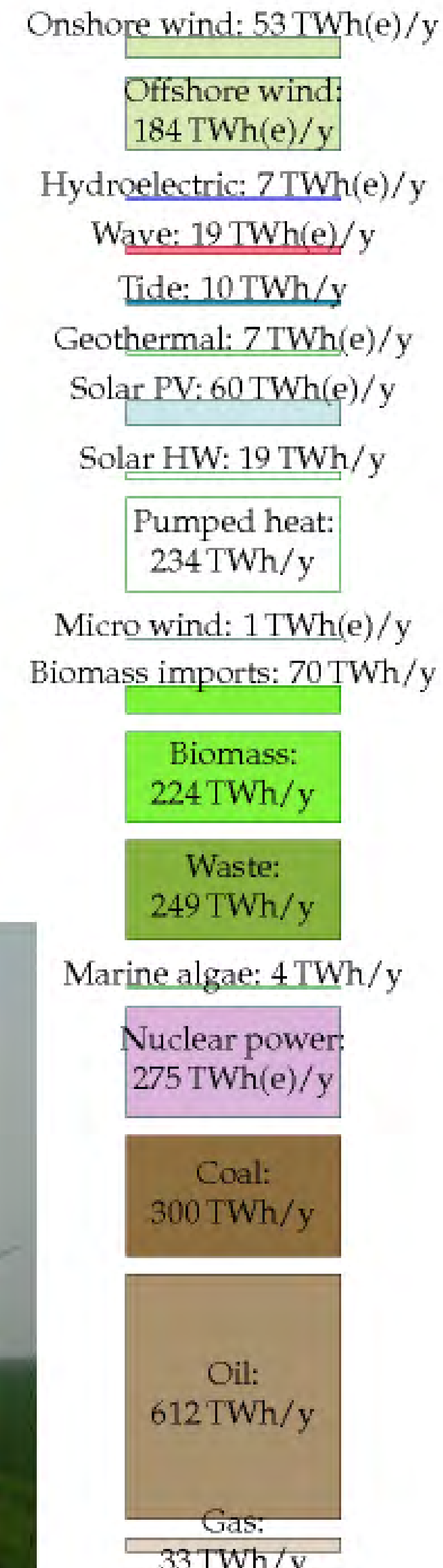
Pathway alpha - supply side



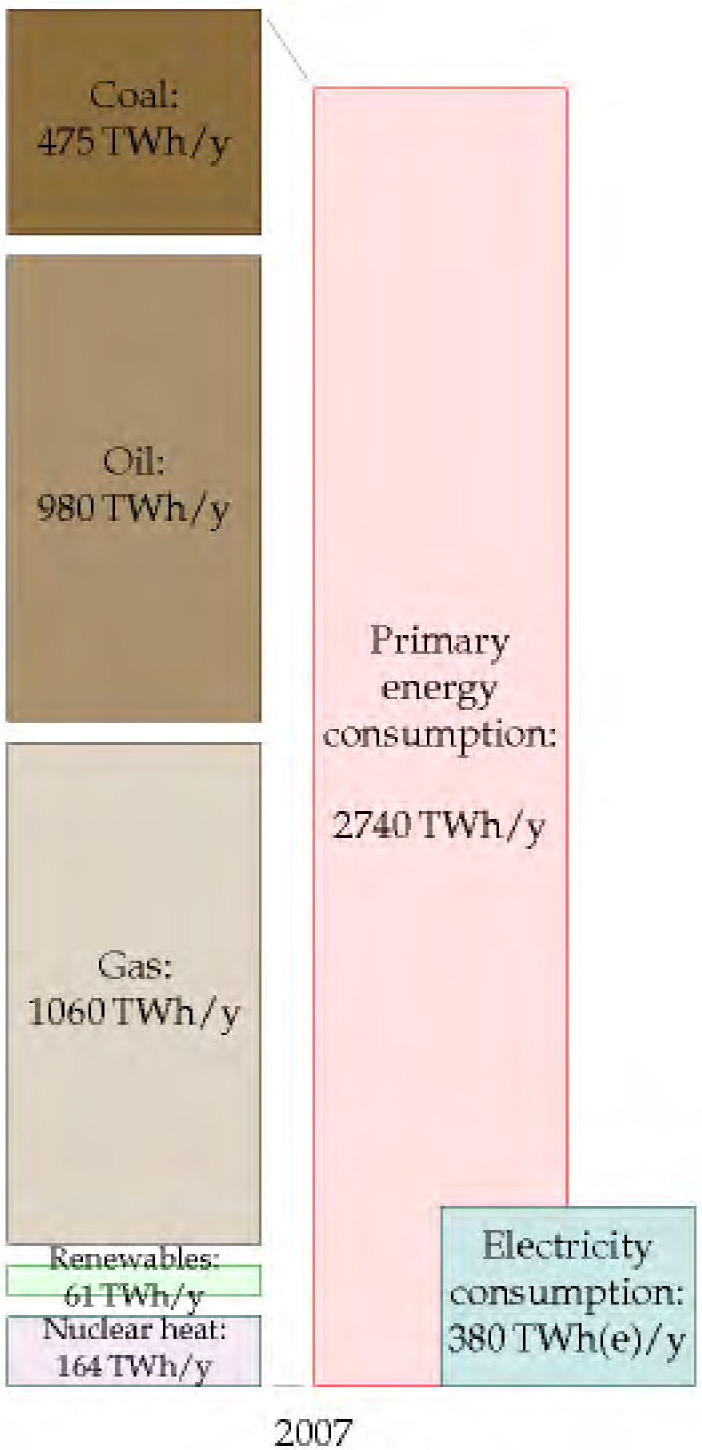


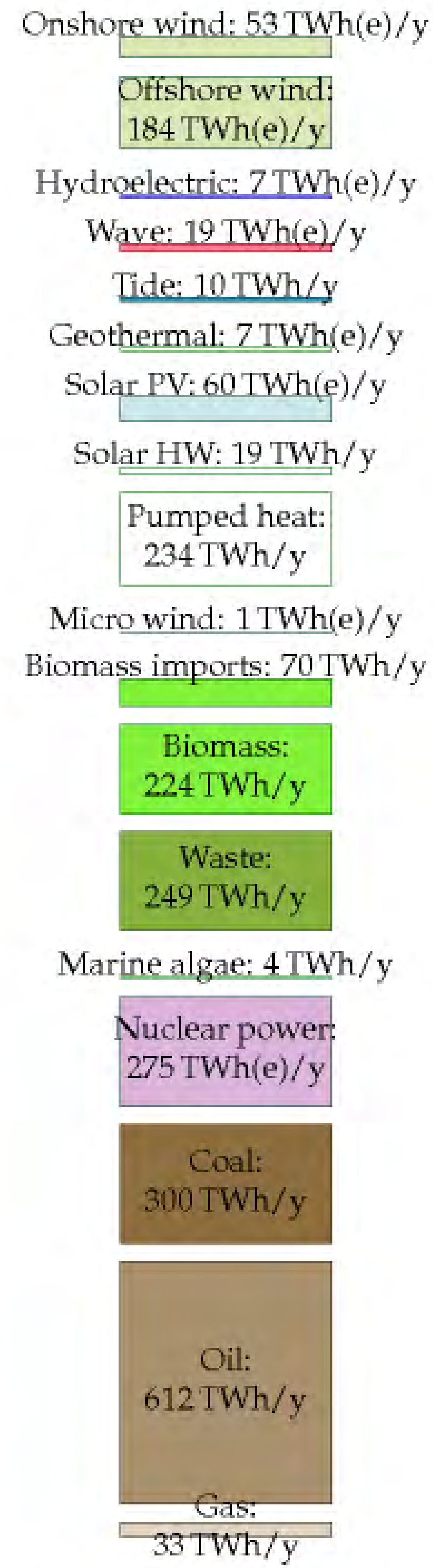




7-fold increase 53 TWh/y 20 GW capacity, cf 2010 3.5 GW. Same wind power per person, and same power per area as Germany

10,000 2MW turbines use an area of 2400 km2 (1% of UK). If spaced evenly along all Mways, dual c, and trunk roads, one every 1.2km



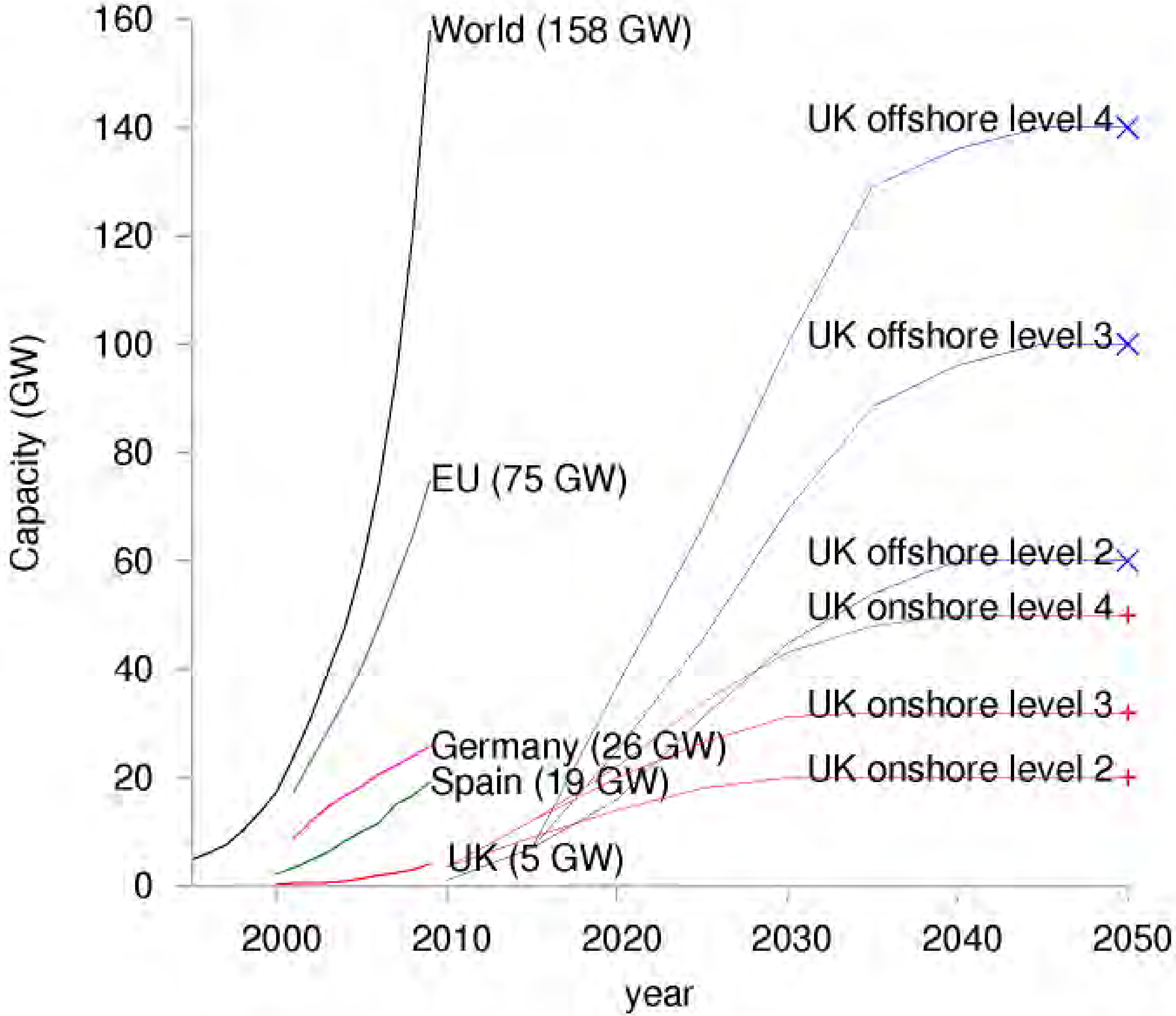


18 Jackup barges

60-fold increase 184 TWh/y 60 GW capacity, cf 2010 1 GW. 20,000 3MW turbines, area 8400 km2 - nearly half a Wales.

If spaced evenly around 3000 km of coastline, there would be 3 per km.

Wind trajectories



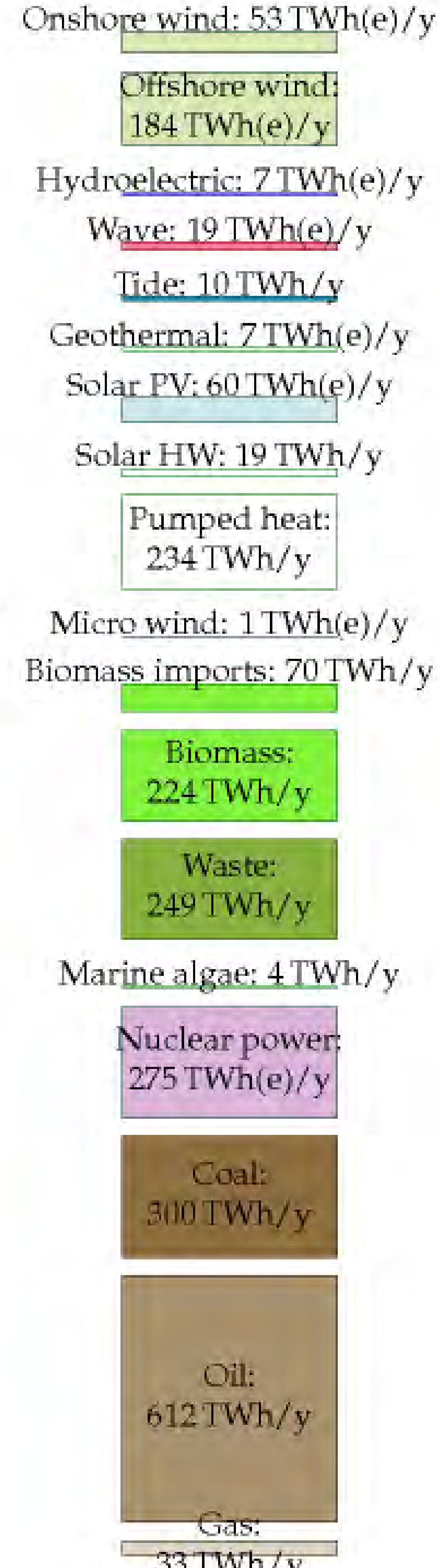
level 2: installing 4-7 wind turbines per day - similar to output of all Denmark's factories

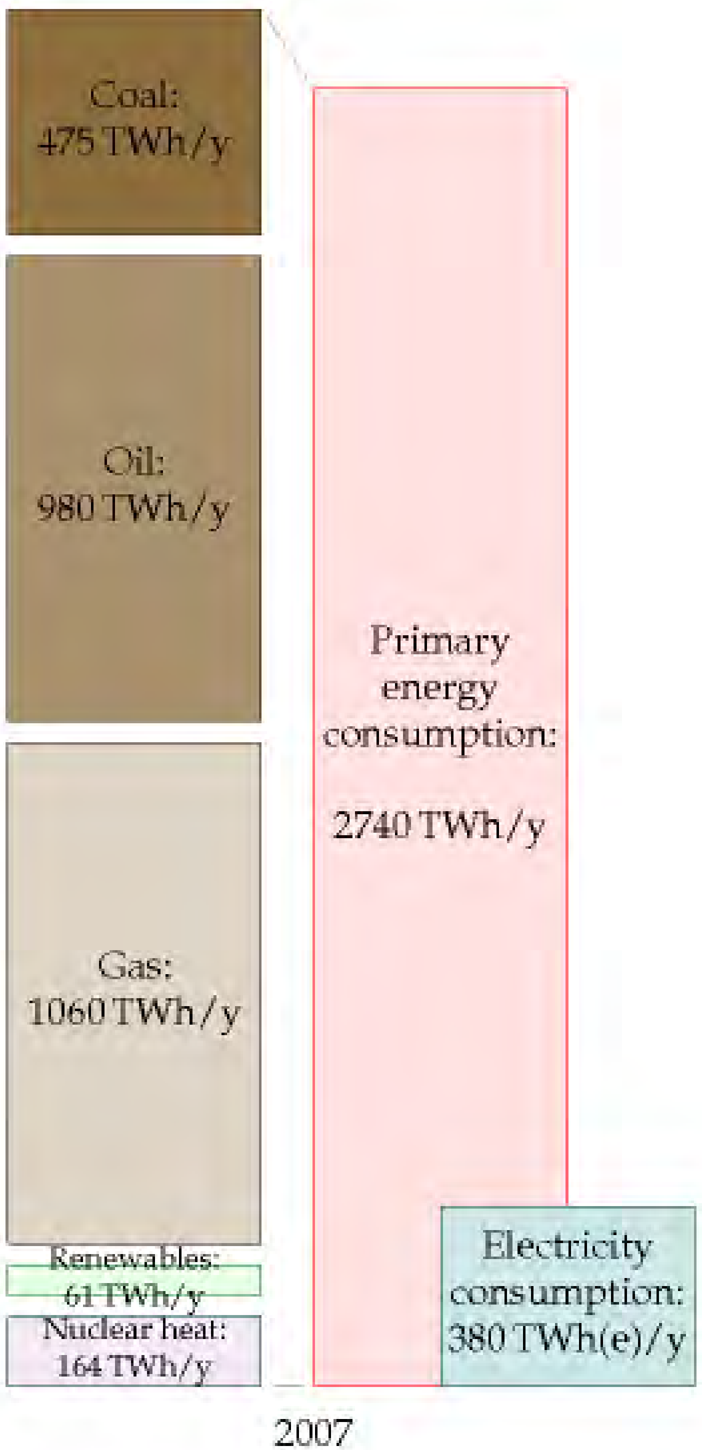
Overall increase in wind: 4.5GW (2010) to 80 GW - 18-fold increase

8000 Pelamises
- one every 40 m
for 300 km

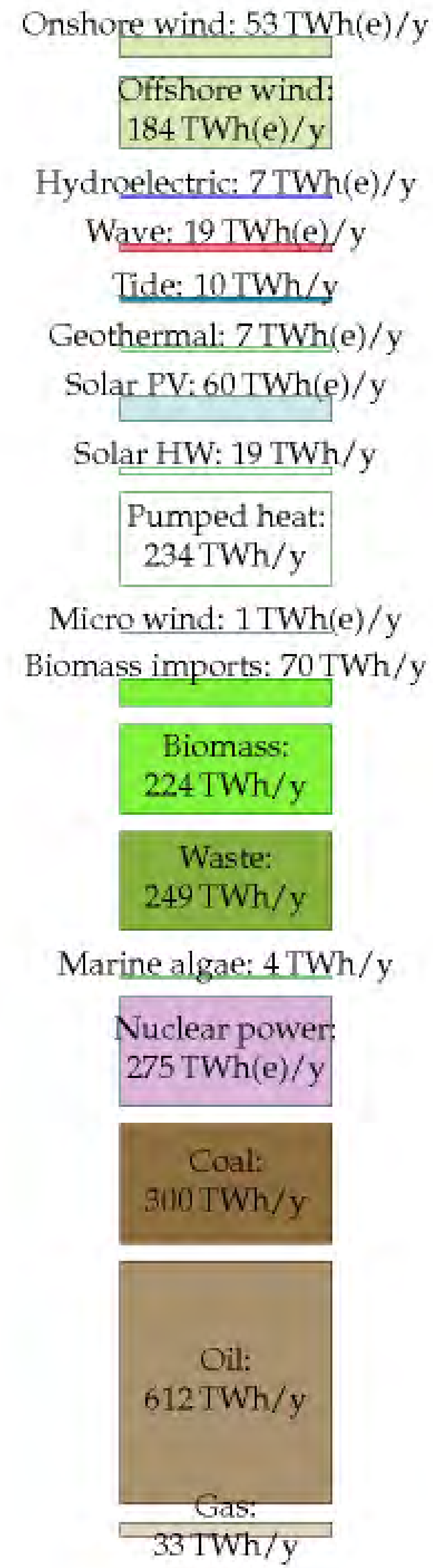
1700 Seagens

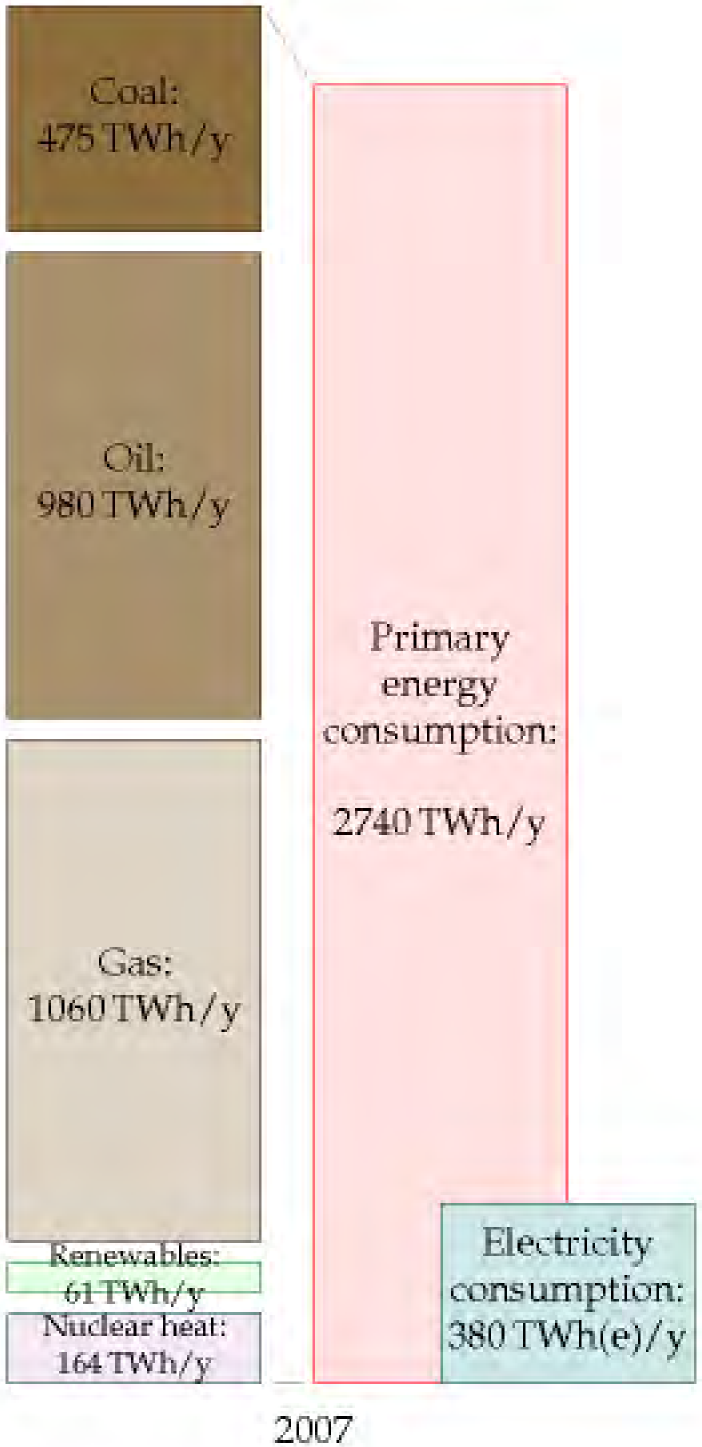
and 130 square km of lagoons or estuaries



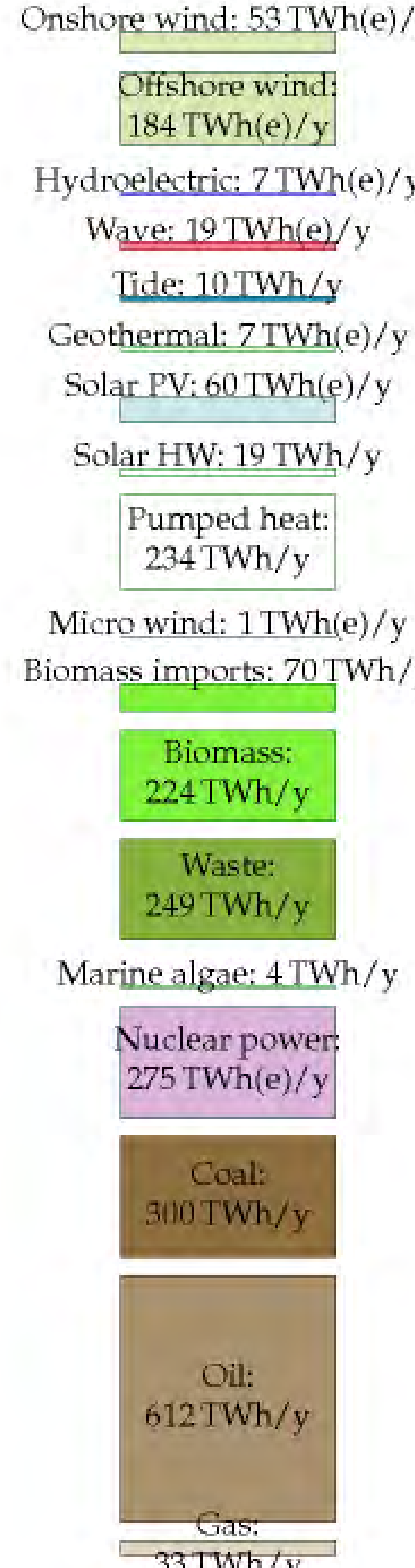


34-million roof-top systems,
10 sq m each
- 4000-fold increase in PV

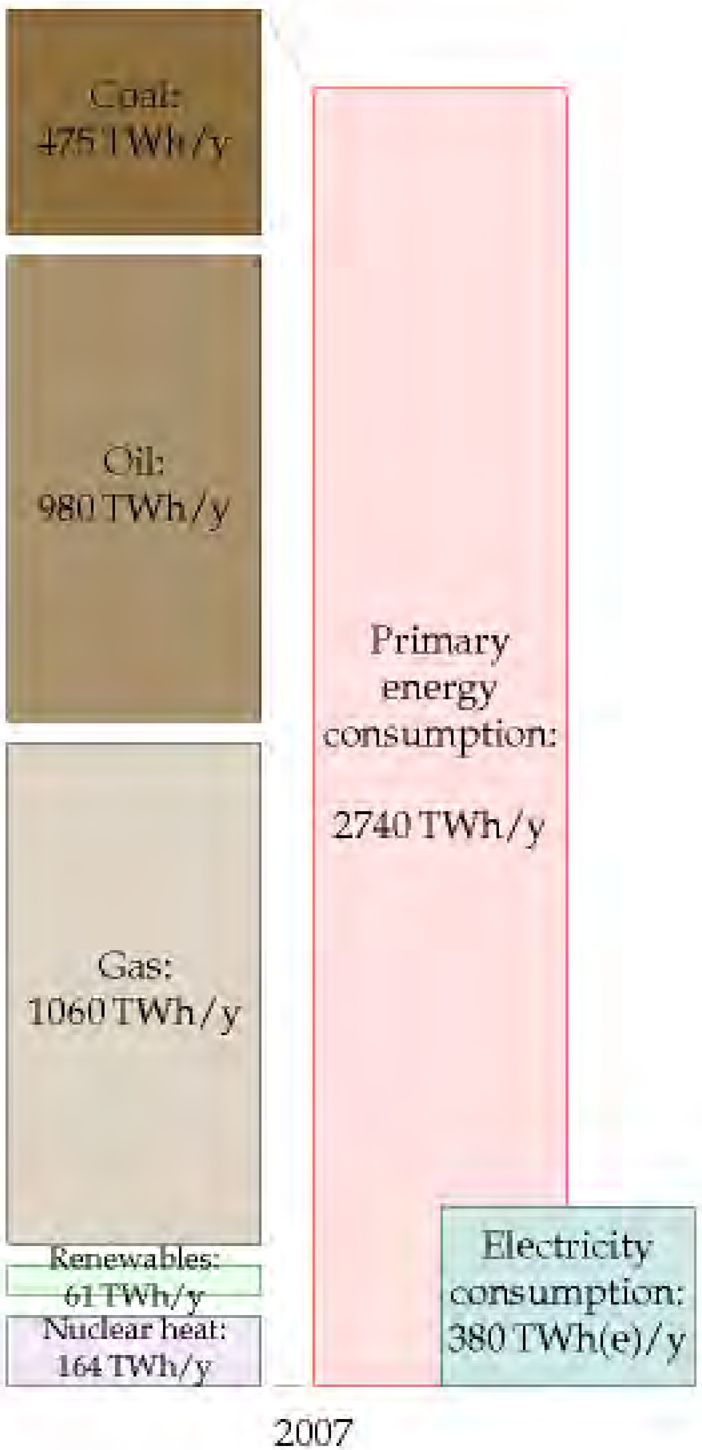


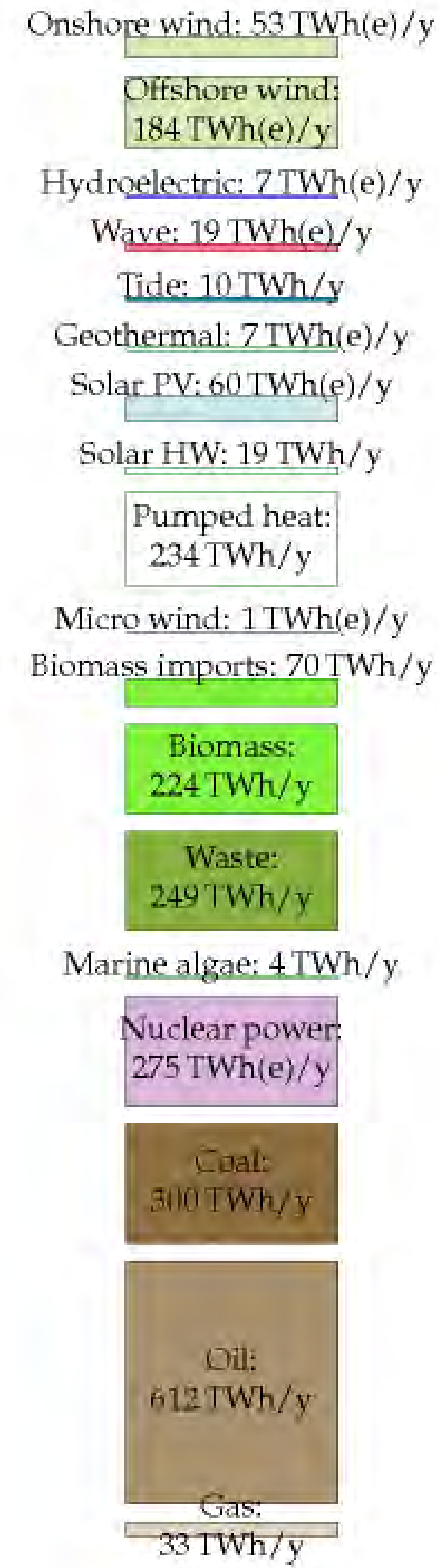


14 million
solar-hot-water systems,
3 sq m each

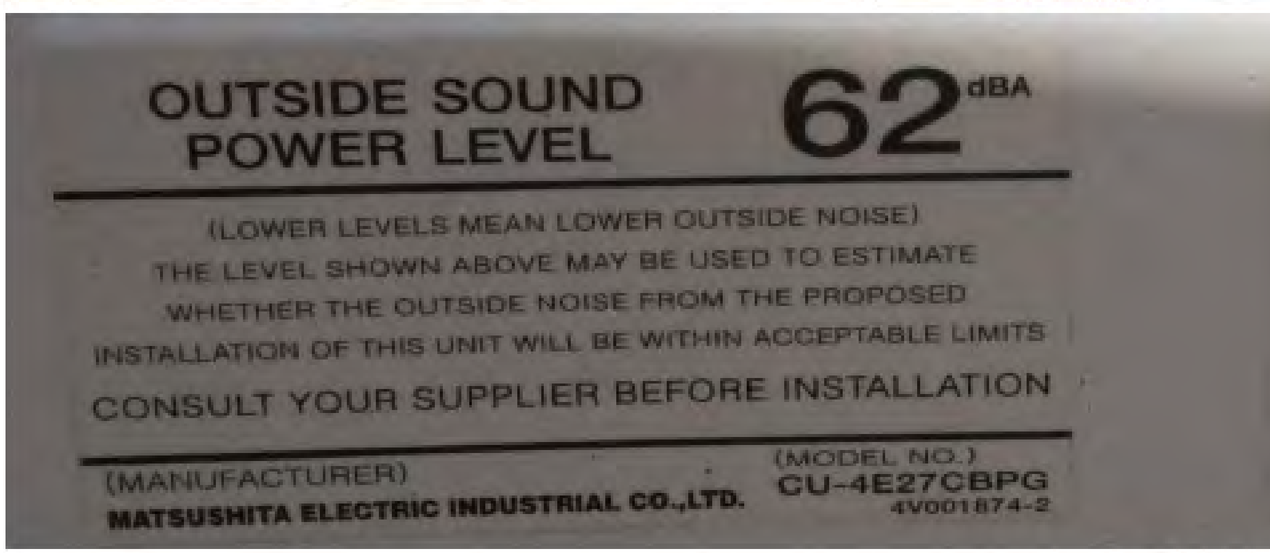


20 million heat pumps



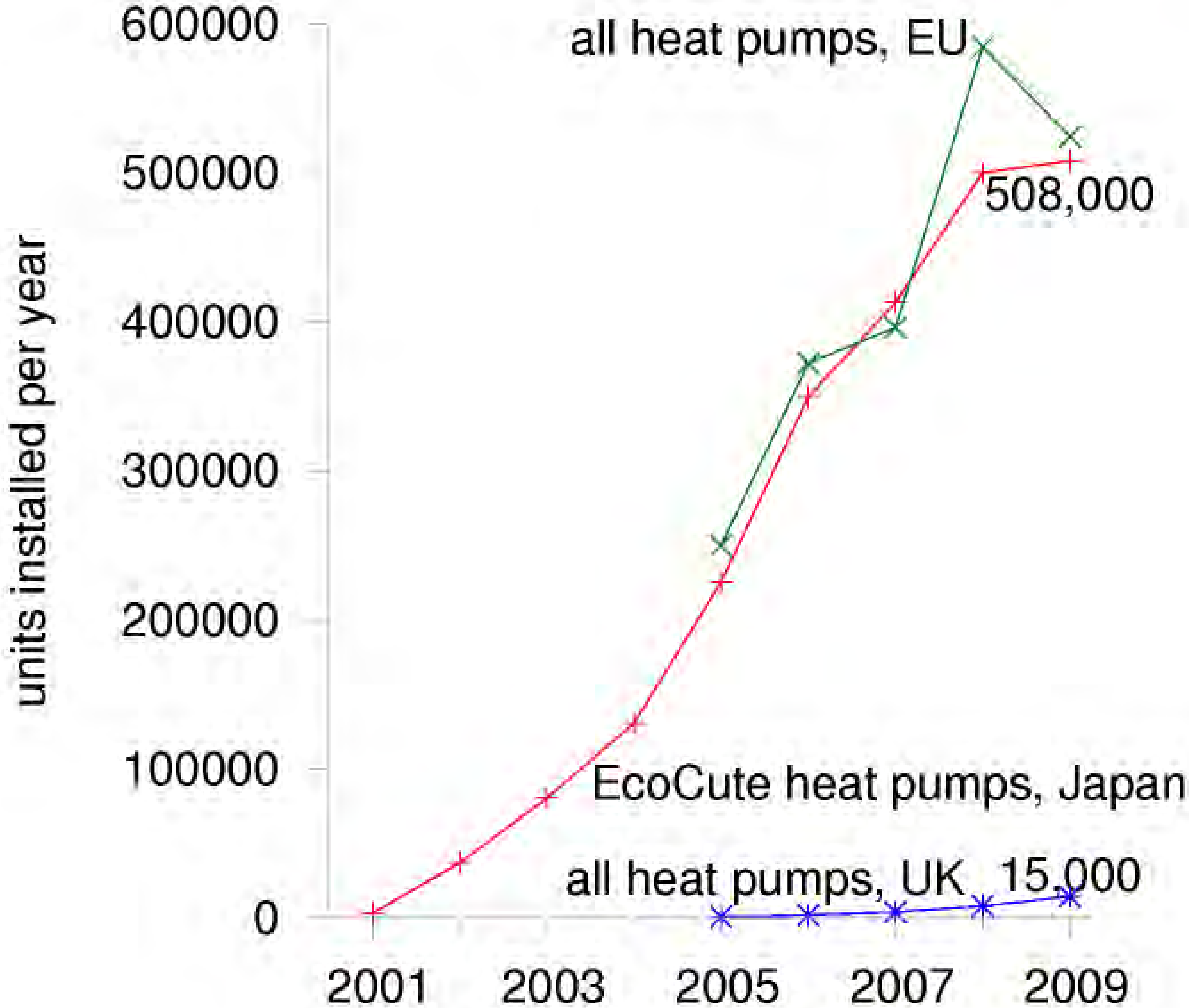


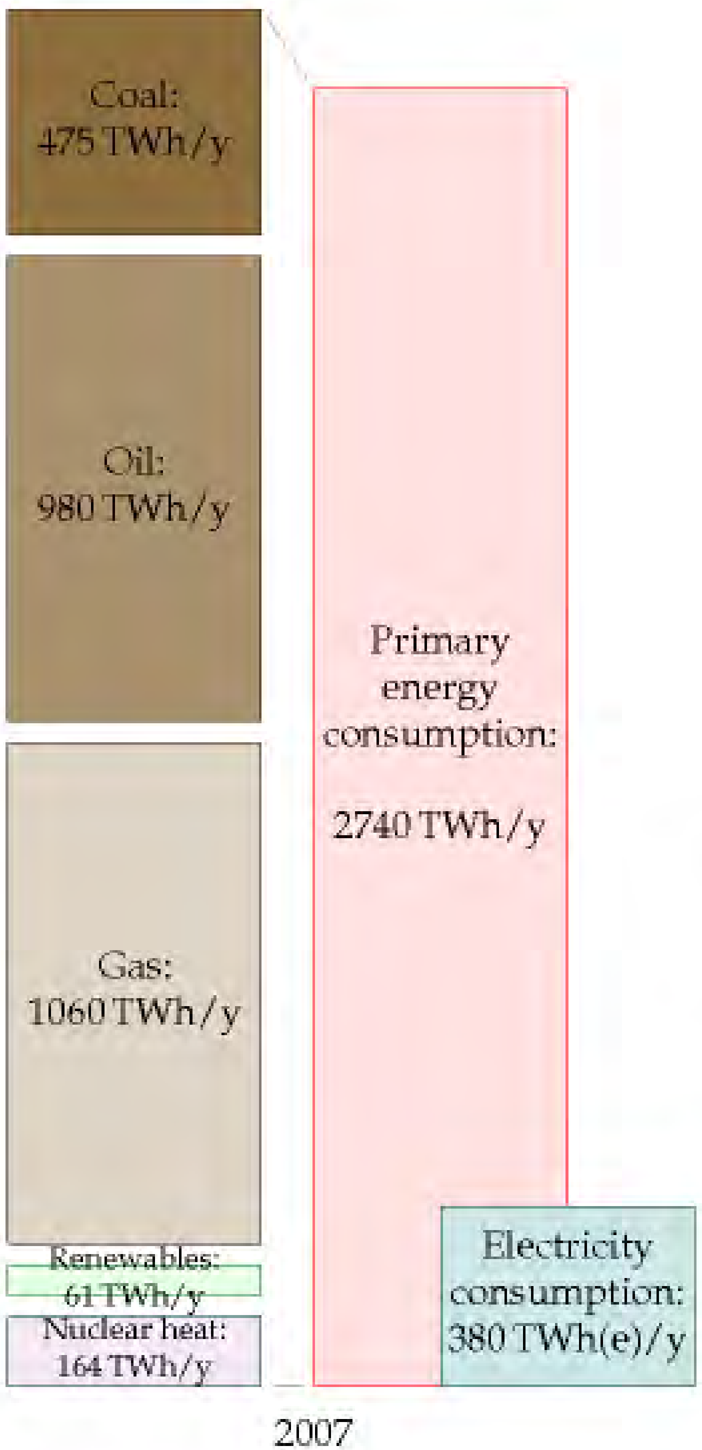
Retrofitted air-to-air air-source heat pump



Claimed COP: 4.5

Heatpump installation rates (Japan, EU, UK)





Biomass imports:

13,000 sq km in someone else's country

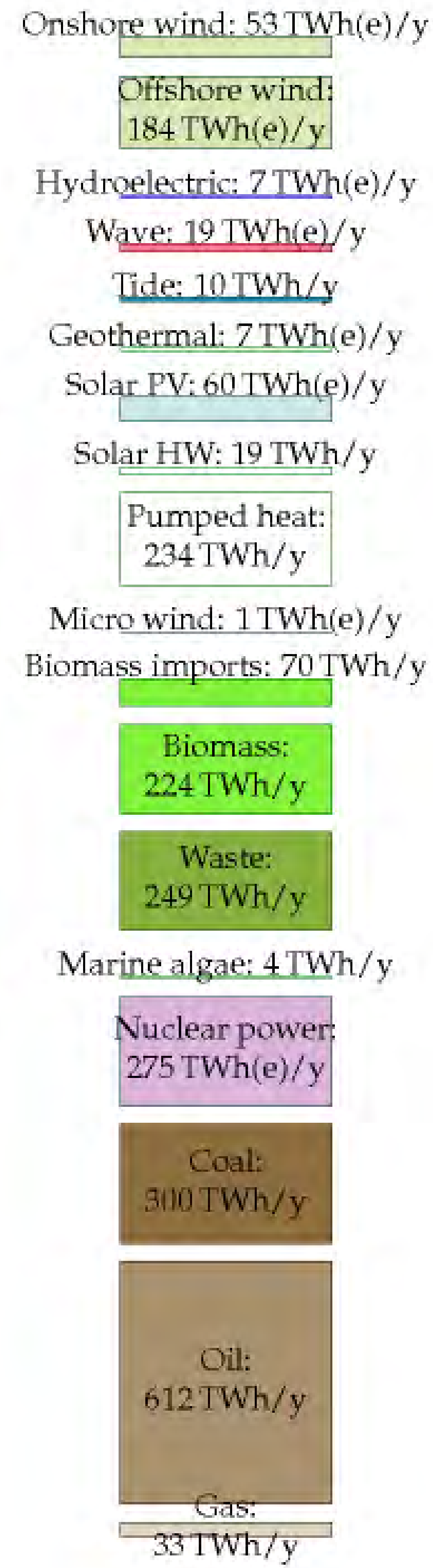
Domestic biomass:

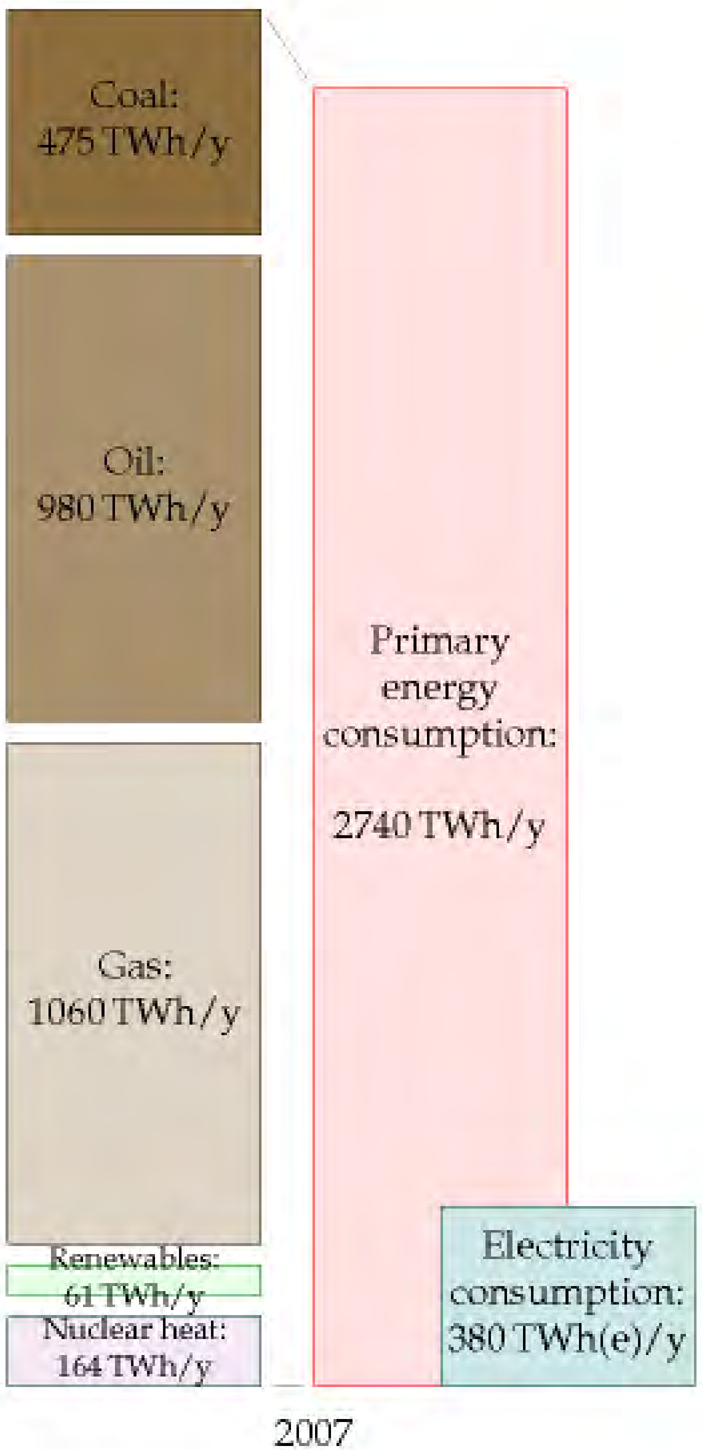
29,000 sq km of biocrops and forestry

- assumes technological progress:
  - higher yields
  - more efficient processing

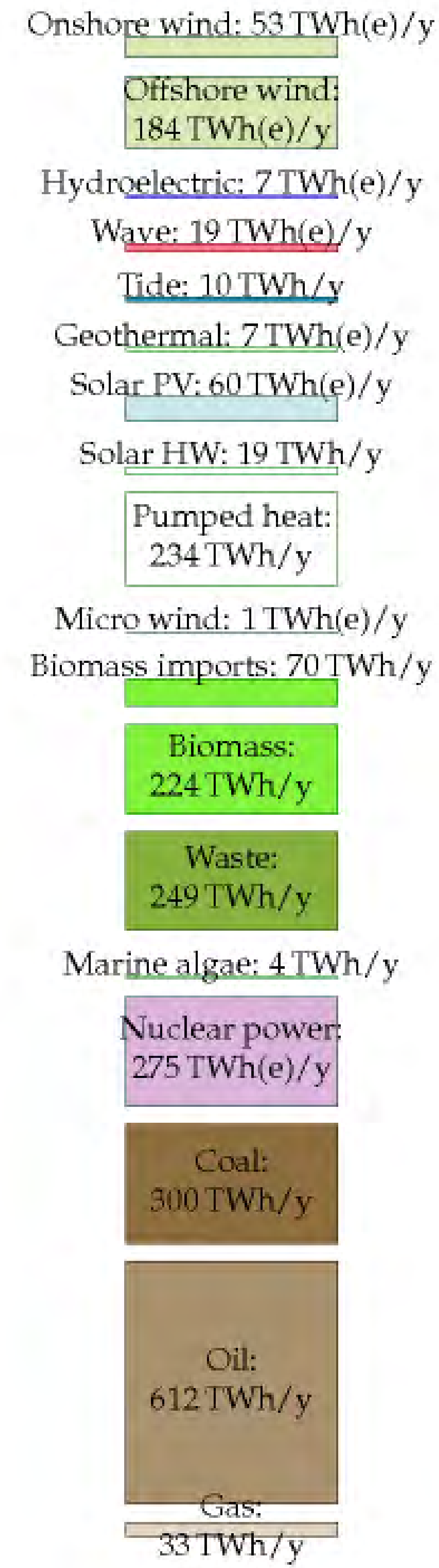
Waste-to-energy:

1000 towns to have a facility
taking 300 tons/day of municipal,
commercial, and agricultural waste

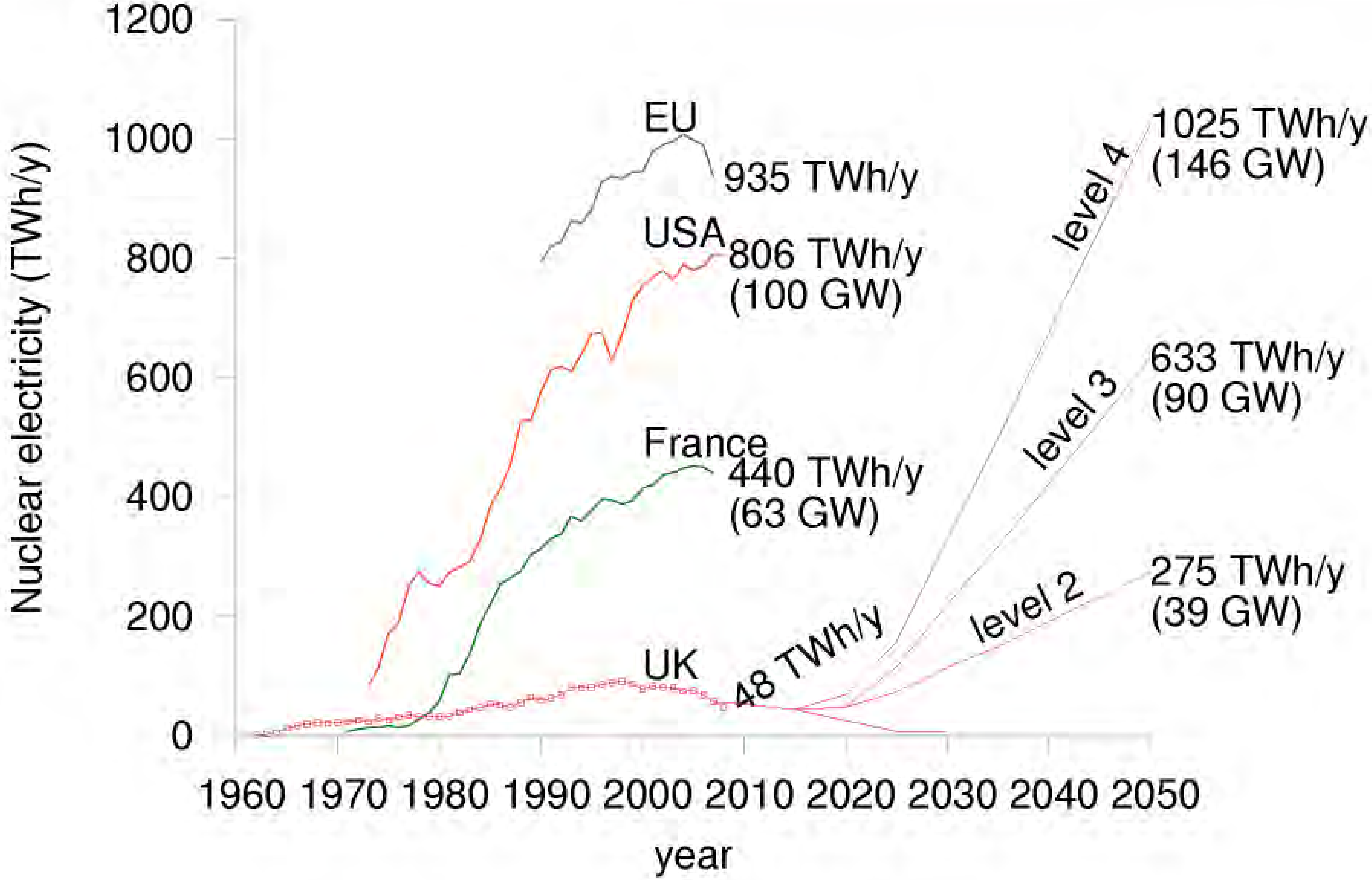




39 GW of nuclear
- four-fold increase

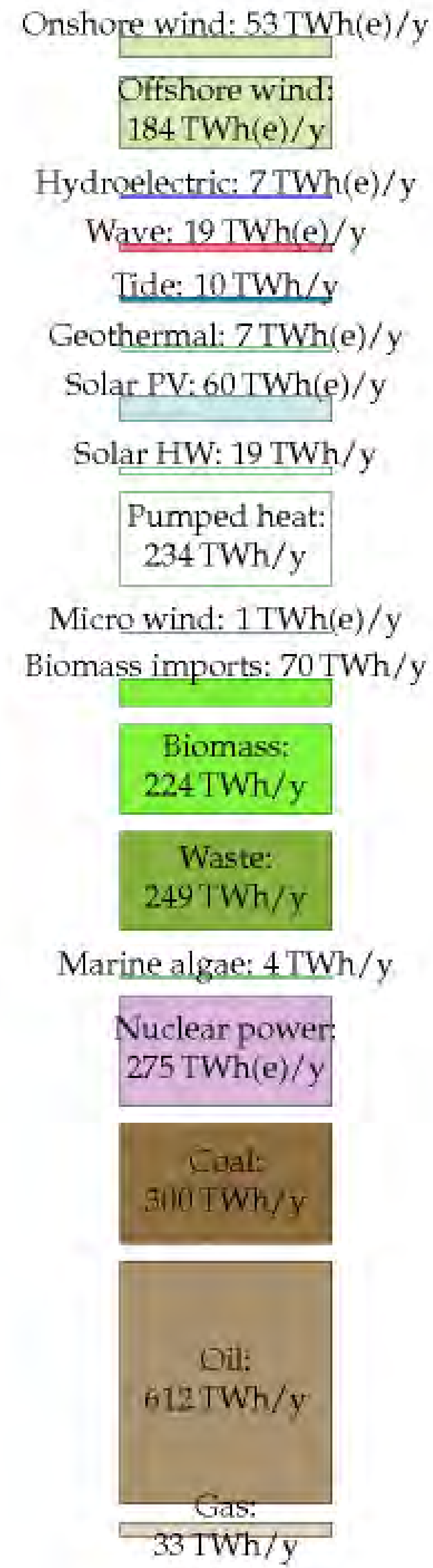


Nuclear trajectories



40 GW of fossil-fuel power stations with CCS, and co-firing biomass

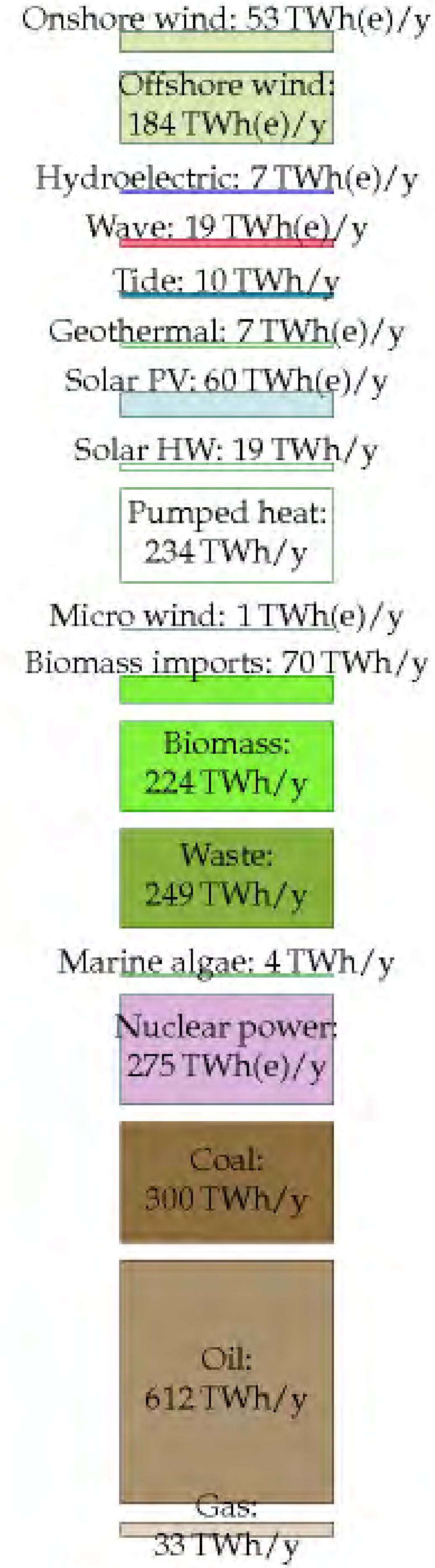
Bigger mass flow-rate into north sea than maximum oil output



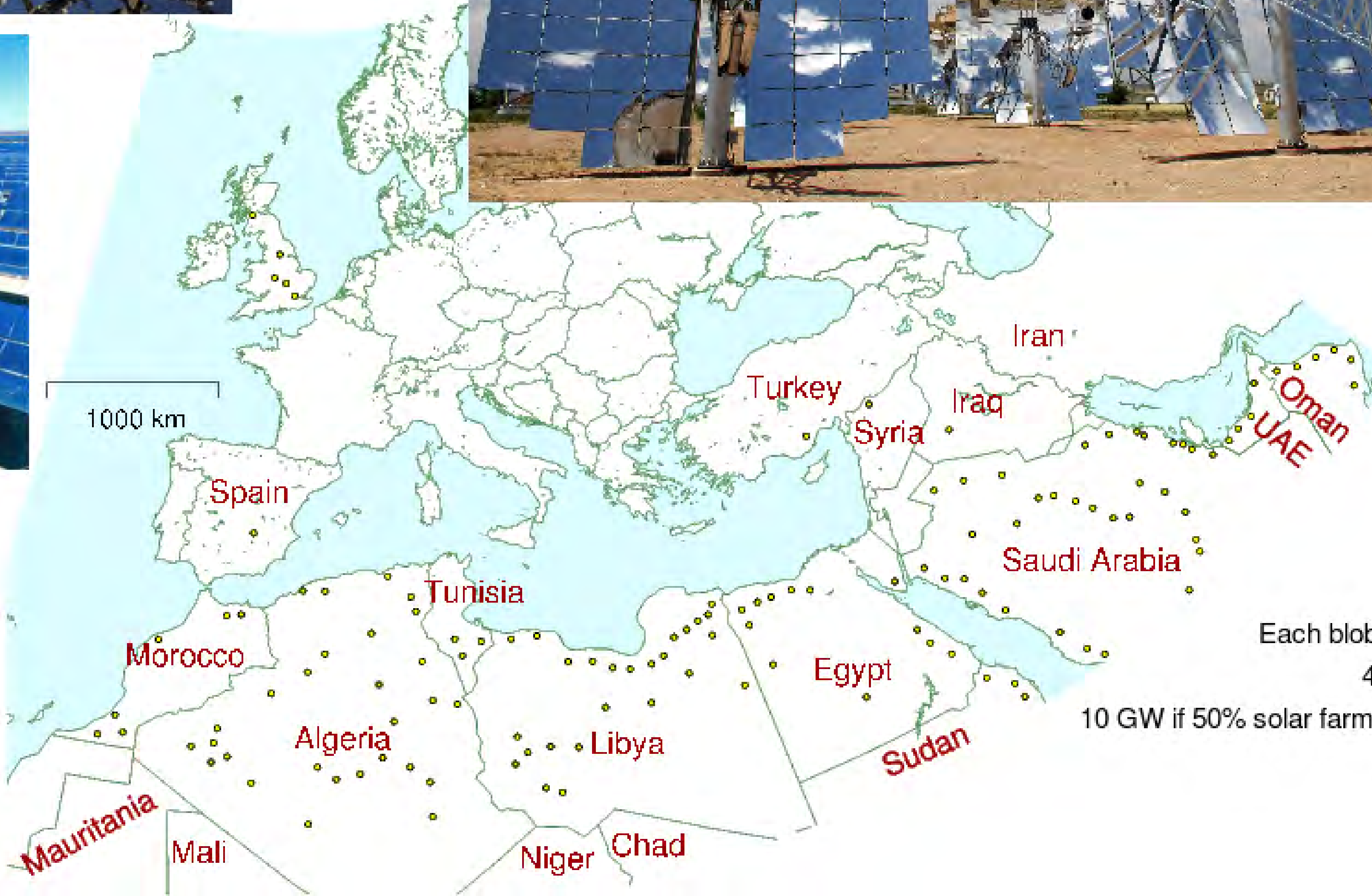
More pumped storage

10 GW of interconnectors

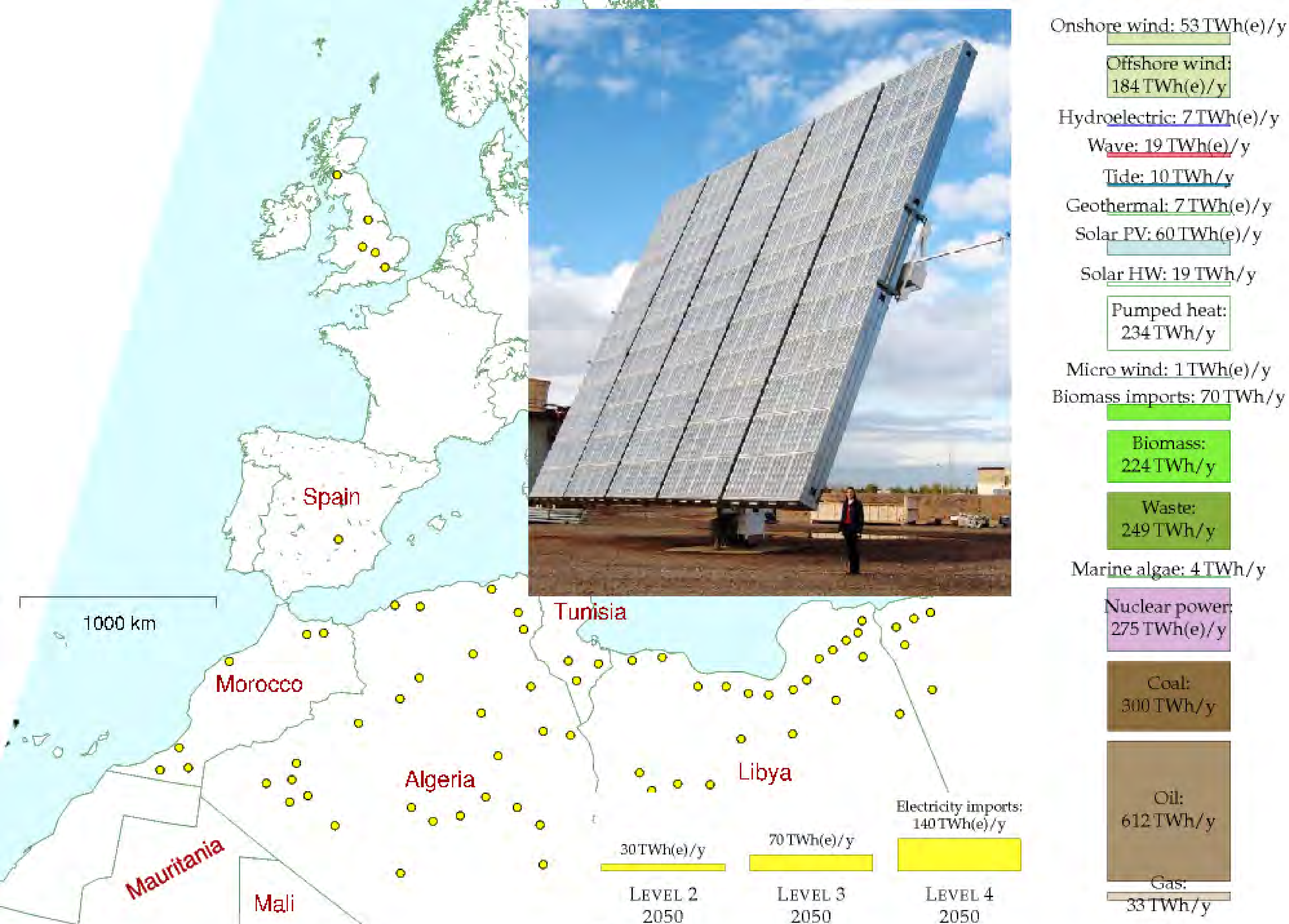
Smart demand-management



Concentrating solar



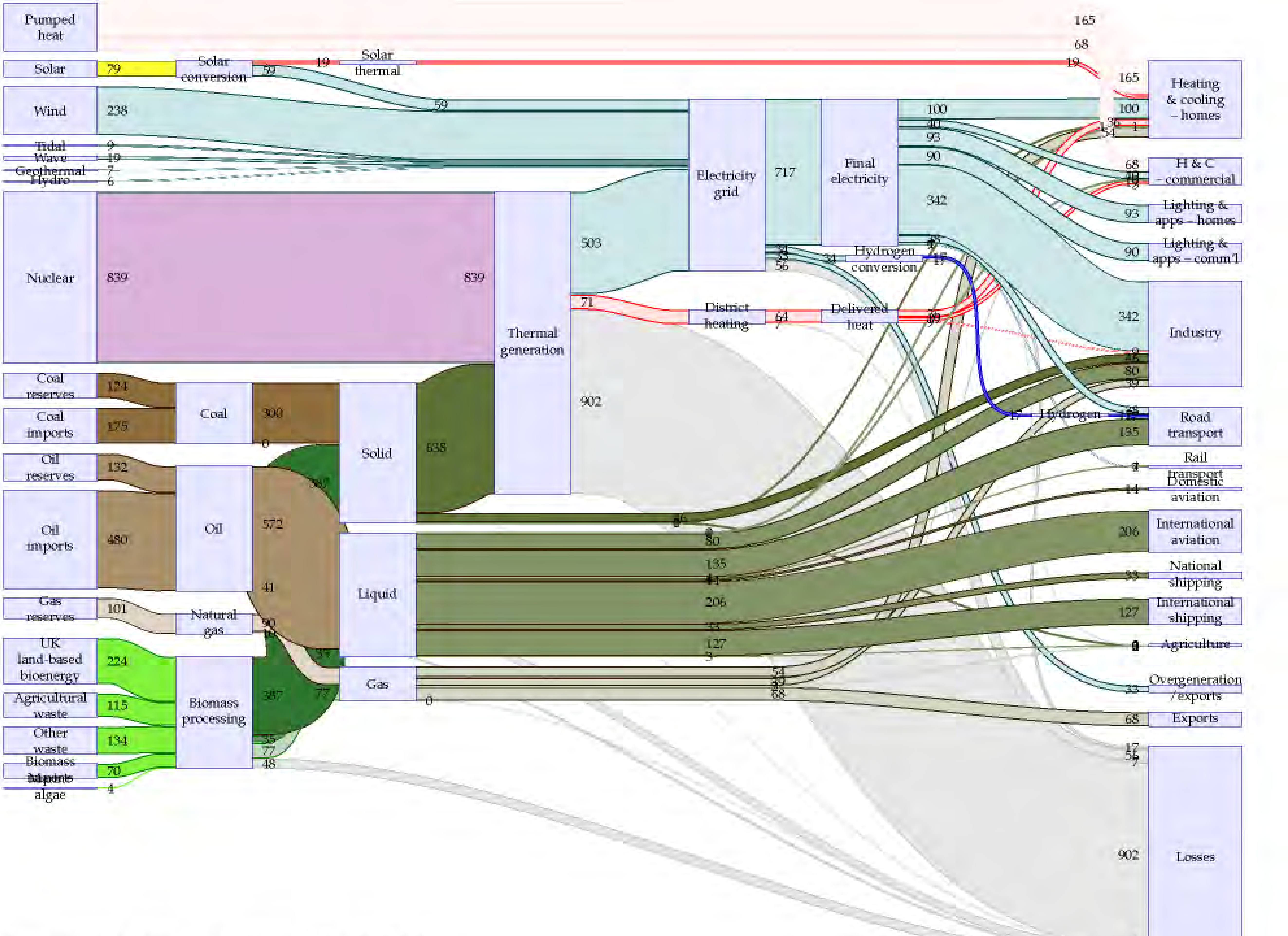
Each blob: 1500 sq km;
44km diameter;
10 GW if 50% solar farm, at 15 W/sq m.
100 TWh/year



Onshore wind: 53 TWh(e)/y
Offshore wind: 184 TWh(e)/y
Hydroelectric: 7 TWh(e)/y
Wave: 19 TWh(e)/y
Tide: 10 TWh/y
Geothermal: 7 TWh(e)/y
Solar PV: 60 TWh(e)/y
Solar HW: 19 TWh/y
Pumped heat: 234 TWh/y
Micro wind: 1 TWh(e)/y
Biomass imports: 70 TWh/y
Biomass: 224 TWh/y
Waste: 249 TWh/y
Marine algae: 4 TWh/y
Nuclear power: 275 TWh(e)/y
Coal: 300 TWh/y
Oil: 612 TWh/y
Gas: 33 TWh/y
Spain
1000 km
Tunisia
Morocco
Algeria
Libya
Mauritania
Mali
Electricity imports: 140 TWh(e)/y
30 TWh(e)/y
70 TWh(e)/y
LEVEL 2 2050
LEVEL 3 2050
LEVEL 4 2050

Innovation needs (top 6)

- Efficiency
  - building insulation
  - vehicles (electric and hydrogen)
- Wind
- Heat pumps
- Biomass- and waste-to-good-things
- Carbon Capture and Storage
- Energy Storage
  - electricity storage
  - interconnectors; smart demand-management
  - seasonal heat stores



Pathway A: Labels on edges show energy flow in TWh/y

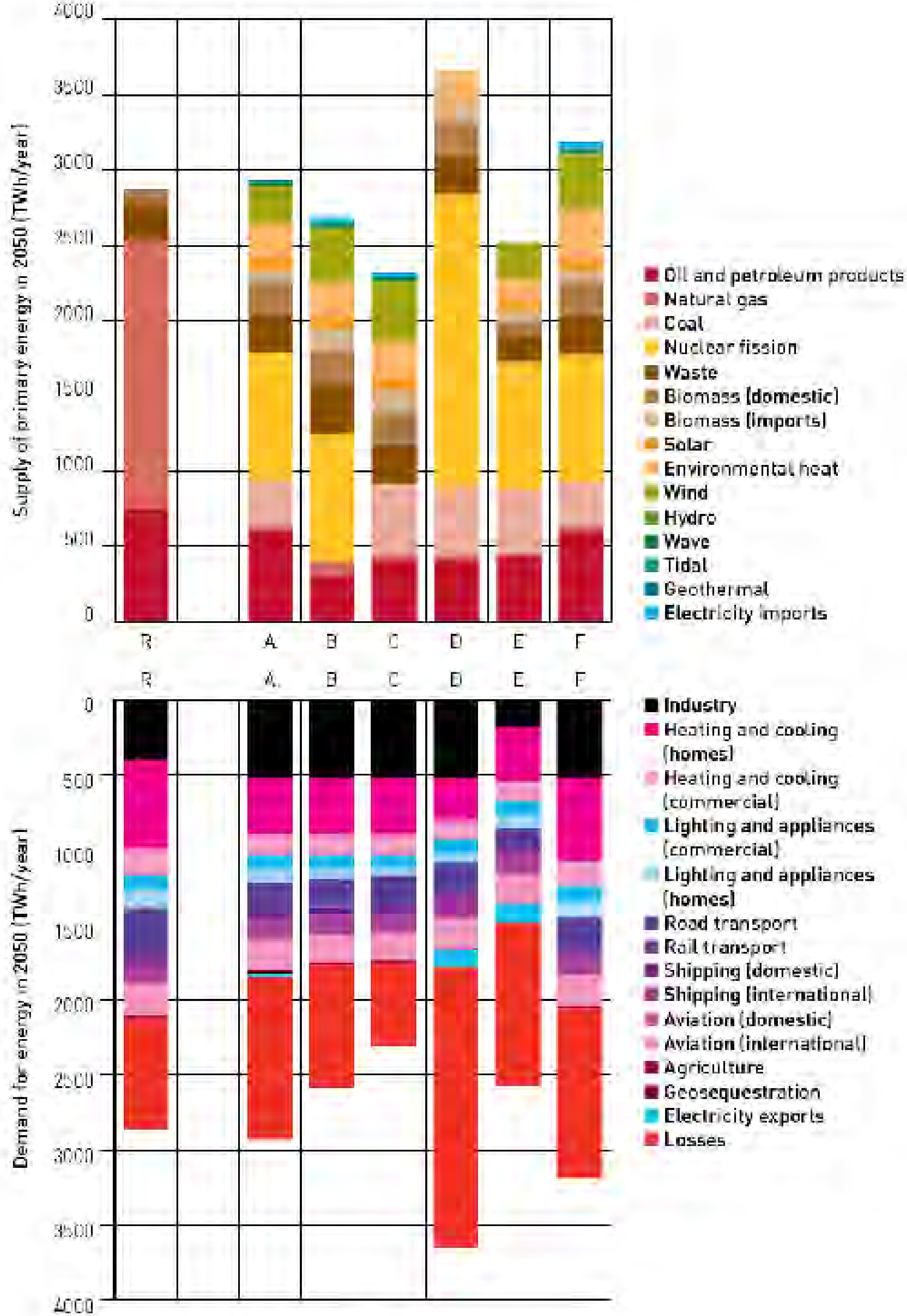
How to 80% decarbonize the UK



- Electrify most transport
- Insulate all buildings; read all meters
- Electrify all building-heating
  - air-source or ground-source heat pumps
  - (some combined-heat-and-power where low-carbon fuel available)

- Our renewables
- Nuclear
- Clean coal and gas with carbon capture
- Other people's renewables
  - storage, interconnectors, smart demand

- Sustainable bioenergy
  - where solid/liquid/gas fuels are essential



B: No CCS

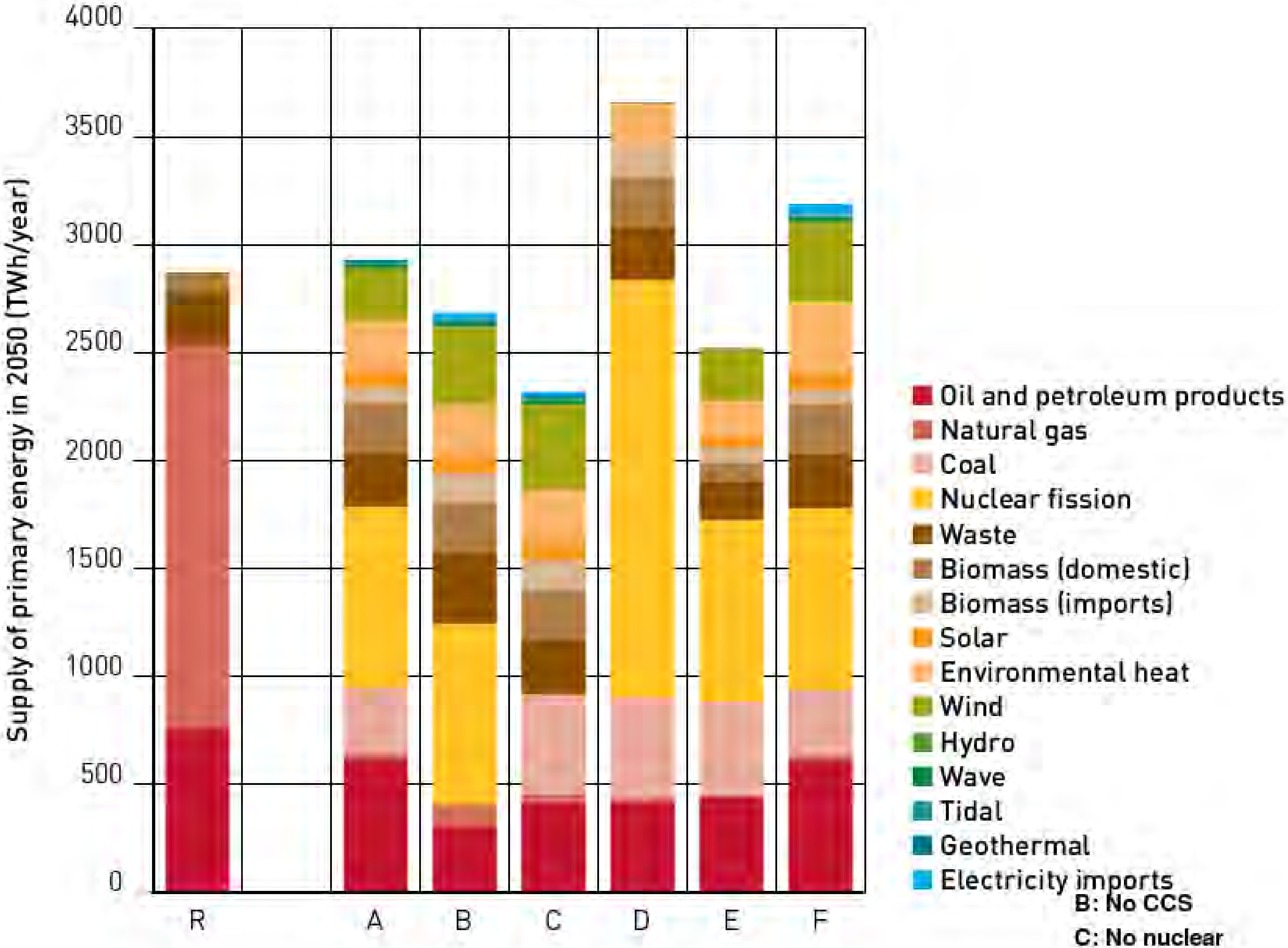
C: No nuclear

D: No renewables

E: Low biomass

F: Low demand-reduction

Supply



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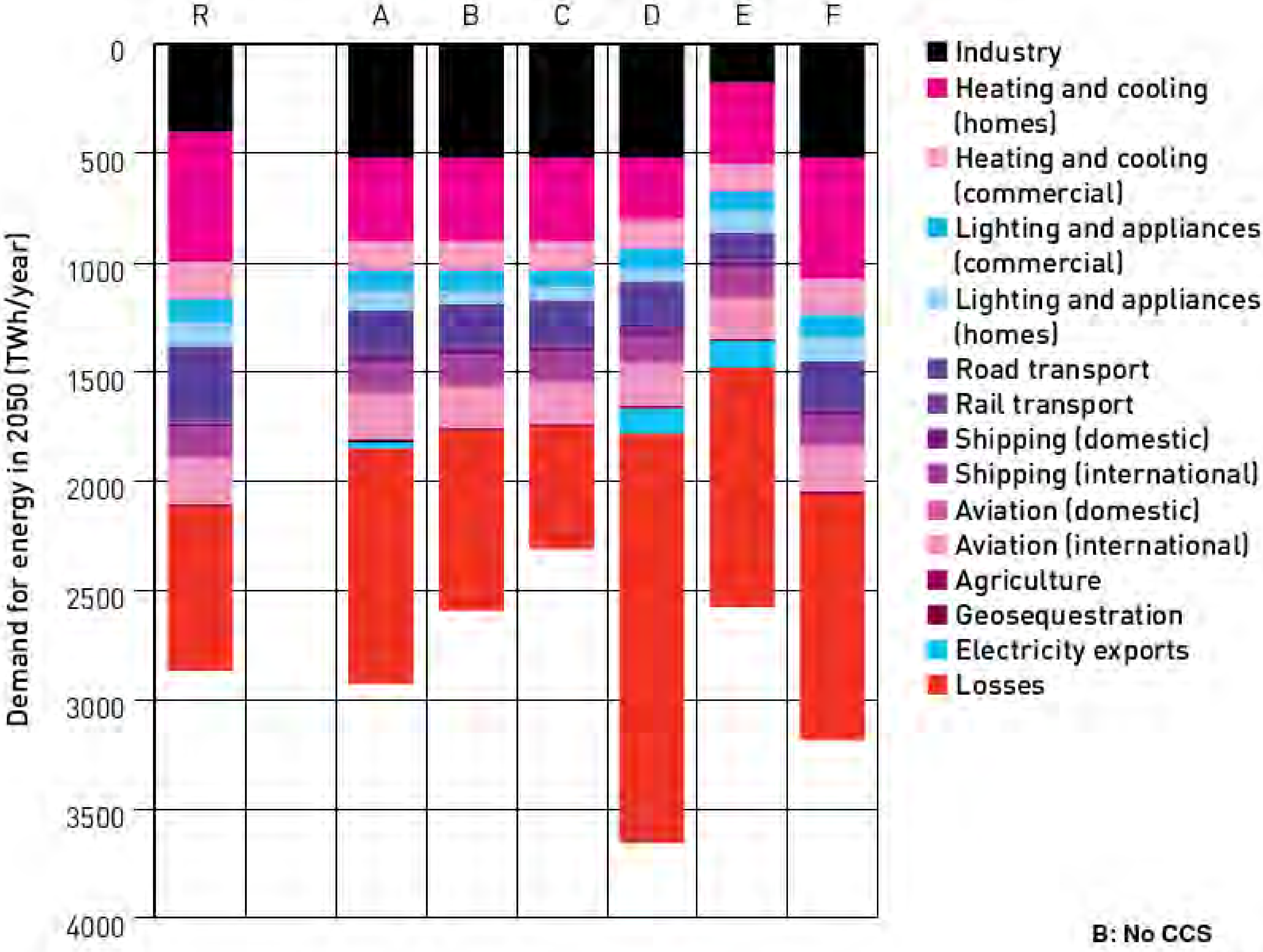
Demand



B: No CCS
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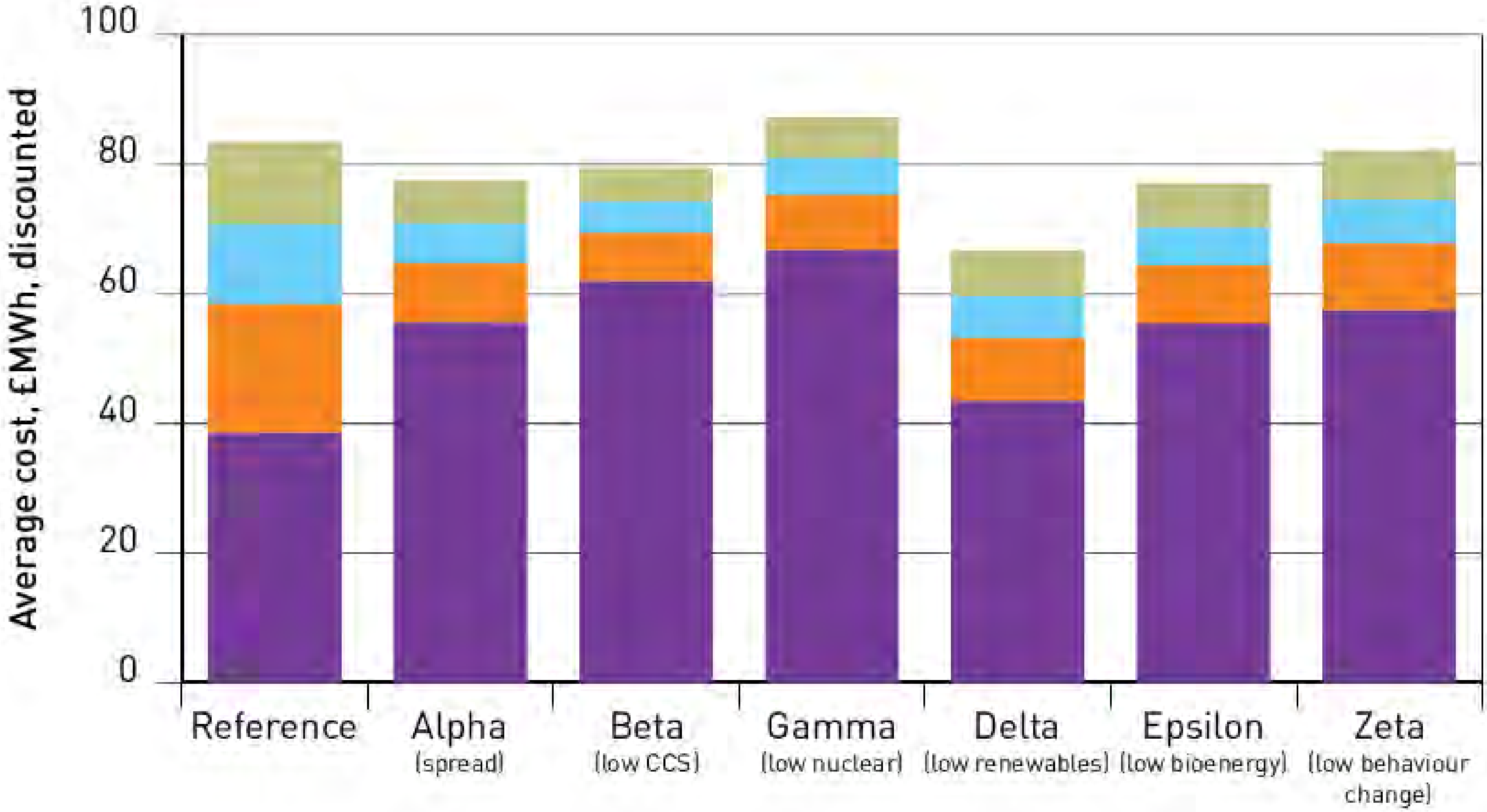
Costs (partial)

Figure 4: Average gross cost per megawatt-hour of the illustrative pathways in 2050

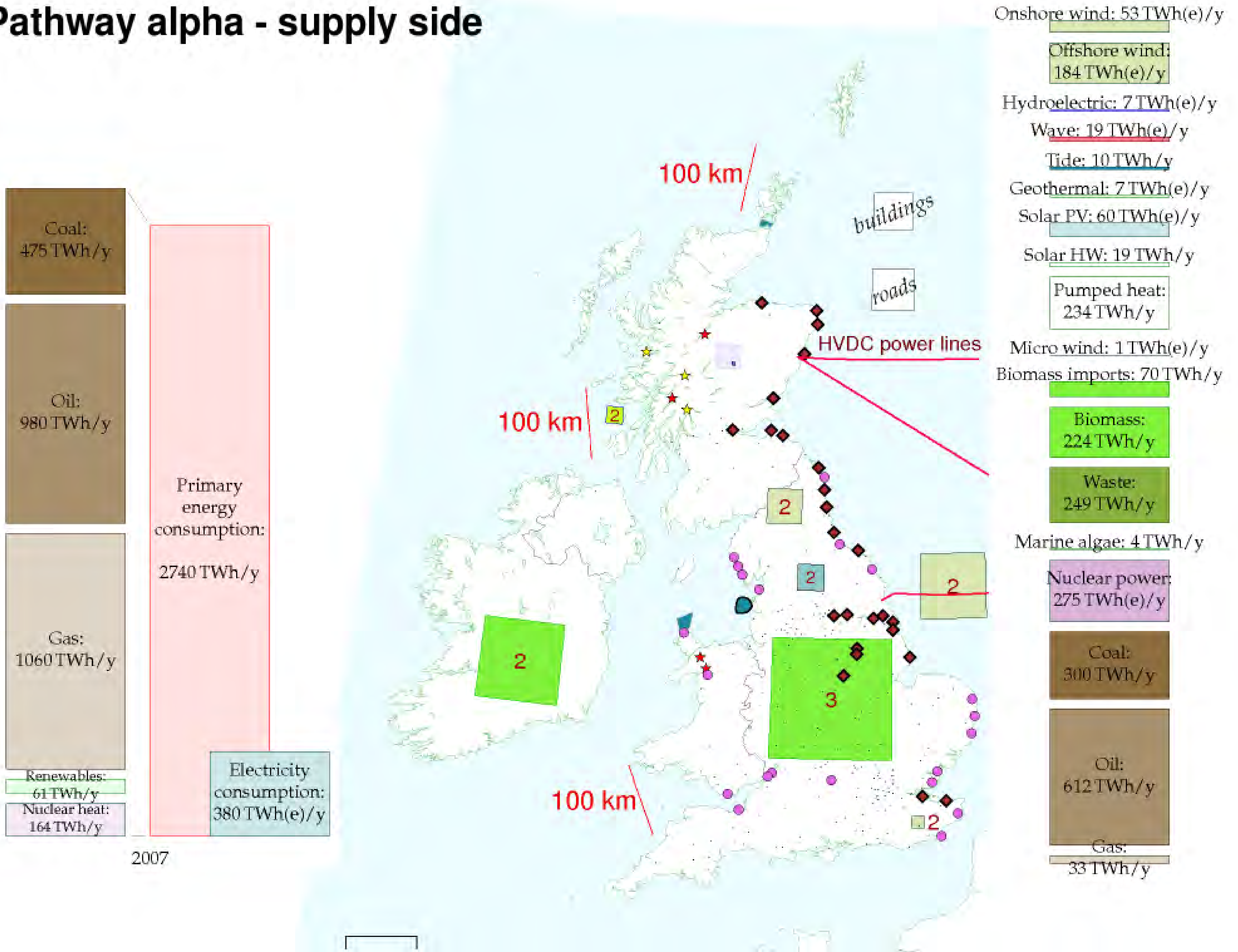


Key implications of the 2050 analysis

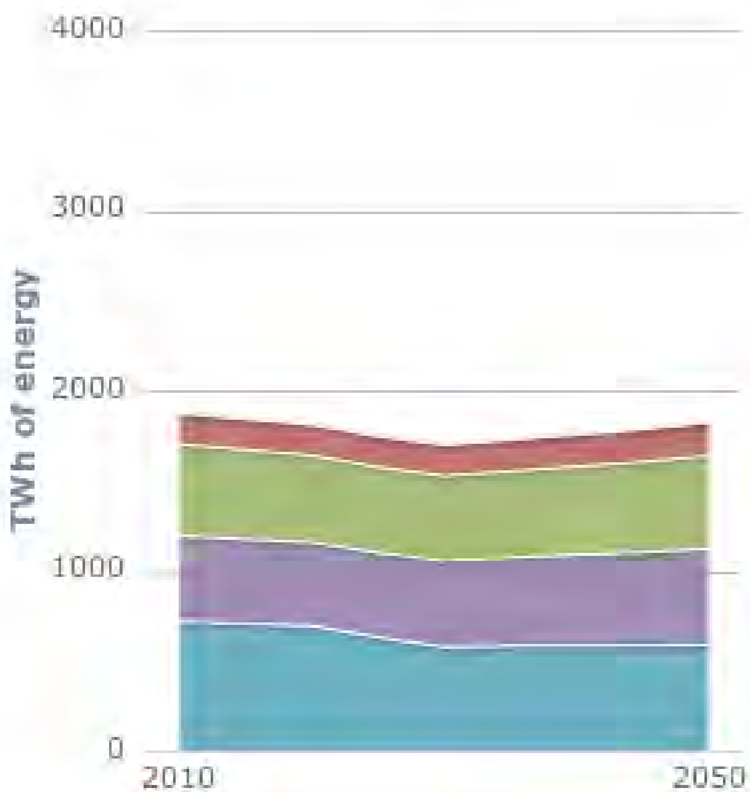
- Ambitious per-capita energy demand reduction is needed
- A substantial level of electrification of heating and surface transport
- Electricity needs to be decarbonised; and electricity supply must roughly double
  - the big fish are: nuclear; wind; fossil-fuels-with-CCS
- Sustainable bioenergy is an important, but finite part of the low-carbon energy system
- We will need to reduce emissions from agriculture, waste, industrial processes and international transport by 2050

challenging, but possible

Pathway alpha - supply side

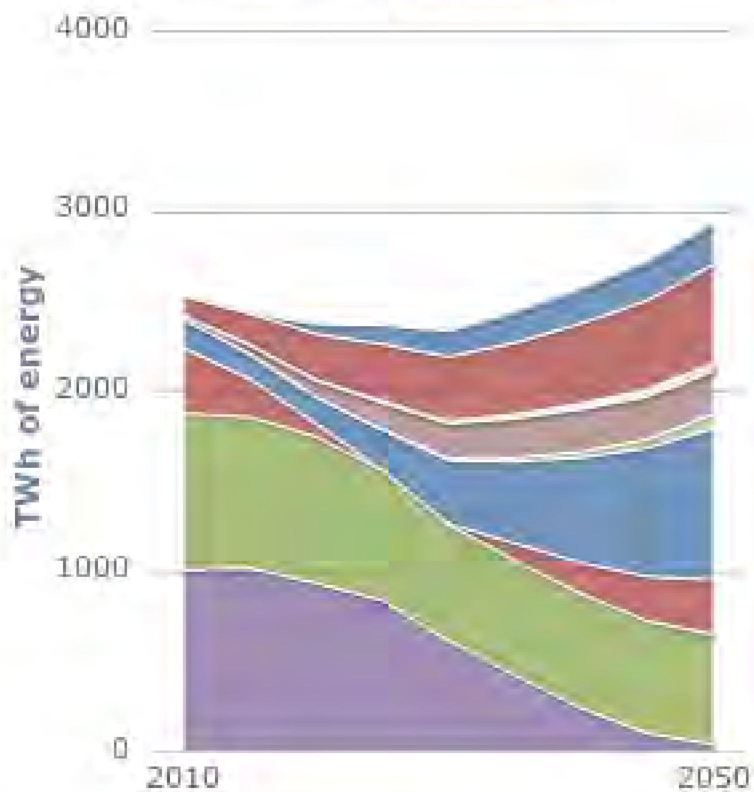


UK demand for energy

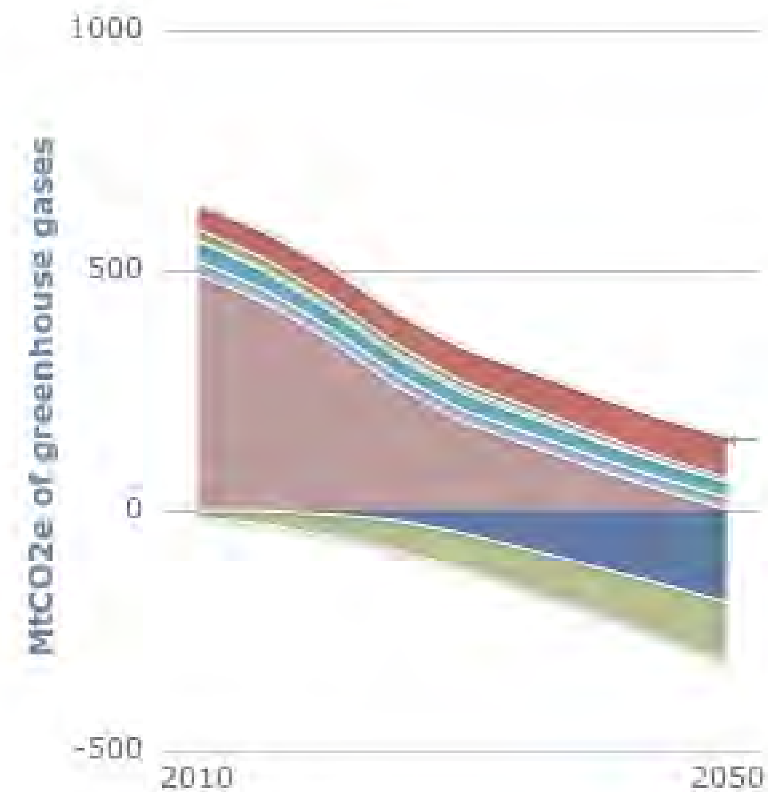


UK supply of primary energy

Switch to chart showing just electricity



Net UK Greenhouse gas emissions



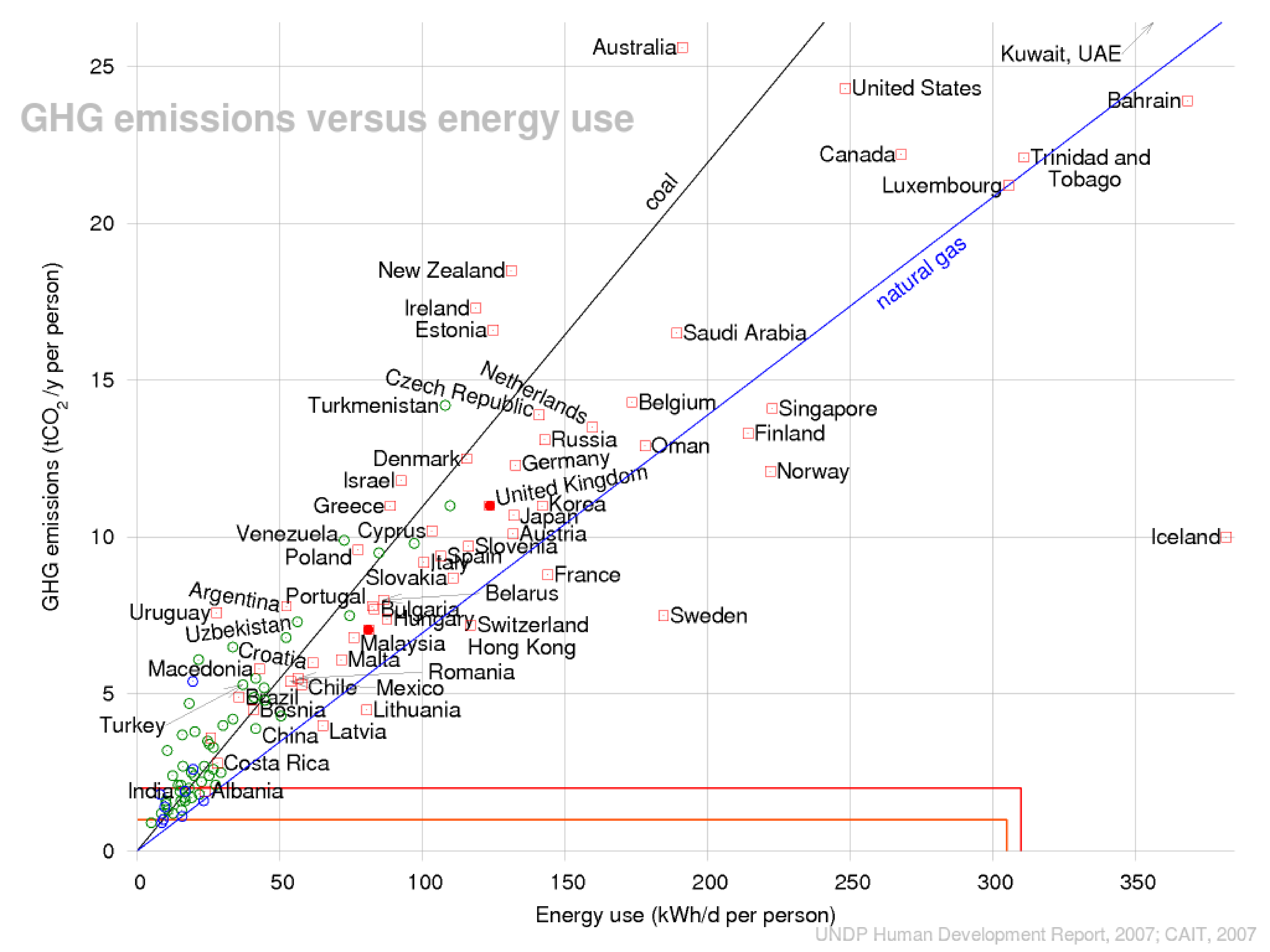
Demand measures:	1	2	3	4
Average temperature of homes	1	2	3	4
Home insulation	1	2	3	4
Home heating electrification	A	B	C	D
Home heating that isn't electric	A	B	C	D
Commercial heat / cooling demand	1	2	3	4
Commercial heating electrification	A	B	C	D
Commercial heating that isn't electric	A	B	C	D
Home light & 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

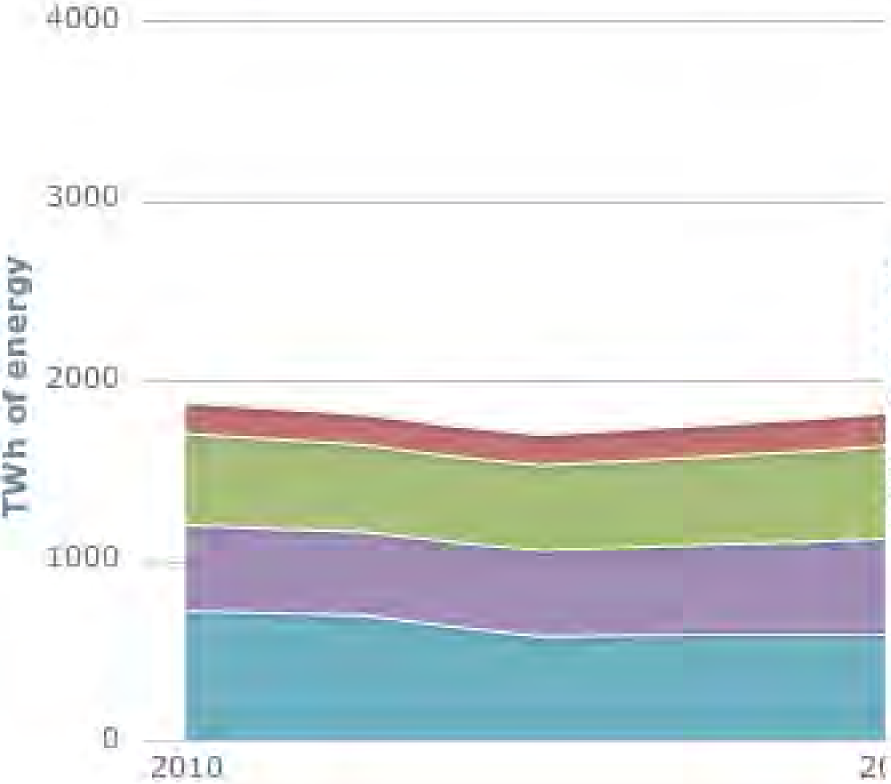
Some of the consequences of this pathway

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



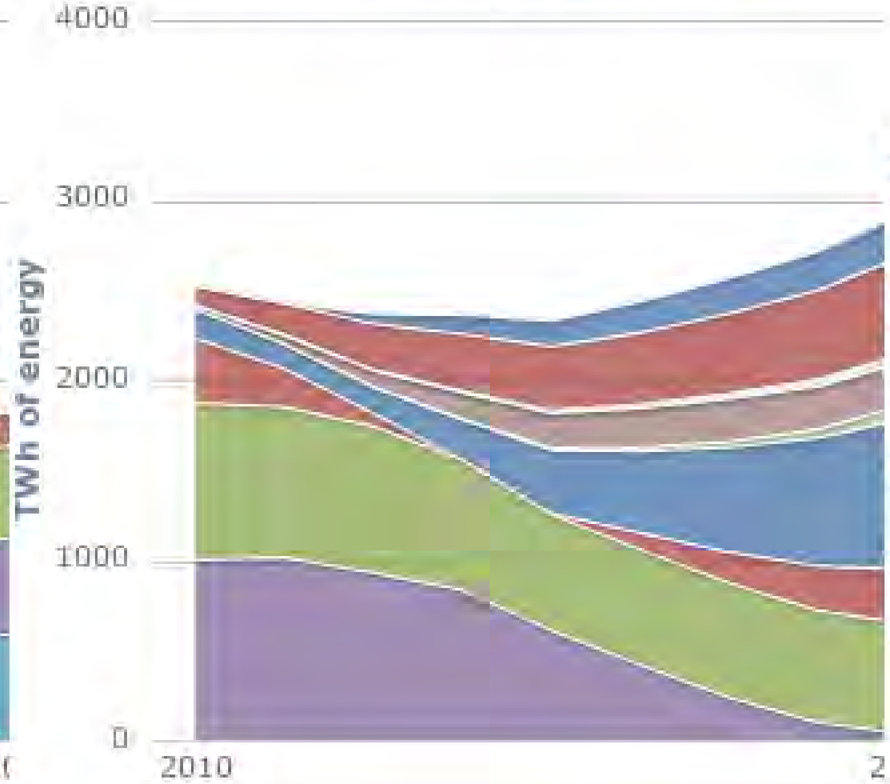
GHG emissions versus energy use
GHG emissions (tCO2 /y per person)
Energy use (kWh/d per person)
coal
natural gas
Australia
Kuwait, UAE
United States
Bahrain
Canada
Trinidad and Tobago
Luxembourg
New Zealand
Ireland
Estonia
Saudi Arabia
Czech Republic
Netherlands
Turkmenistan
Belgium
Singapore
Finland
Russia
Oman
Denmark
Germany
Norway
Israel
United Kingdom
Greece
Korea
Japan
Venezuela
Cyprus
Austria
Iceland
Poland
Slovenia
Spain
Italy
Slovakia
France
Argentina
Portugal
Belarus
Uruguay
Bulgaria
Hungary
Switzerland
Sweden
Uzbekistan
Malaysia
Hong Kong
Croatia
Malta
Macedonia
Romania
Chile
Mexico
Brazil
Bosnia
Lithuania
Turkey
China
Latvia
Costa Rica
India
Albania
UNDP Human Development Report, 2007; CAIT, 2007

UK demand for energy

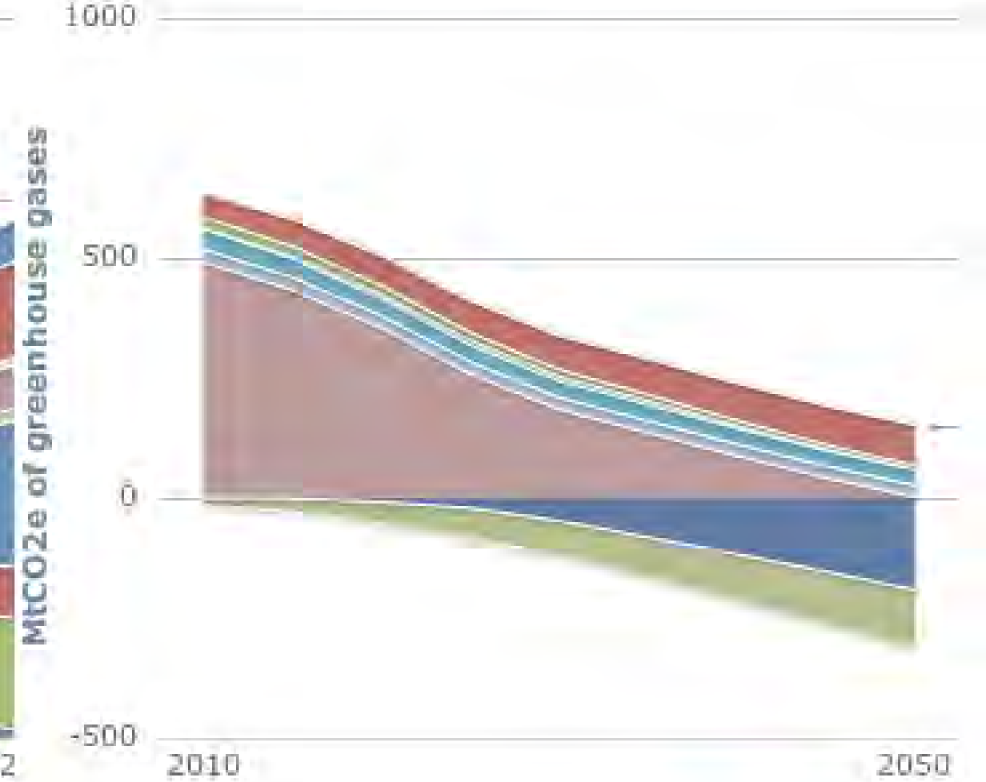


UK supply of primary energy

Switch to chart showing just electricity



Net UK Greenhouse gas emissions



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Offshore wind	1	2	3
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Marine	1	2	3
Geothermal	1	2	3
Distributed solar PV	1	2	3
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Geosequestration	1	2	3	4

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and	2 GW of standby generation required
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Seasonal heat storage

home | about DLSC | news | awards | photos | partners | links | contact us

- how it works
- the homes
- solar collection
- district heating system
- energy centre
- borehole thermal energy storage
- view DLSC animation
- DLSC brochures
- reports

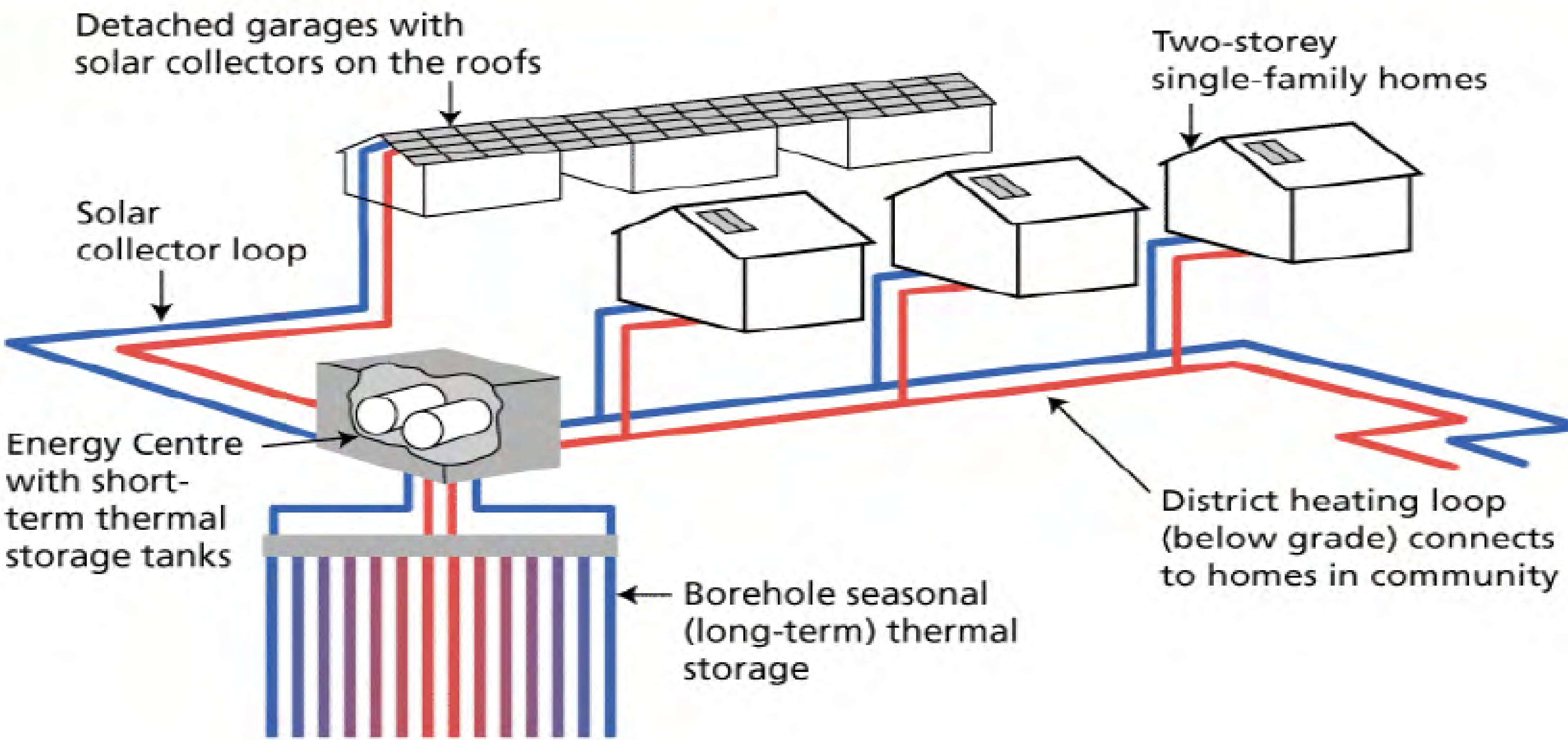
Welcome to Drake Landing Solar Community.

The Drake Landing Solar Community (DLSC) is a master planned neighbourhood in the Town of Okotoks, Alberta, Canada that has successfully integrated Canadian energy efficient technologies with a renewable, unlimited energy source - the sun.

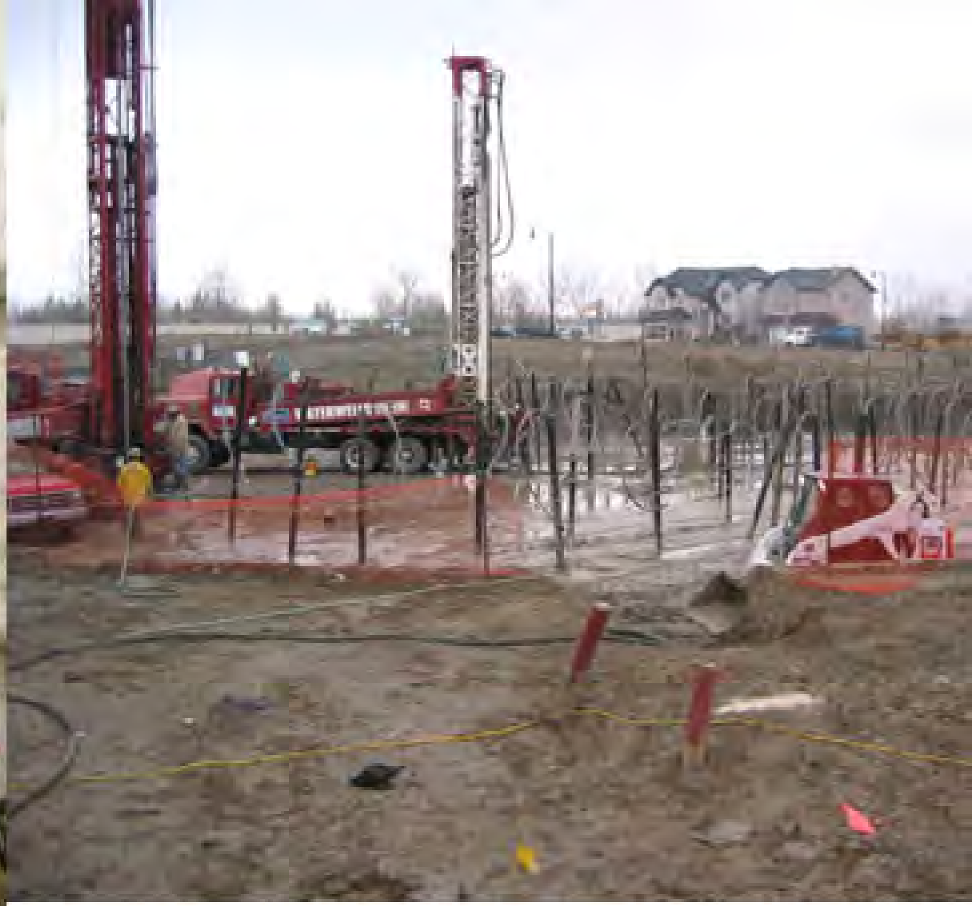
The first of its kind in North America, DLSC is heated by a district system designed to store abundant solar energy underground during the summer months and distribute the energy to each home for space heating needs during winter months.

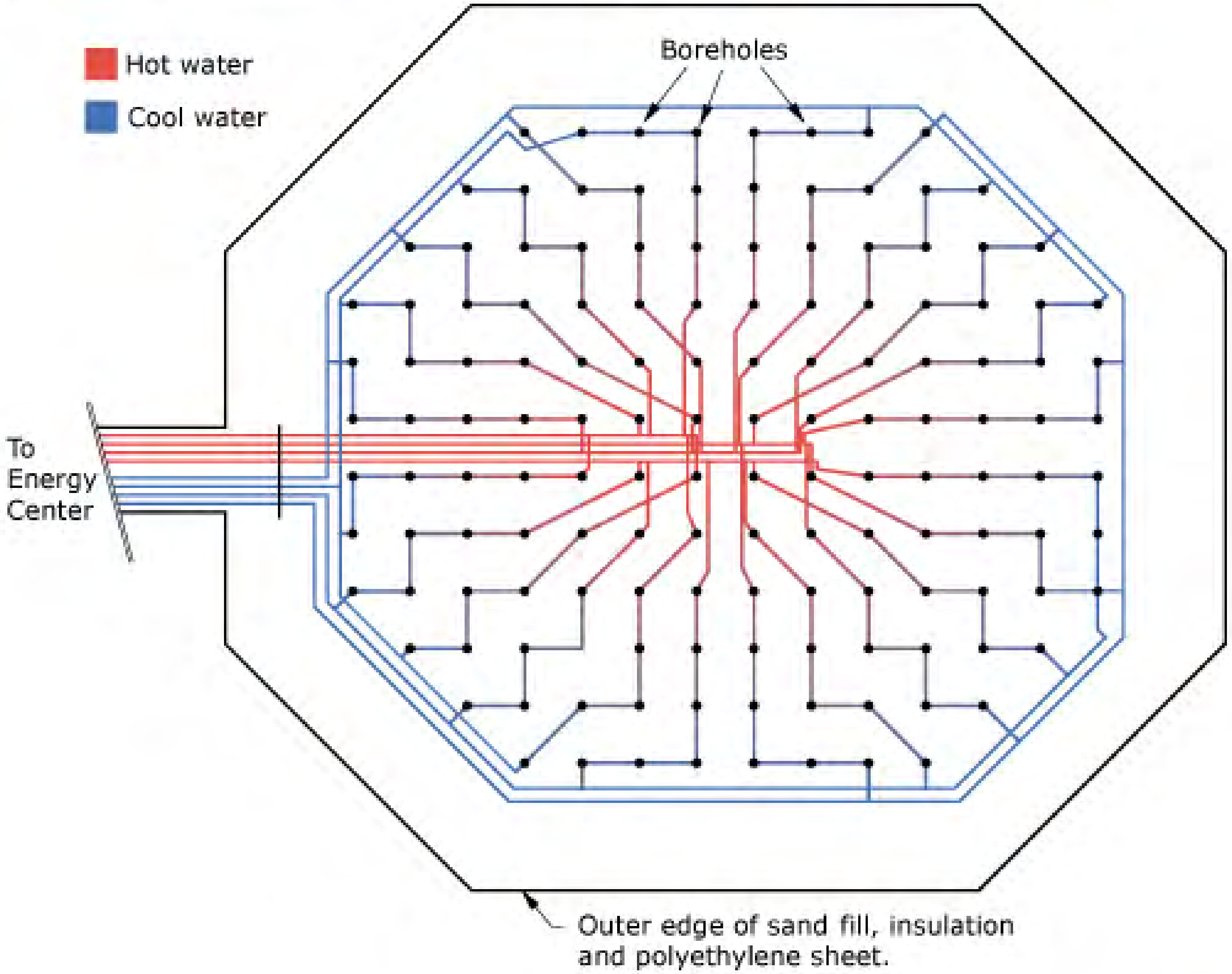
The system is unprecedented in the World, fulfilling ninety percent of each home's space heating requirements from solar energy and resulting in less dependency on limited fossil fuels.

The Government of Canada and its Canadian industry partners are proud to showcase Canadian solar thermal and energy efficient technologies in this one-of-a-kind community.


Detached garages with
solar collectors on the roofs
Two-storey
single-family homes
Solar
collector loop
Energy Centre
with short-
term thermal
storage tanks
District heating loop
(below grade) connects
to homes in community
Borehole seasonal
(long-term) thermal
storage







heat store: 37m deep, 35m wide

roughly 1 GWh(th) - roughly 100 kWh/d per dwelling, for 50 dwellings, for 100 days

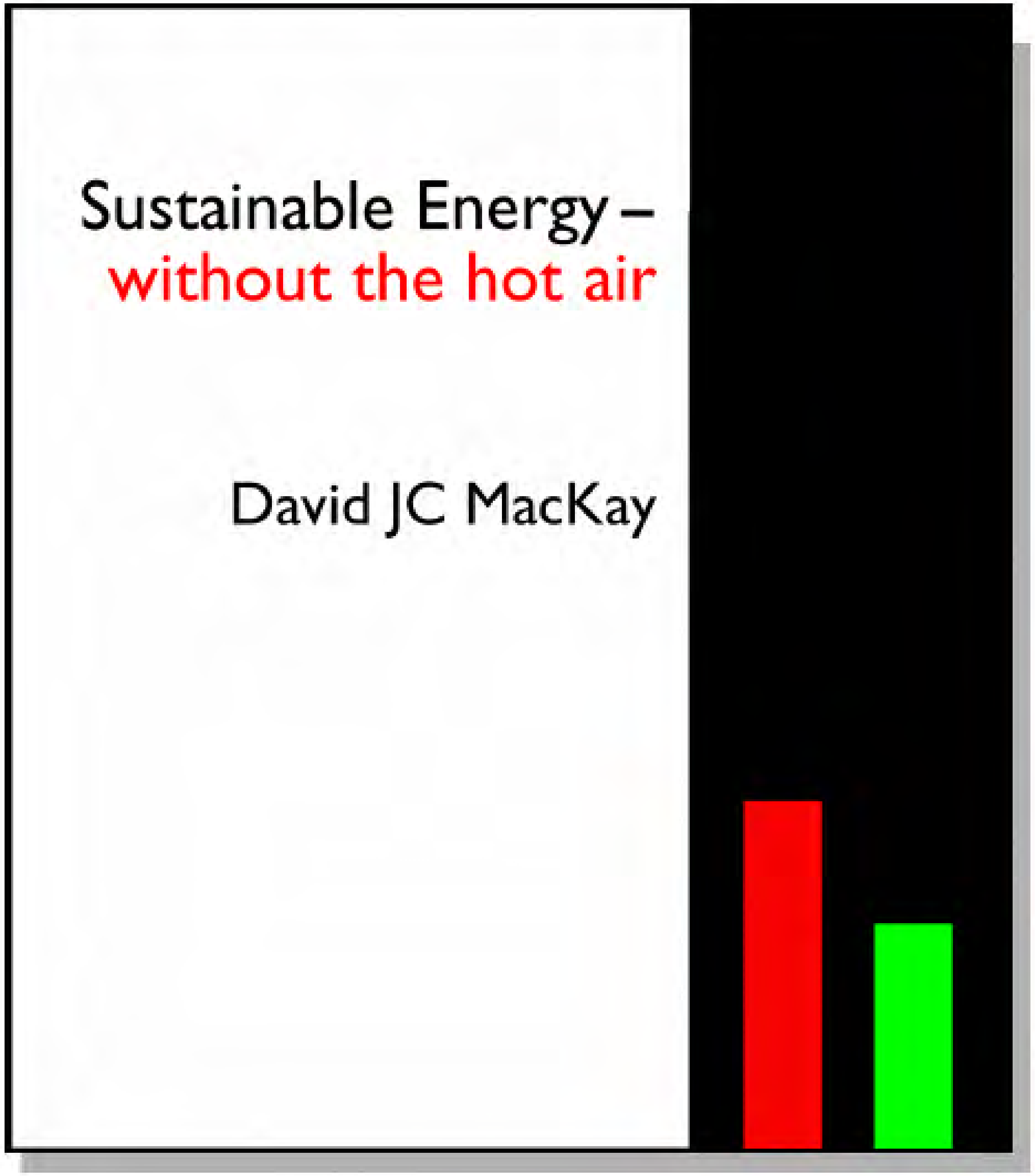
140 kWh/d

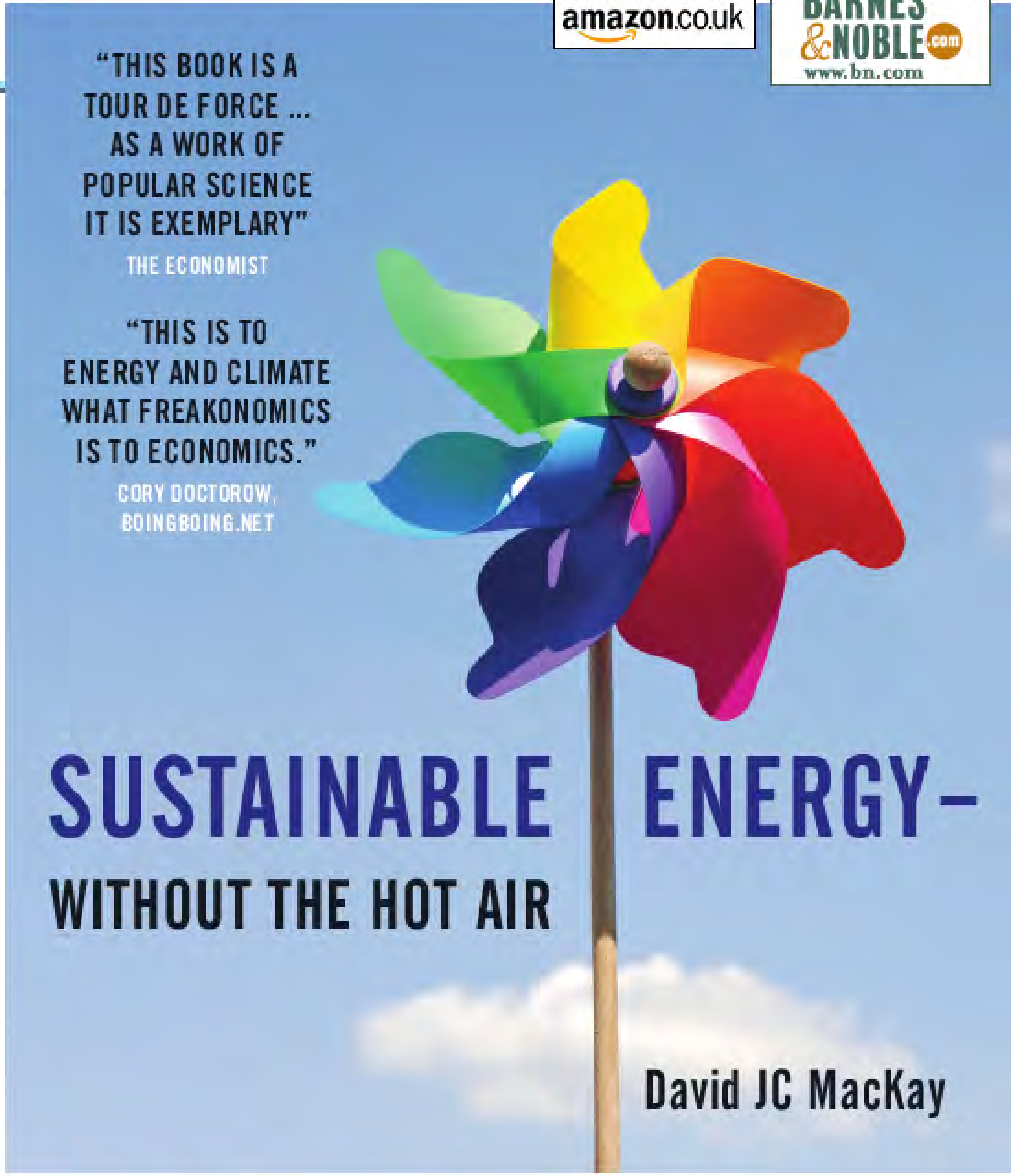
peak 25 kW

Concentrating photovoltaic by Amonix - Photo by David Faiman.


www.stirlingenergy.com
one dish: 160 kWh/d
peak 25 kW

This book is free online





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