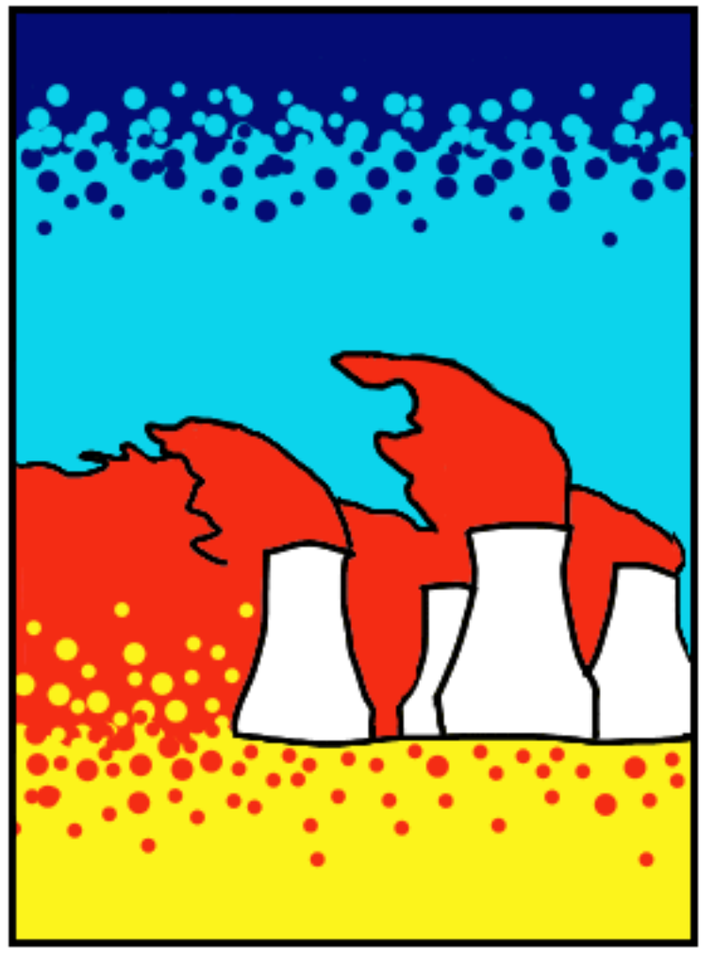
Sustainable Energy

- without the hot air



David MacKay

Department of Physics
University of Cambridge

www.withouthotair.com

Questions about sustainable energy

- Can we live on our own renewables?
  - What would that look like?
- How can we make a sustainable energy plan that adds up?

- We need to get off fossil fuels
  - Numbers, not adjectives
  - Not easy; but possible
- All renewables are diffuse
  - to make a difference, renewable facilities have to be country-sized
- The supply options are:
  - our renewables
  - other countries' renewables
  - nuclear

We have an addiction to fossil fuels, and it's not sustainable

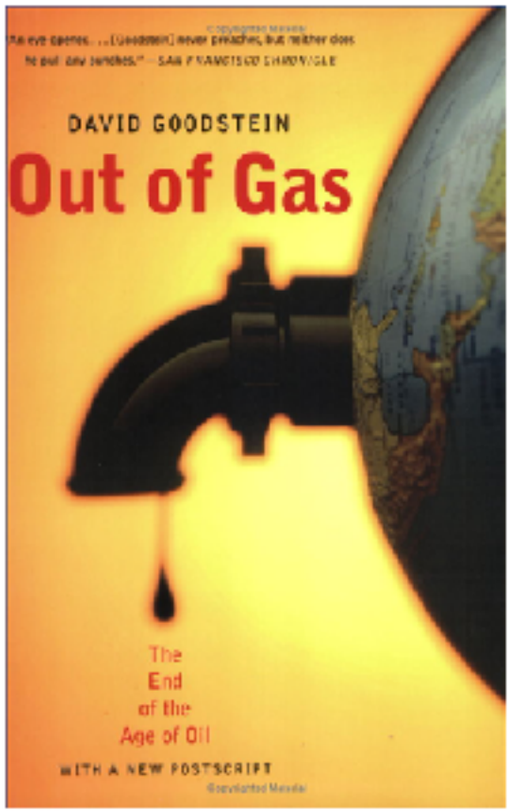
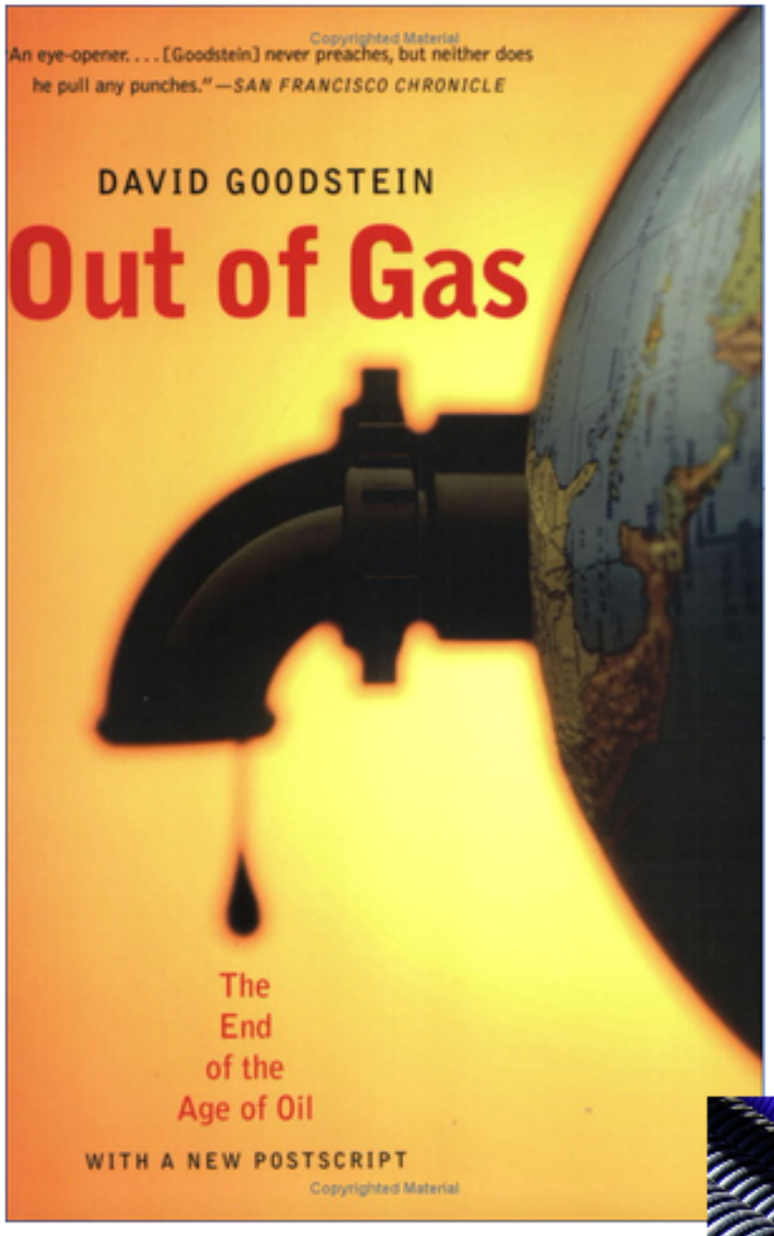
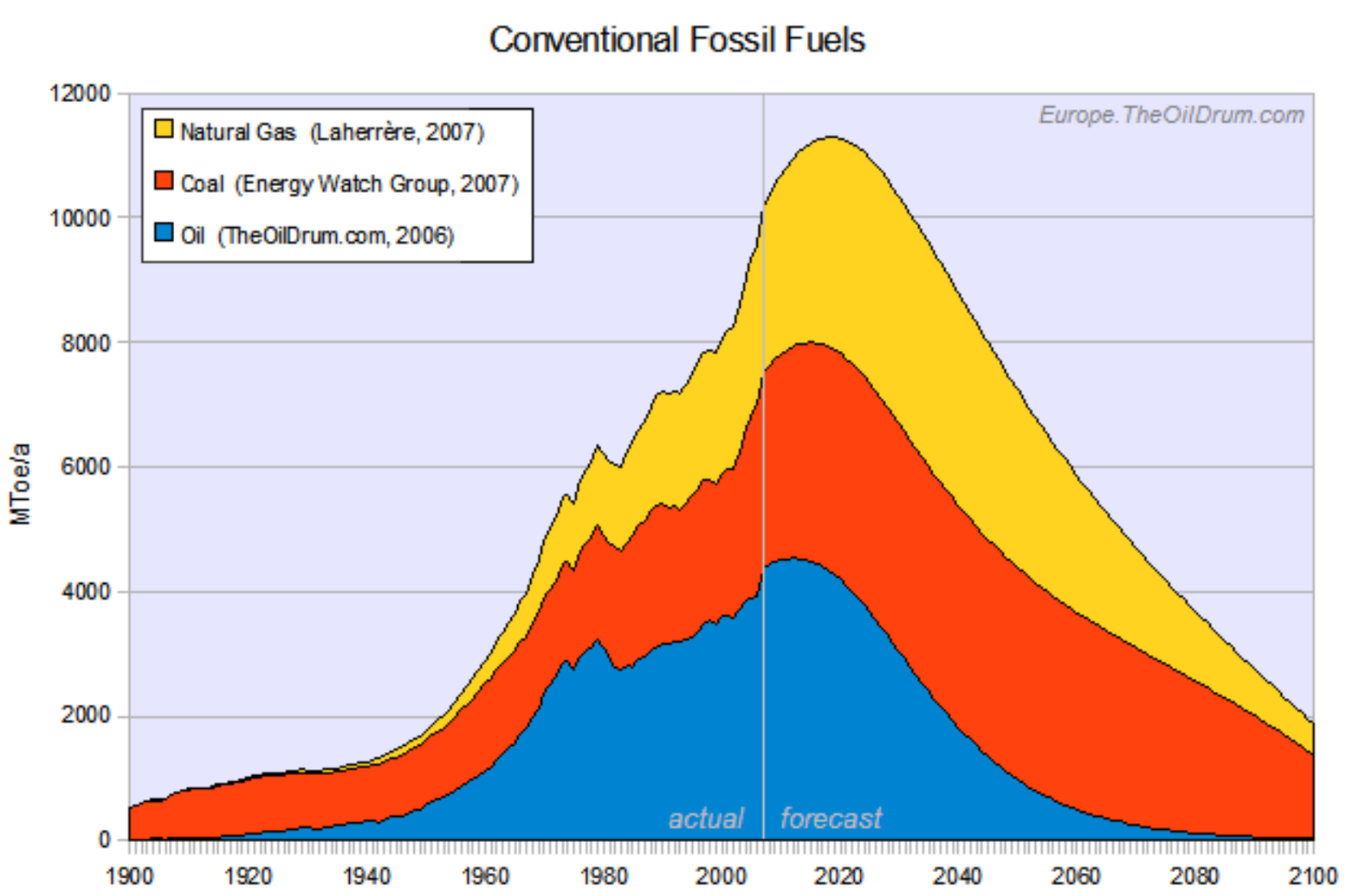


Photo by Terry Cavner





photos by Nik Stanbridge

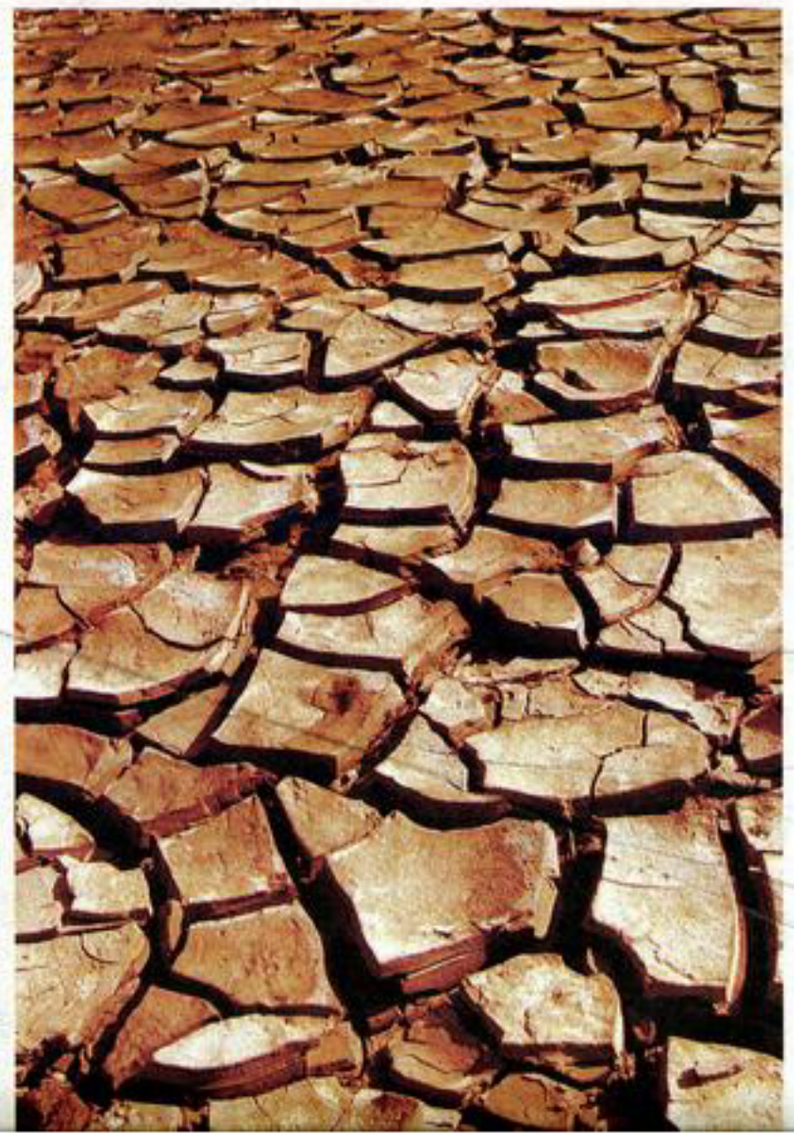
Newspaper of the Year

THE INDEPENDENT

No 5,700 www.independent.co.uk MONDAY 24 JANUARY 2005 ★ (Republic of Ireland €0.95) 60p

● Climate change: report warns point of no return may be reached in 10 years, leading to droughts, agricultural failure and water shortages

Countdown to global catastrophe



By Michael McCarthy
Environment Editor

THE GLOBAL warming danger threshold for the world is clearly marked for the first time in an international report to be published tomorrow – and the bad news is, the world has nearly reached it already.

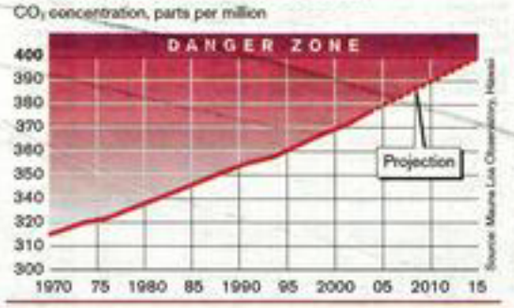
The countdown to climate-change catastrophe is spelt out by a task force of senior politicians, business leaders and academics from around the world – and it is remarkably brief. In as little as 10 years, or even less, their report indicates, the point of no return with global warming may have been reached.

The report, *Meeting The Climate Challenge*, is aimed at policymakers in every country, from national leaders down. It has been timed to coincide with Tony Blair's promised efforts to advance climate change policy in 2005 as chairman of both the G8 group of rich countries and the European Union.

And it breaks new ground by putting a figure – for the first time in such a high-level docu-

ATMOSPHERIC CARBON DIOXIDE

CO_2 concentration, parts per million



changes. These could include widespread agricultural failure, water shortages and major droughts, increased disease, sea-level rise and the death of forests – with the added possibility of abrupt catastrophic events such as "runaway" global warming, the melting of the Greenland ice sheet, or the switching-off of the Gulf Stream.

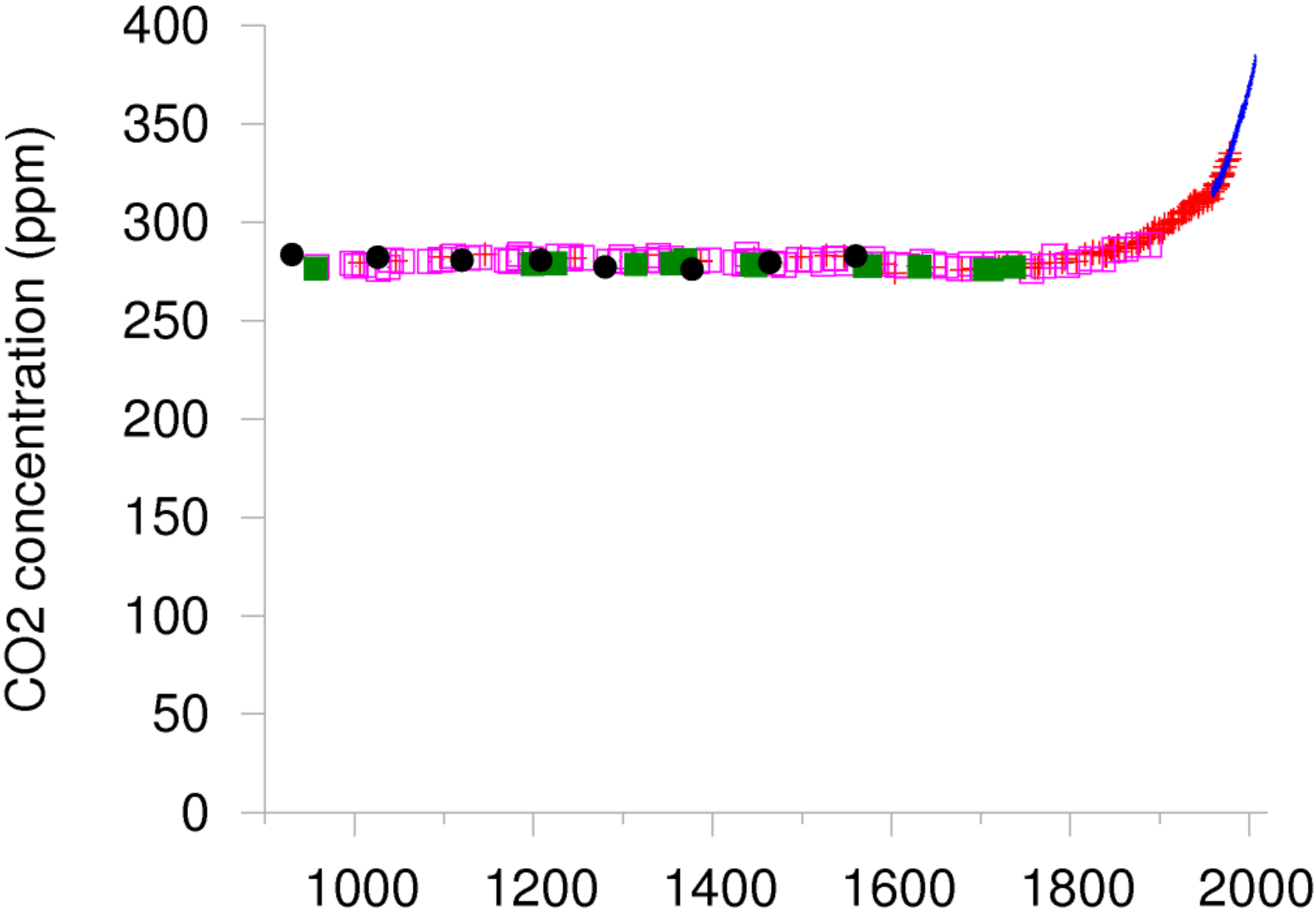
The report says this point will be two degrees centigrade above the average world temperature prevailing in 1750 before the industrial revolution, to affect the climate. But it points out that global average temperature has already risen by 0.8 degrees since then, with more rises already in the pipeline – so the world has little more than a single degree of temperature latitude before the crucial point is reached.

More ominously still, it assesses the concentration of carbon dioxide in the atmosphere after which the two-degree rise will become inevitable, and says it will be 400 parts per million by volume (ppm) of CO_2.

'Security of supply'

Magnus platform - delivers 5GW; 71,000 tonnes of steel

Photo by Terry Cavner

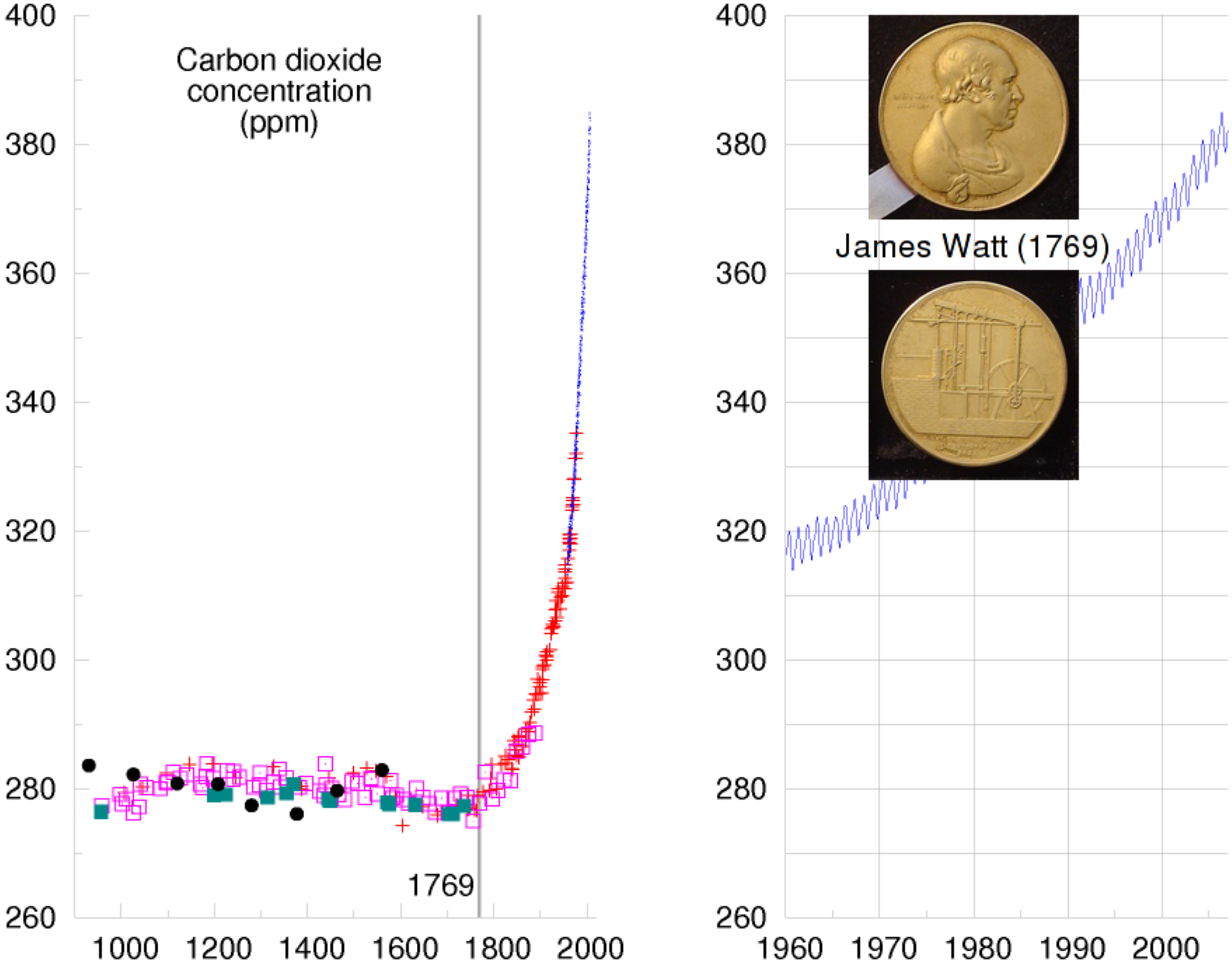

CO2 concentration (ppm)
400
350
300
250
200
150
100
50
0
1000
1200
1400
1600
1800
2000

Carbon dioxide concentration (ppm)

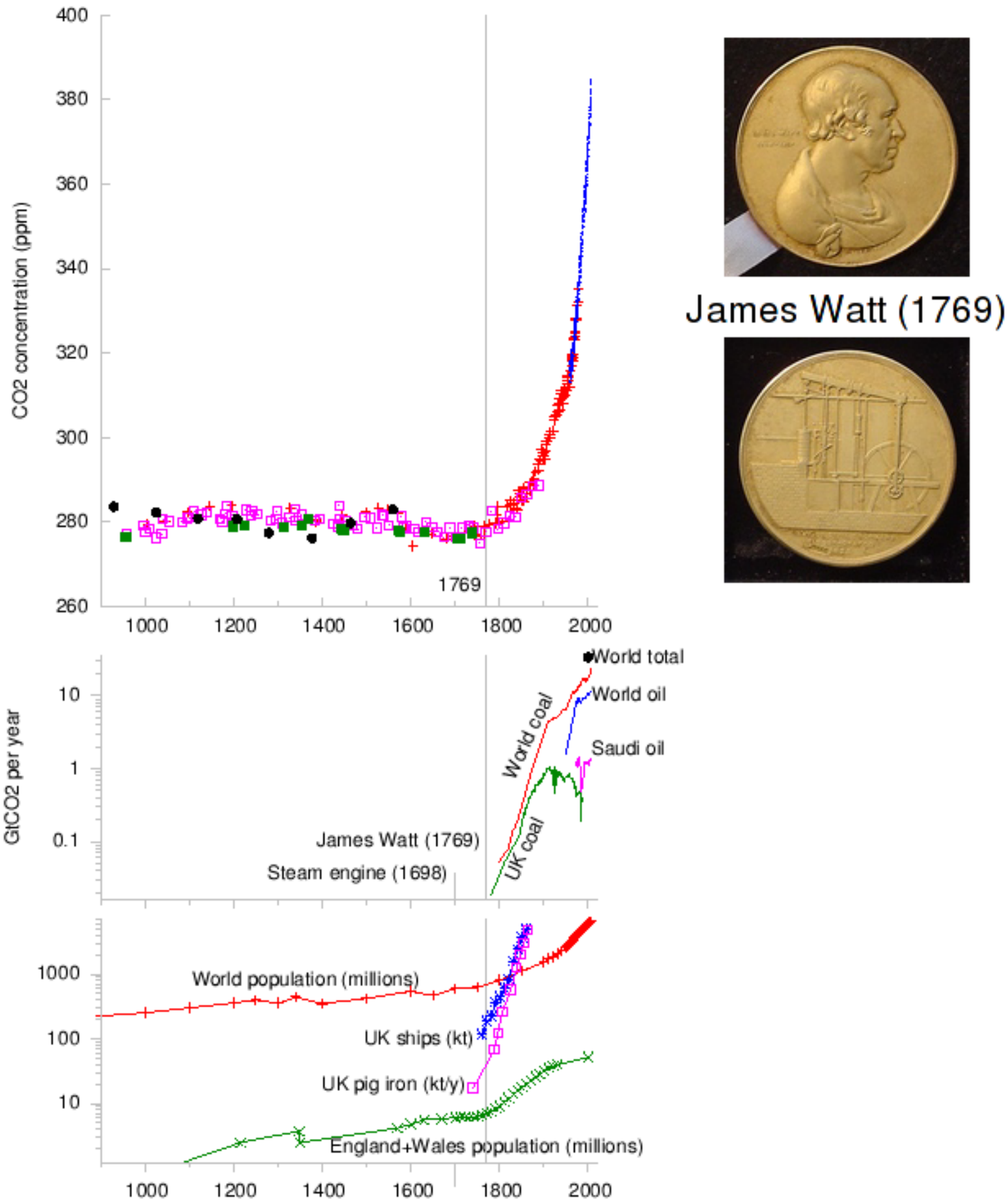
400
380
360
340
320
300
280
260
1000
1200
1400
1600
1800
2000

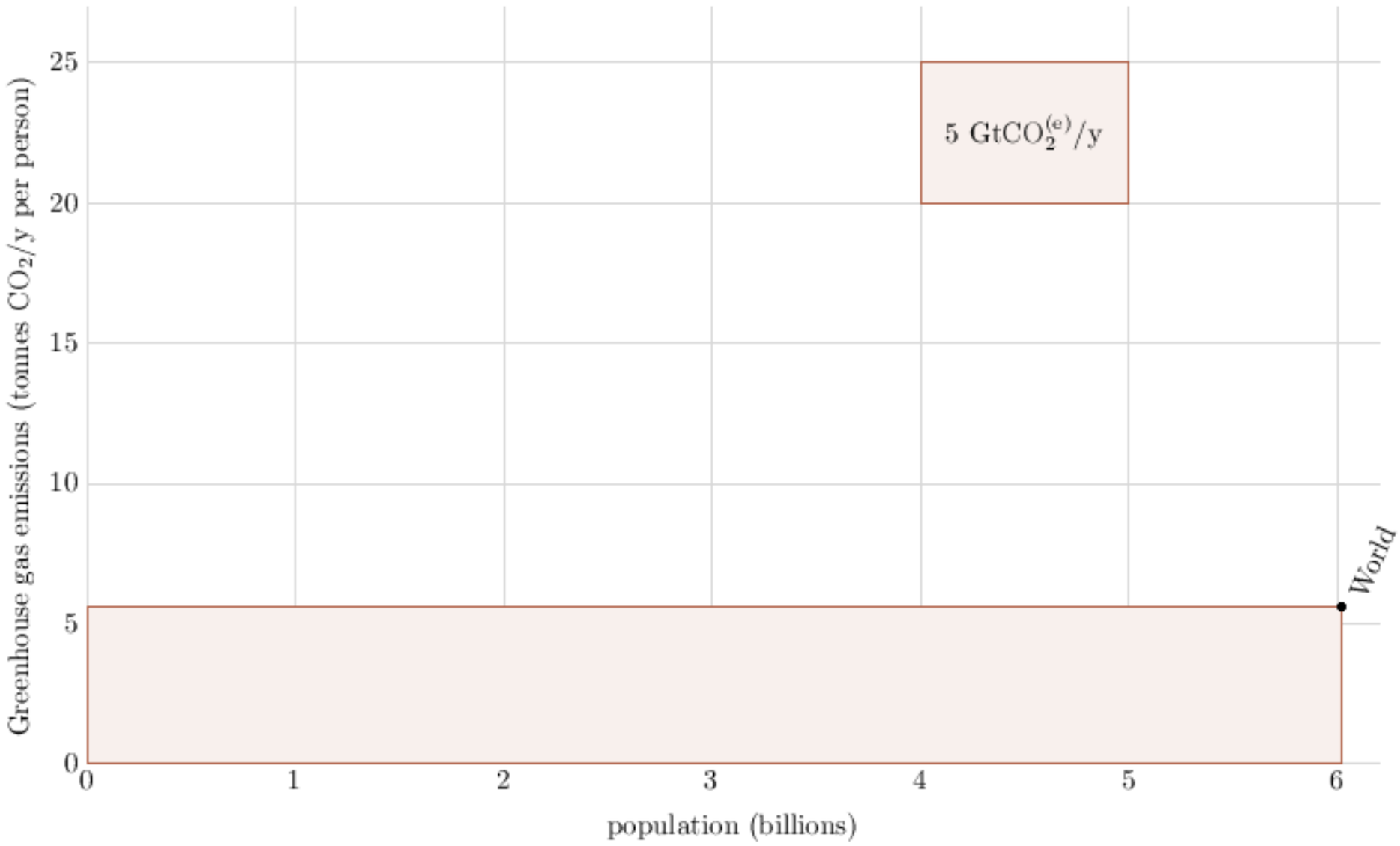
400
380
360
340
320
300
280
260
1960
1970
1980
1990
2000

Sources: Keeling and Whorf (2005); Neftel et al (1994); Etheridge et al (1998); Siegenthaler et al (2005); Indermuhle et al (1999)



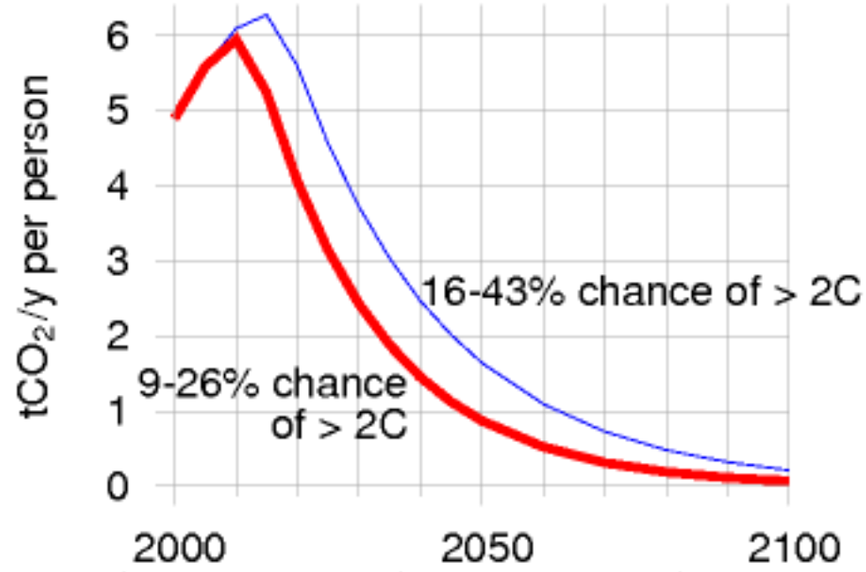
Sources: Keeling and Whorf (2005); Neftel et al (1994); Etheridge et al (1998); Siegenthaler et al (2005); Indermuhle et al (1999)


CO2 concentration (ppm)
400
380
360
340
320
300
280
260
1769
1000
1200
1400
1600
1800
2000
James Watt (1769)
GtCO2 per year
10
1
0.1
World total
World oil
Saudi oil
World coal
UK coal
James Watt (1769)
Steam engine (1698)
1000
100
10
World population (millions)
UK ships (kt)
UK pig iron (kt/y)
England+Wales population (millions)
1000
1200
1400
1600
1800
2000

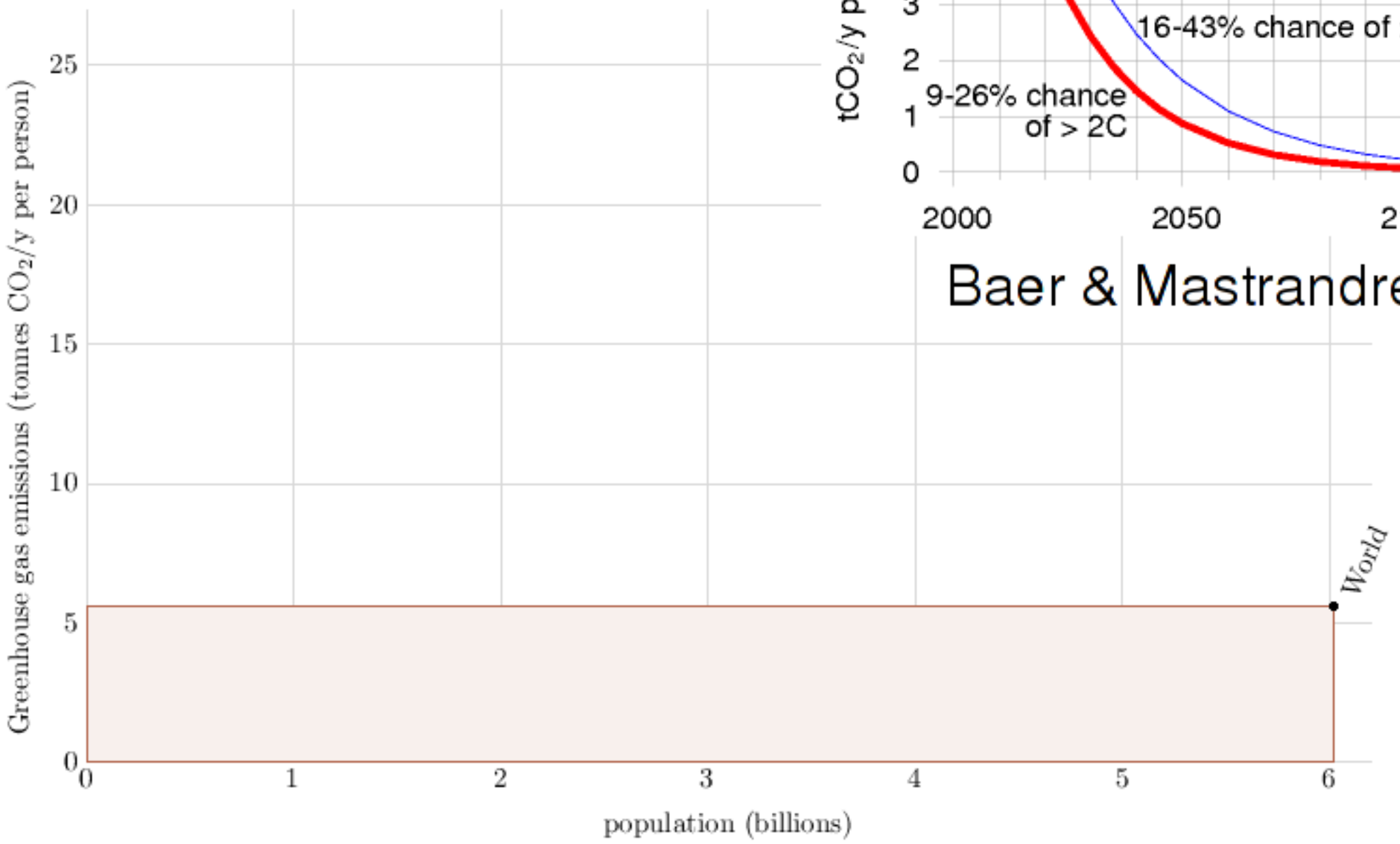


Total GHG emissions (2000) = 34 $GtCO_2e$

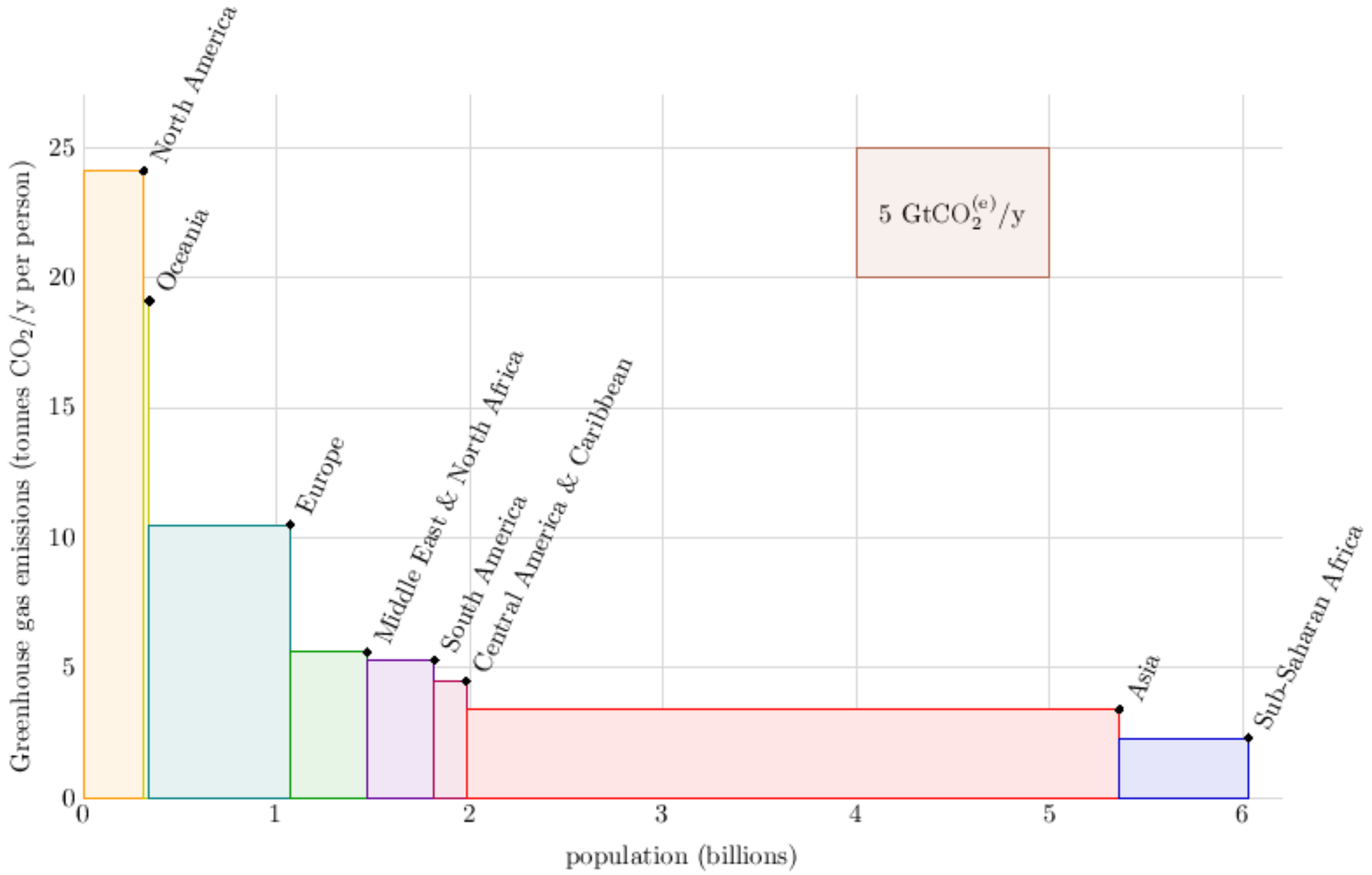
What's required:



Baer & Mastrandrea

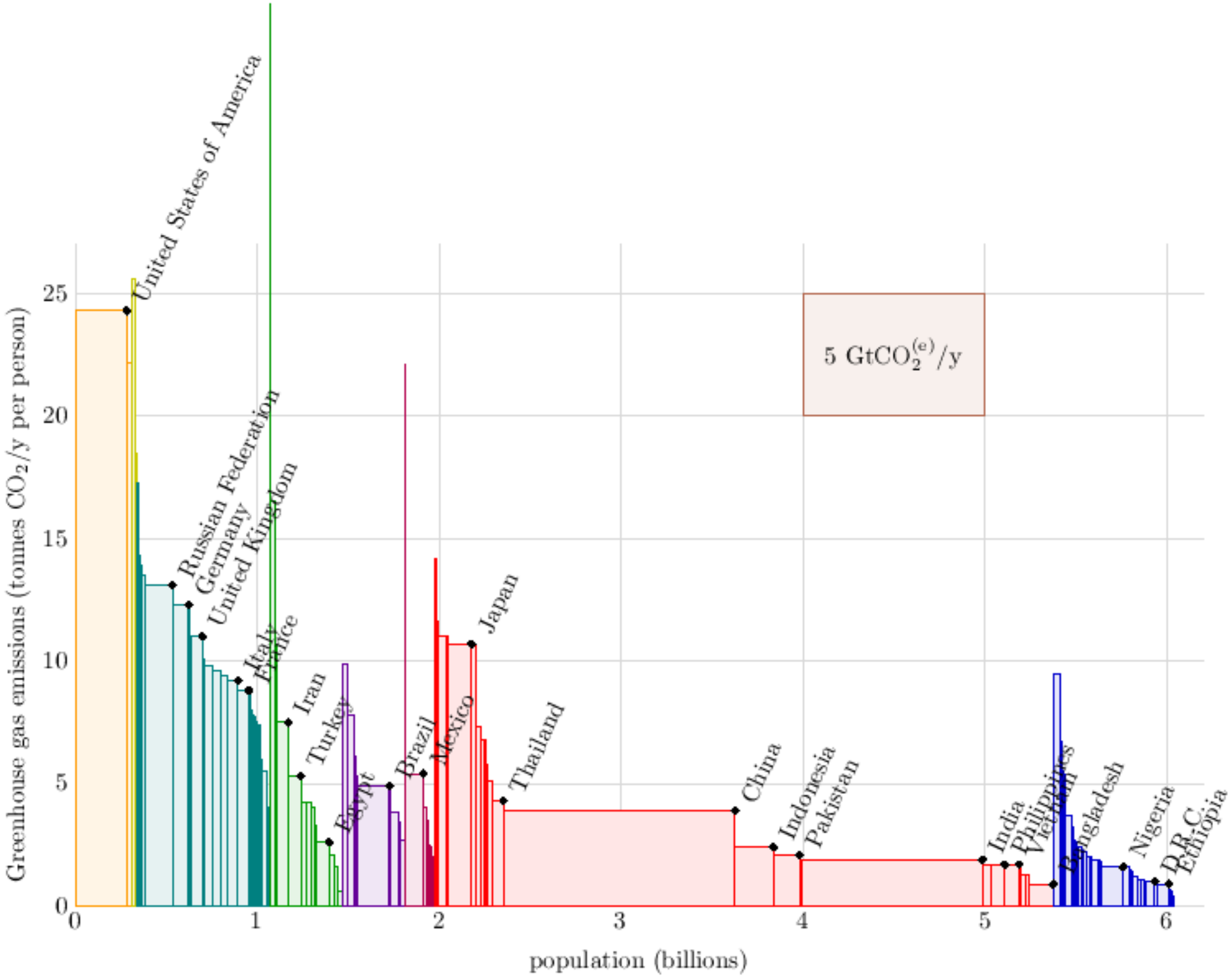


Total GHG emissions (2000) = 34 $GtCO_2e$



Total GHG emissions (2000) = 34 $GtCO_2e$

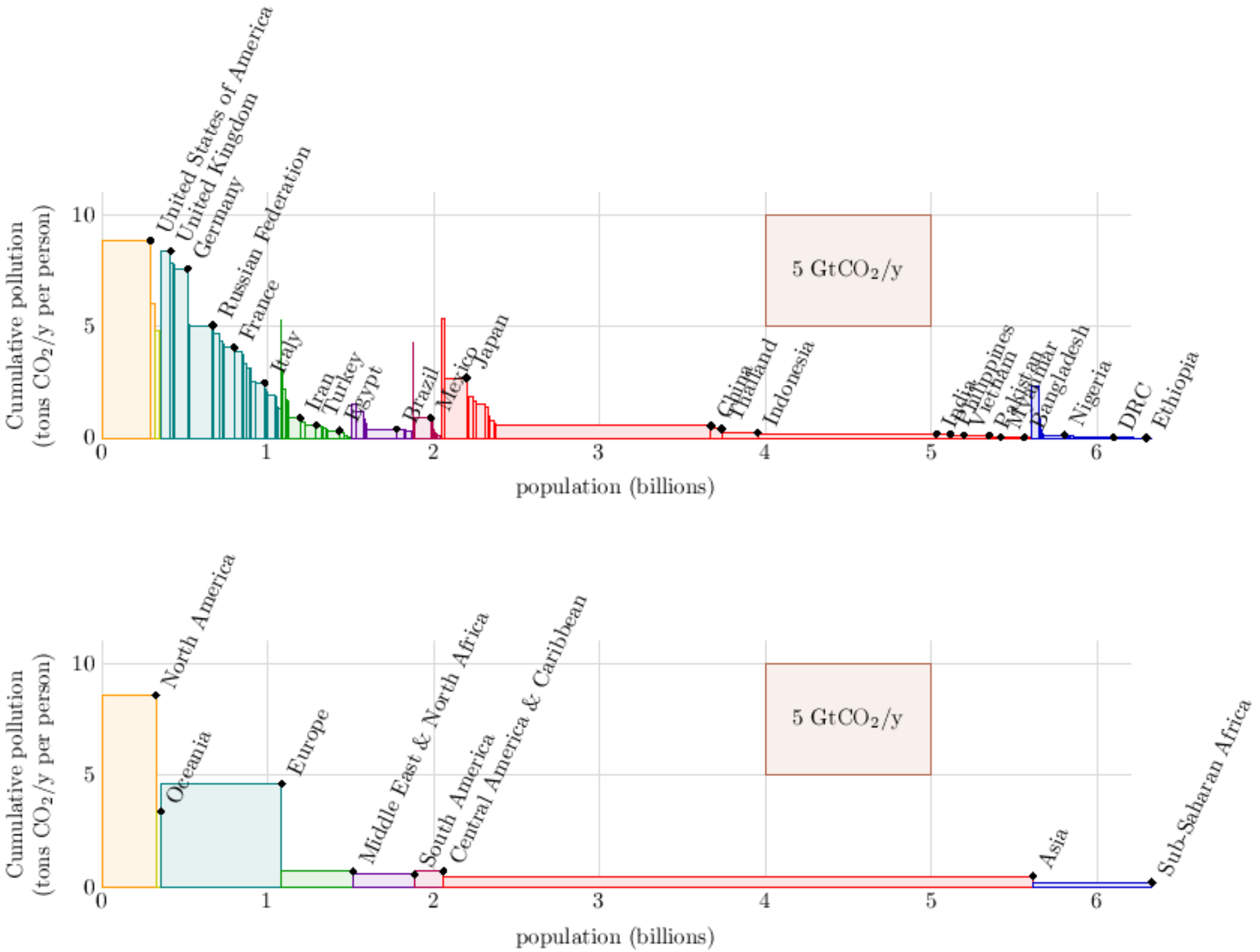
Data source: Climate Analysis Indicators Tool (CAIT)
Version 4.0. (Washington, DC: World Resources Institute, 2007).



Total GHG emissions (2000) = 34 $GtCO_2e$

Data source: Climate Analysis Indicators Tool (CAIT)
Version 4.0. (Washington, DC: World Resources Institute, 2007).

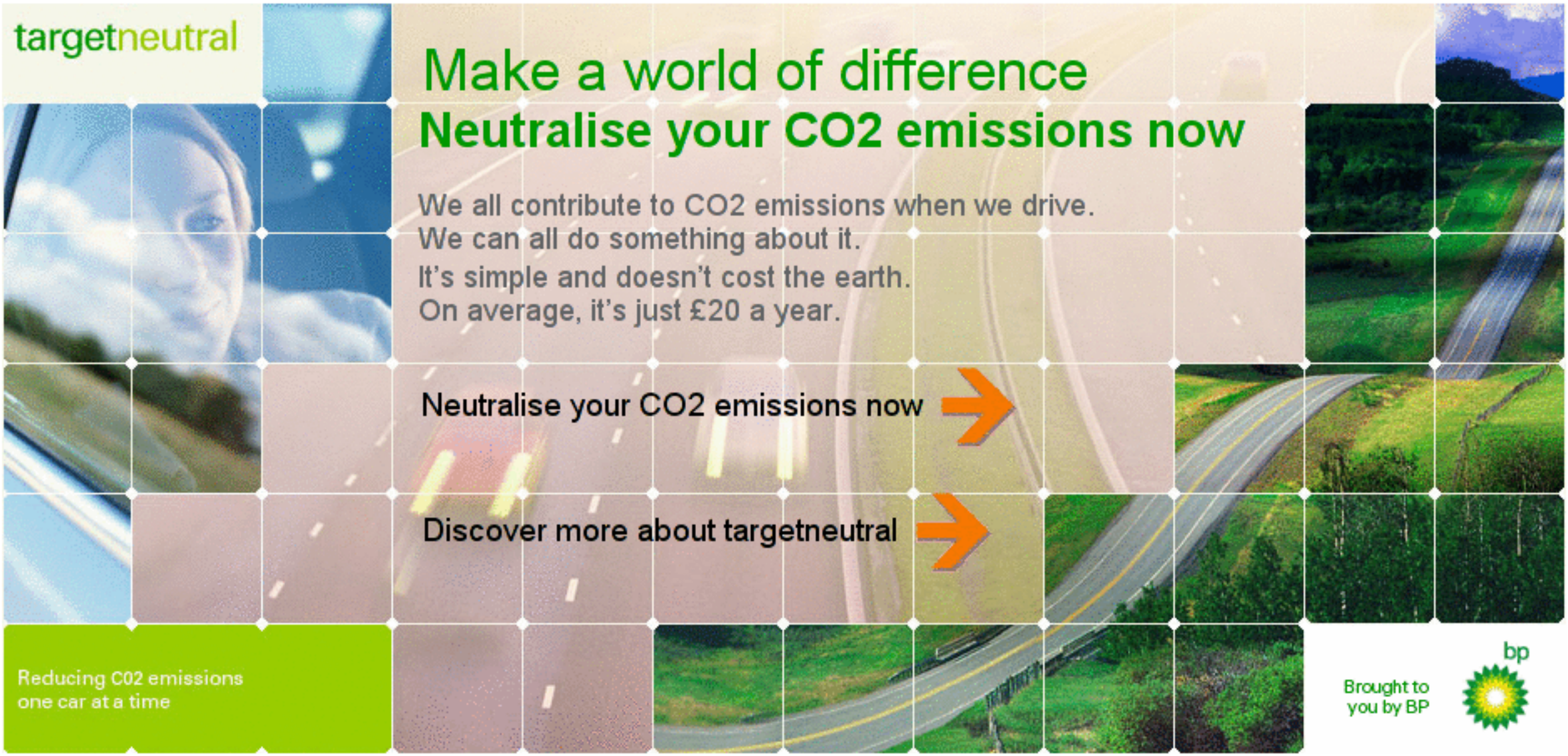
Qatar, United Arab Emirates, and Kuwait


Cumulative emissions (average for 1880–2004) – CO_2 only
Cumulative pollution (tons CO_2/y per person)
population (billions)
5 $GtCO_2$/y
United States of America
United Kingdom
Germany
Russian Federation
France
Italy
Iran
Turkey
Egypt
Brazil
Mexico
Japan
China
Thailand
Indonesia
India
Philippines
Vietnam
Pakistan
Myanmar
Bangladesh
Nigeria
DRC
Ethiopia
North America
Oceania
Europe
Middle East & North Africa
South America
Central America & Caribbean
Asia
Sub-Saharan Africa

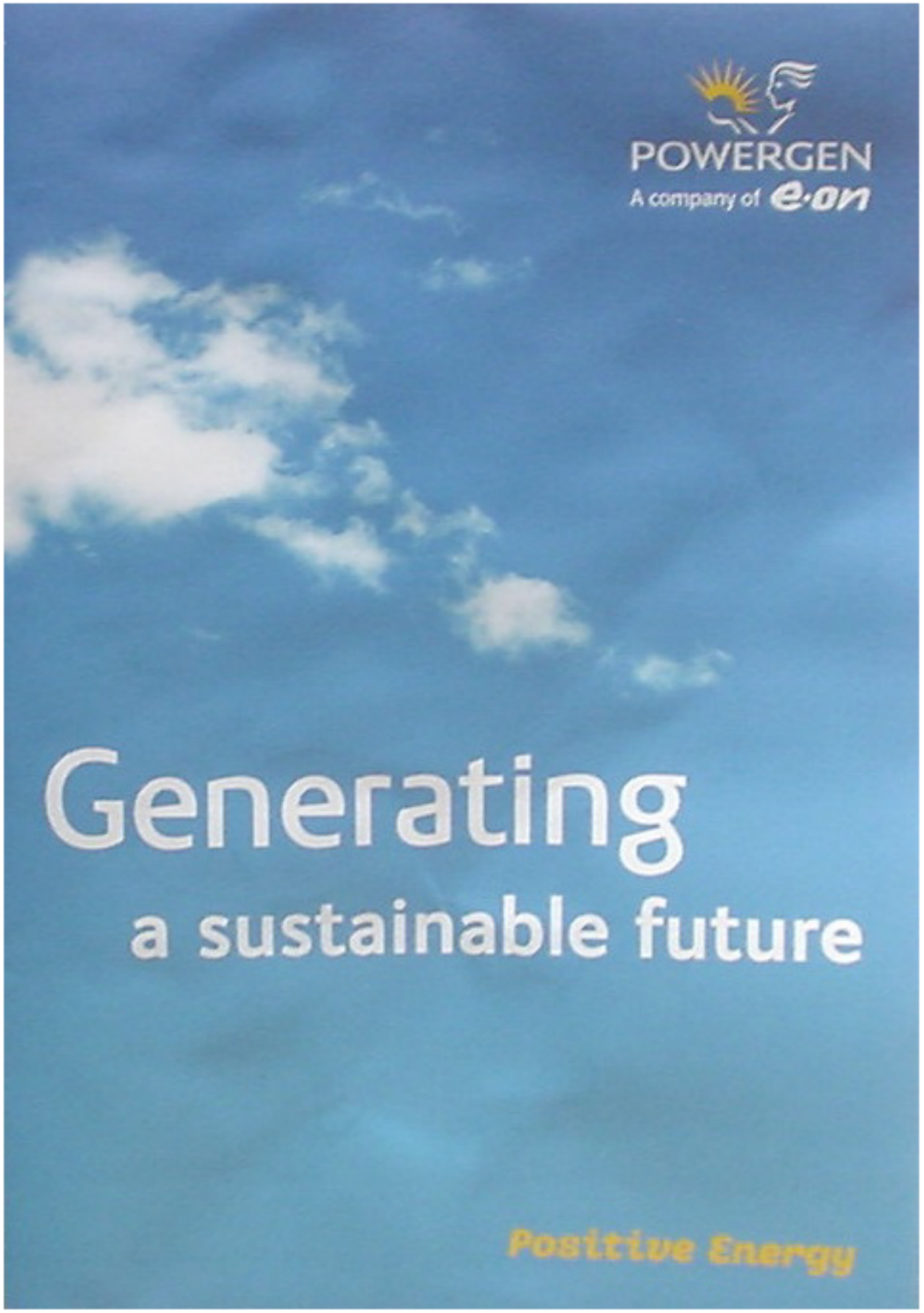
1880-2004

Something must be done!

'Make a difference'



'Do your bit'!



98% of Powergen's electricity is fossil; just 2% renewables

'Industry have done their bit'

The car industry has done its bit by making greener vehicles. Now we have to buy them, says **Sean O'Grady**

34mpg

- **219g/km**

ything.

HEAD

huge prob-
finding a
space and
usually re-
ning that
like
ehi-
V3

te

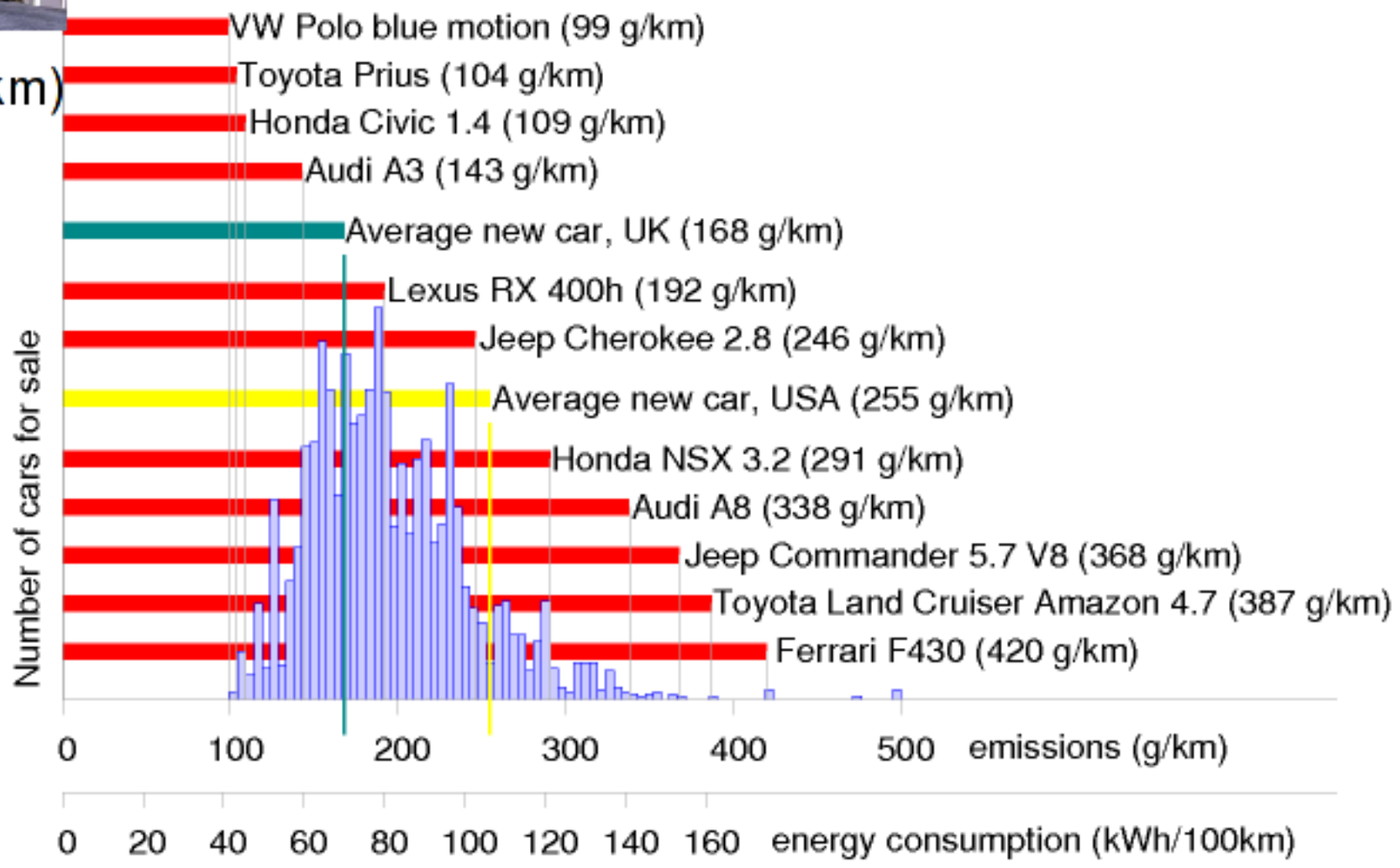
The 2.4 Diesel is efficient and probably the best all-round choice, offering 34mpg overall. During the past few years, it has

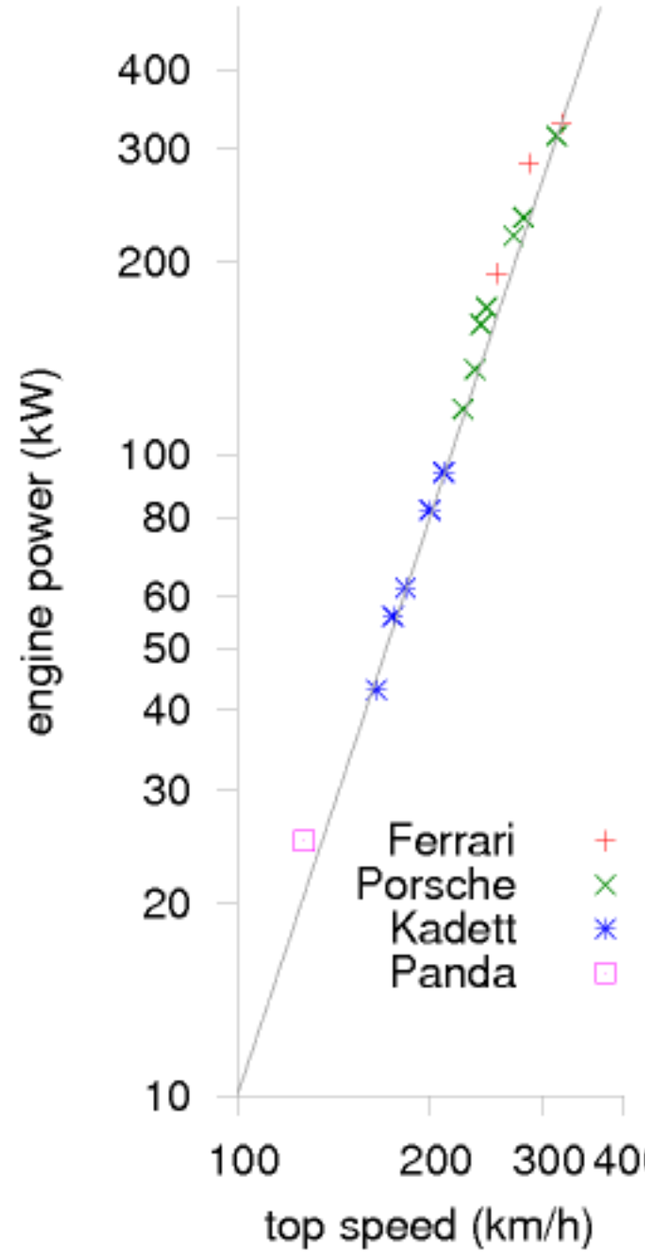
trouble is, the R-Class is furiously expensive, with prices starting at more than £38,000.

Practically perfect: the Volvo XC90

Carbon emissions from cars

Polo (102 g/km)





Efficiency through technology

'a highly fuel-efficient aircraft'

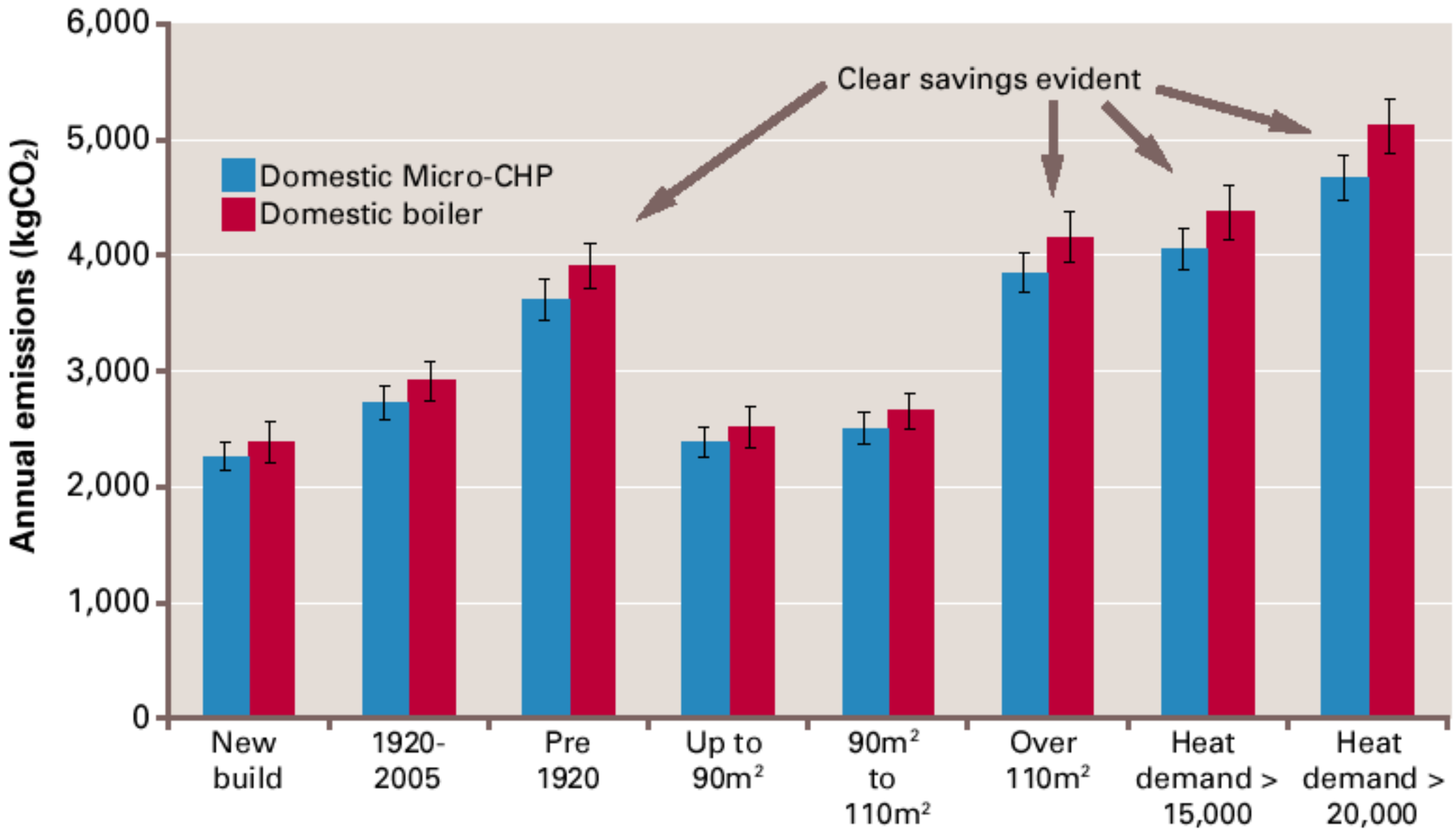
- it burns 12 percent less fuel per passenger-km than a 747

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*



Solar bra brings conservation closer to the heart

Wed May 14, 2008 8:53pm IST

anytime soon, said Triun
Masuda, as "people usua
wearing clothes over it."

Eco Money Savers : HY-Mini - Personal Portable Wind Power

£39.95

Quantity: 1 ADD TO CART

17956 HY-Mini - Personal Portable Wind Power

Attach this innovative portable and personal wind turbine to your arm, bike bars, or windowsill, and it will capture wind energy, transforming it into usable power for your mobile devices. This brilliantly clever recharger is perfect for travel and cycling holidays! With a built-in turbine, it's chargable by kinetic energy (requires minimum wind speed 9mph), but you can also charge it using an ordinary socket.

Plug in, charge up, and it becomes a power storage unit. HY-Mini is universally adaptable for your mobile devices. An AC/DC power adaptor for 3-pin wall plugs, USB transfer cable and mobile phone (Nokia / Motorola / Sony Ericsson /Samsung / LG) adaptors are included. MP3 player, iPod, PDA, digital camera, and other 5V handheld devices can be charged with original manufacturer USB or aftermarket USB cables.

Order an Armband Kit (17958) or Bicycle Kit (17957) to attach the charger for power on-the-move.

Something must be done!

Nuclear versus Wind

"if we're going to cut greenhouse gases by 60% by 2050 there is no other possible way of doing that except through renewables".

Michael Meacher

former Environment Minister

"anybody who is relying upon renewables to fill the energy gap is living in an utter dream world and is, in my view, an enemy of the people."

Sir Bernard Ingham

former civil servant, Chief Press Secretary, Head of the Government Information Service

'We have a *huge* amount of wave and wind'.

'Nuclear is a money pit'.

Ann Leslie

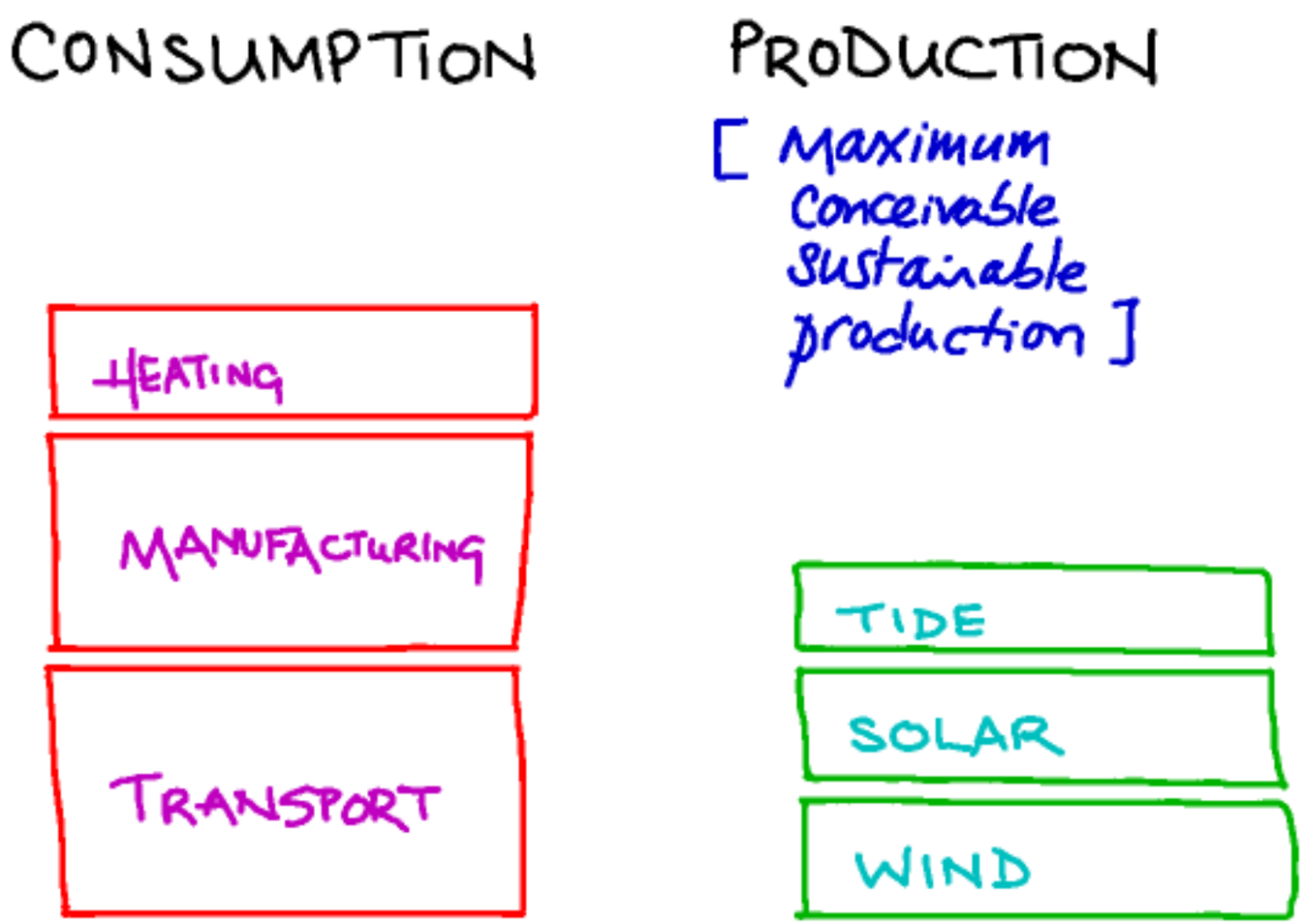
journalist

We need numbers, not adjectives

- Part I: Numbers, not adjectives
  - Could a country like Britain live on its own renewables?
- Part II: Energy plans that add up

Part I: Numbers, not adjectives

- Ignore economic, social, + environmental constraints



Choose good units

- No millions, billions, or trillions
- Make quantities comprehensible and comparable

- Do calculations per person, to one significant figure

- Energy unit: kWh

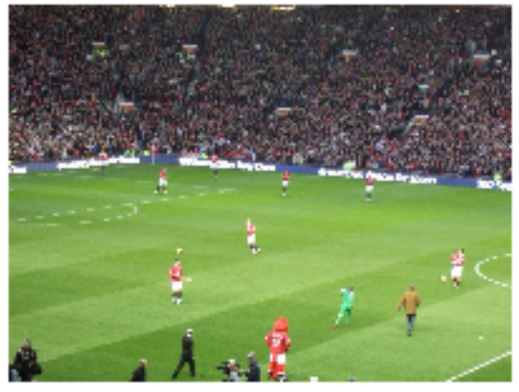
- Power unit: kWh per day

- Fluxes: W per square metre

- Examples
  - 20 mins of kettle - 1 kWh
  - food - 3 kWh / day(*)
  - bath - 5 kWh(*)
  - litre of petrol - 10 kWh
  - aluminium can - 0.6 kWh

- Population density: square metres per person

UK: $4000\ \mathrm{m}^2$ per person



Cars

$$\begin{aligned}
\text{Energy used per day} &= \frac{\text{Distance travelled per day}}{\text{Distance per unit of fuel}} \times \text{Energy per unit of fuel} \\
&= \frac{50\,\text{km/day}}{12\,\text{km/litre}} \times 10\,\text{kWh/litre} \\
&\simeq 40\,\text{kWh/day}.
\end{aligned}$$

Car:
40 kWh/d

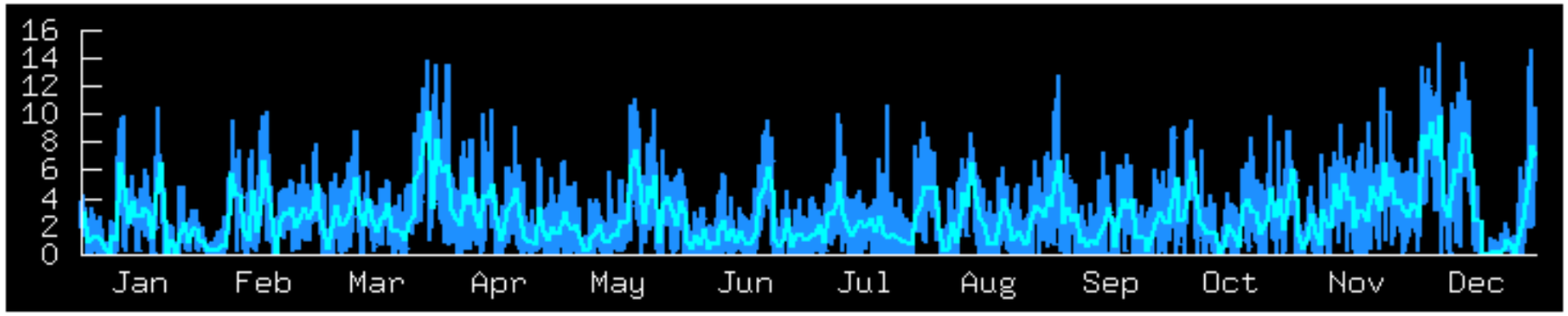
33 miles per UK gallon

40 kWh is not an average figure for UK, but a plausible value for an ordinary car-lover

f

Wind

Wind



Windspeeds Cambridge 2006 (m/s) Half-hourly and daily

Wind

$v = 6\,\mathrm{m/s}$ (force 4)
Wind farm $2\,\mathrm{W/m^2}$ flat ground

UK: $4000\ \mathrm{m^2}$ per person

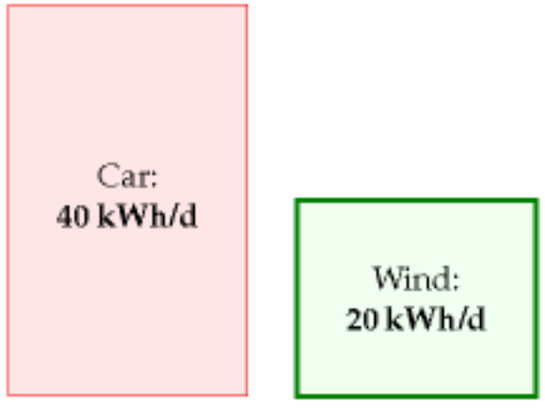
Put wind farms on 10% of the country

- 400 square metres each

...Twice as much windpower as the whole world;

50 x Denmark's

7 x Germany's



Flight

$$7\,600\,\text{miles: one round-trip / year:}$$

$$\frac{2 \times 240\,000\,\text{litre}}{416\,\text{passengers}} \times 10\,\text{kWh/litre/year}$$

$$= 29\,\text{kWh/day}$$

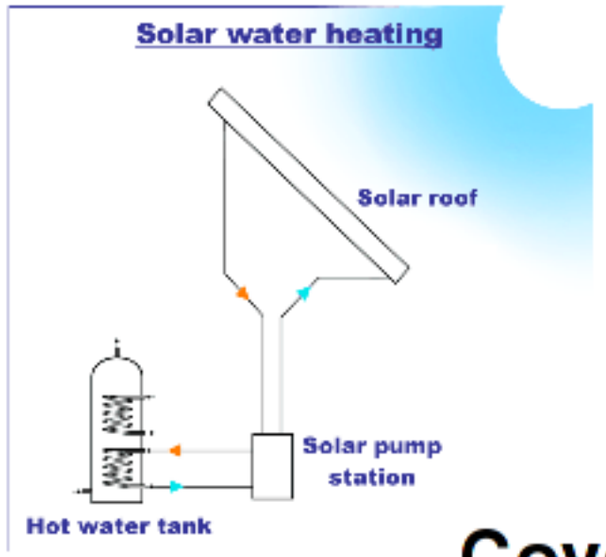
Jet flights:
30 kWh/d

Car:
40 kWh/d

Wind:
20 kWh/d

Solar

- Solar thermal



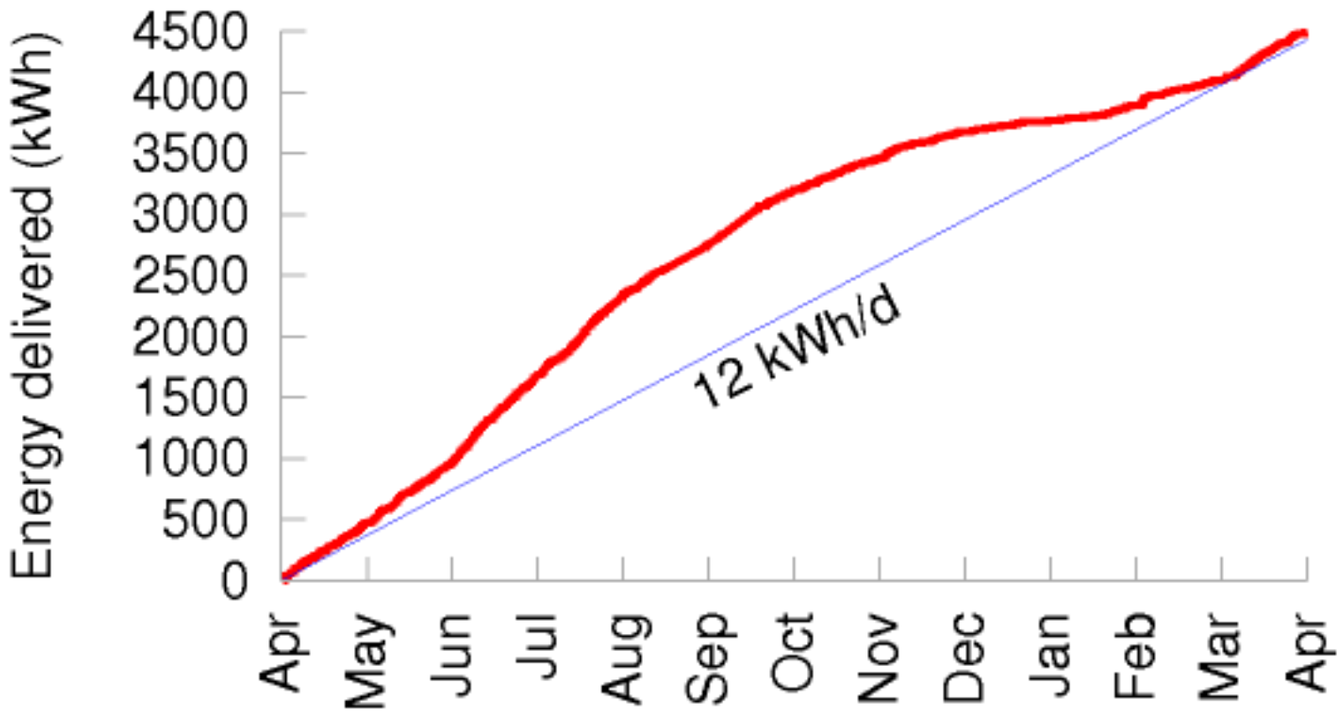
Cover every south-facing roof

Jet flights: **30 kWh/d**	$10\,\mathrm{m}^2$ per person:
Car: **40 kWh/d**	$13\,\mathrm{kWh/day}$ per person
	Solar heating: **13 kWh/d**
	Wind: **20 kWh/d**

Solar electric (photovoltaics)

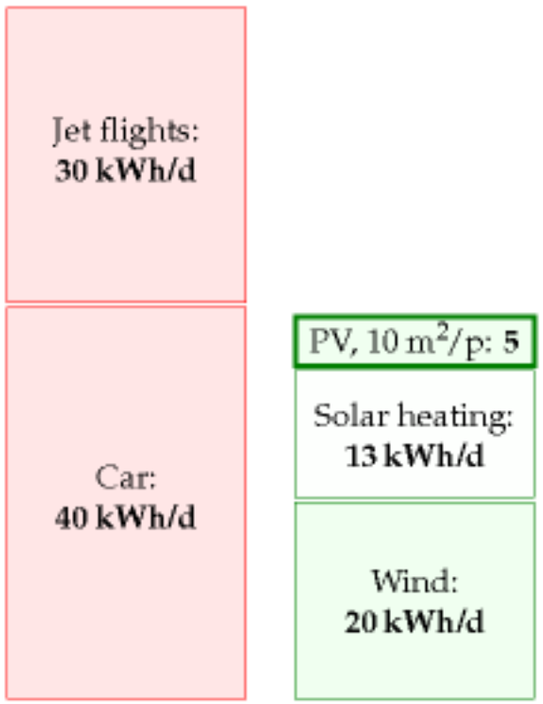
solarcentury

Solar electric



Data and photo by Jonathan Kimmitt

Cover *every South-facing roof*,
$10\,\mathrm{m}^2$ per person: $5\,\mathrm{kWh/day}$ per person



Solar PV farming

Bavaria Solar Park: $5\,\mathrm{W/m^2}$; this picture shows $0.7\,\mathrm{MW}$ (average)

Solar PV (covering 5-10% of the country)

Jet flights:
30 kWh/d

Car:
40 kWh/d

PV farm
(200 m^2/p):
50 kWh/d

PV, 10 m^2/p: **5**

Solar heating:
13 kWh/d

Wind:
20 kWh/d

Solar biomass

- Best plants (0.5% efficient)
  - cover 75% of the country;
  - 1/3 lost in processing.

Jet flights: **30 kWh/d**

Car: **40 kWh/d**

Biomass: food, biofuel, wood, waste incin'n, landfill gas: **24 kWh/d**

PV farm (200 m^2/p): **50 kWh/d**

PV, 10 m^2/p: **5**

Solar heating: **13 kWh/d**

Wind: **20 kWh/d**

includes

sustainable waste incineration

cellulosic ethanol

methanol

Heating and cooling

Hot water

Bath: 5 kWh

Shower: 1.4 kWh

Clothes wash: 1 kWh

Cooking, kettle, microwave, dishes

Hot water:
12 kWh/d

Hot air

Hot air:
24

Fridge, Airconditioning

Cooling: **1 kWh/d**

Heating, cooling:
37 kWh/d

Jet flights:
30 kWh/d

Car:
40 kWh/d

Biomass: food, biofuel, wood, waste incin'n, landfill gas:
24 kWh/d

PV farm (200 m^2/p):
50 kWh/d

PV, 10 m^2/p: **5**

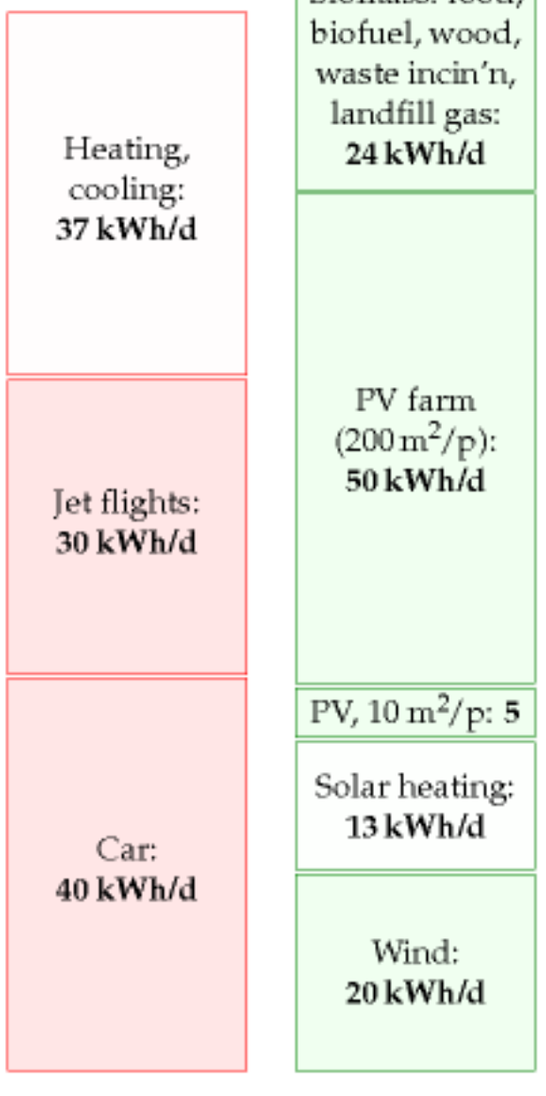
Solar heating:
13 kWh/d

Wind:
20 kWh/d

Hydro

- 1.5 kWh/d per person

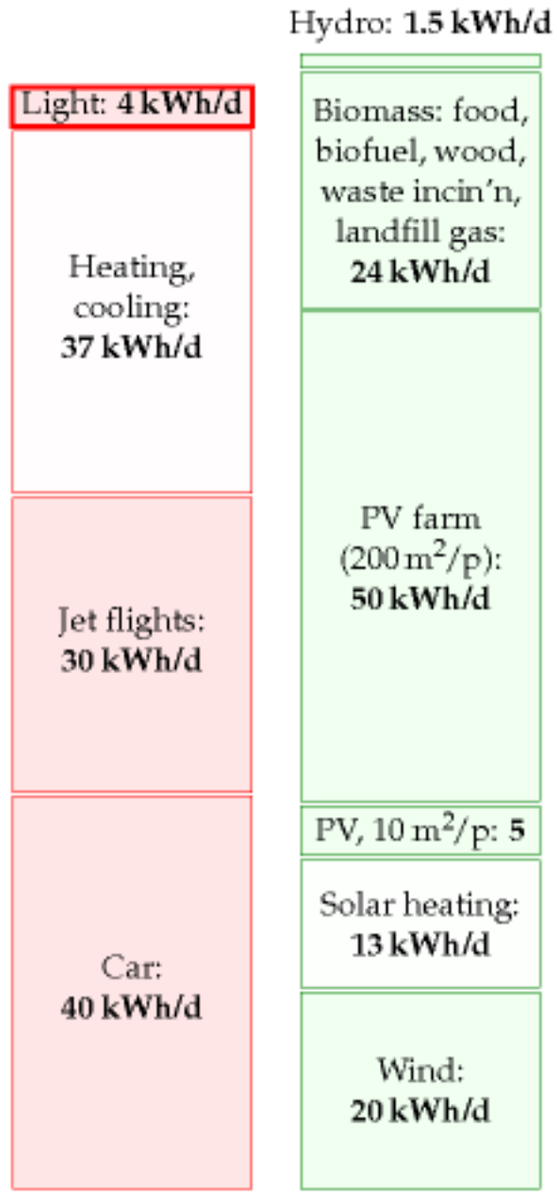
(currently 0.2 kWh/d per person)



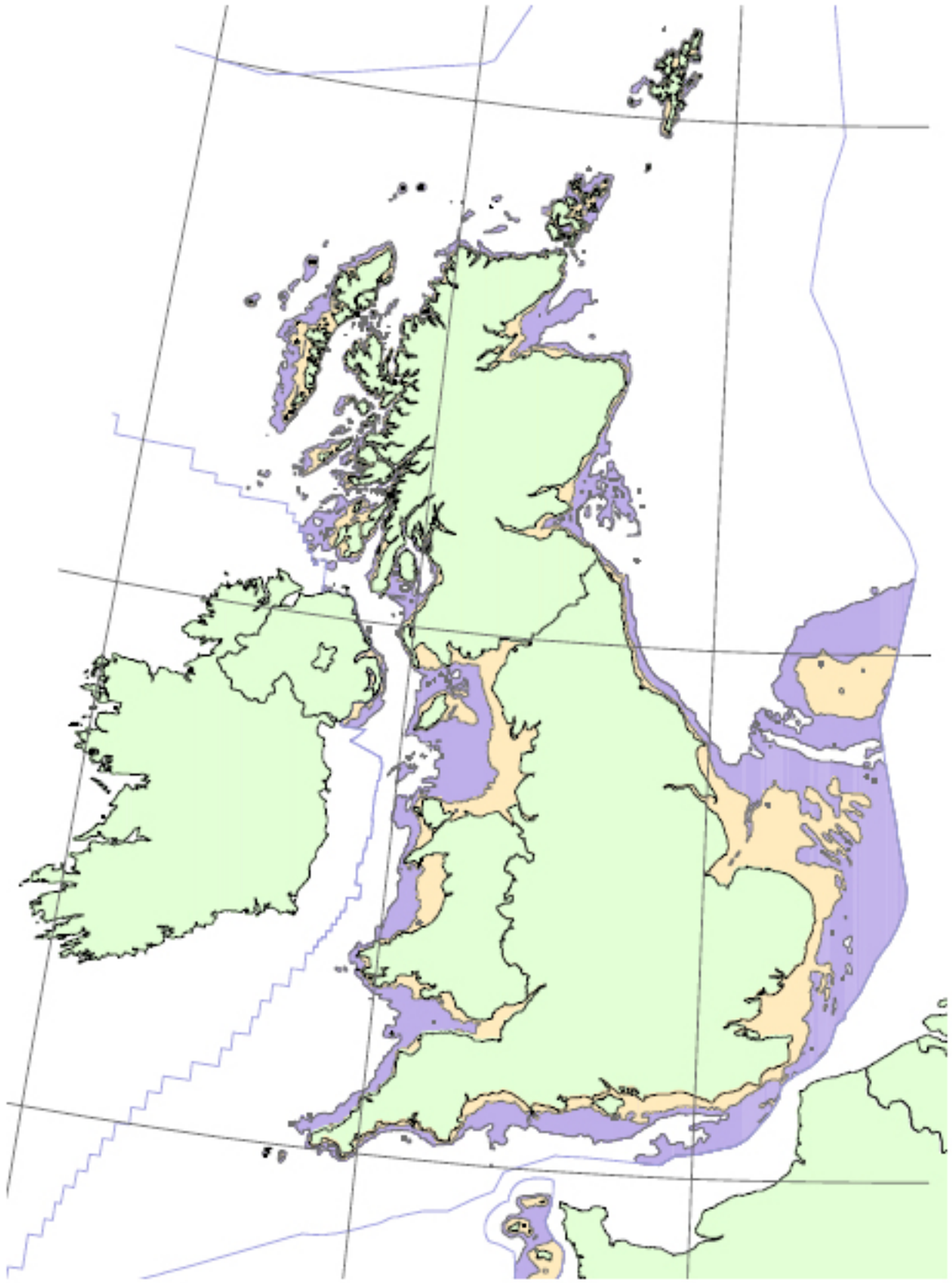
Nant-y-Moch by Dave Newbould
www.origins-photography.co.uk

Light

- 10 bulbs
- 5 hours per day



Offshore wind



depth less than 25m (yellow); depth between 25m and 50m (magenta).
Data from DTI Atlas of Renewable Marine Resources. Crown copyright.

Light: **4 kWh/d**

Heating, cooling: **37 kWh/d**

Jet flights: **30 kWh/d**

Car: **40 kWh/d**

Shallow offshore wind: **16 kWh/d**

Hydro: **1.5 kWh/d**

Biomass: food, biofuel, wood, waste incin'n, landfill gas: **24 kWh/d**

PV farm (200 m^2/p): **50 kWh/d**

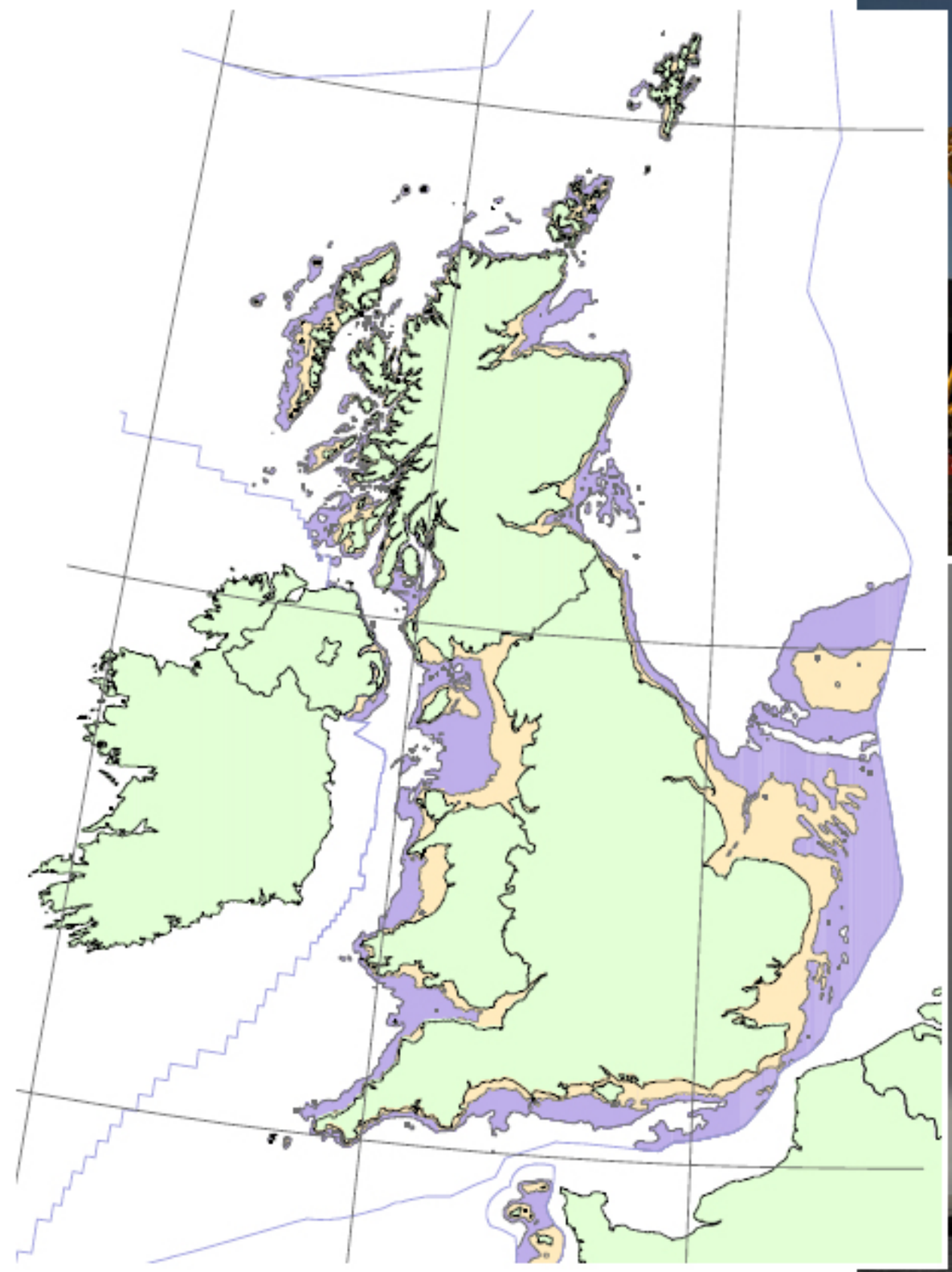
PV, 10 m^2/p: **5**

Solar heating: **13 kWh/d**

Wind: **20 kWh/d**

(c) Elsam (elsam.com).
Used with permission.

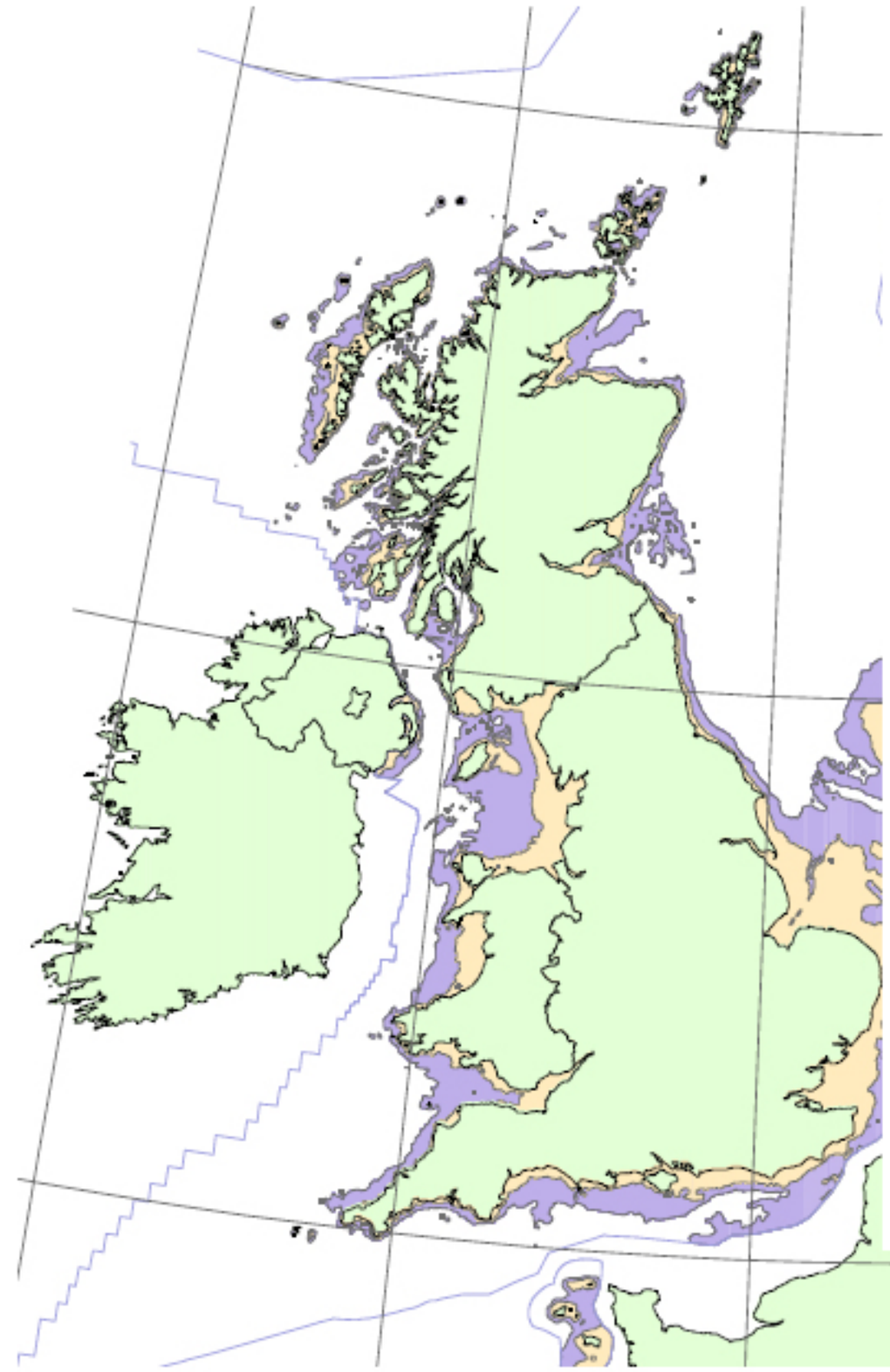
Deep offshore wind



depth less than 25m (yellow); depth between 25m and 50m (magenta).

Data from DTI Atlas of Renewable Marine Resources. Crown copyright.

Deep offshore wind



depth less than 25m (yellow); depth between 25m and 50m (magenta).

Light: **4 kWh/d**

Heating, cooling: **37 kWh/d**

Jet flights: **30 kWh/d**

Car: **40 kWh/d**

Deep offshore wind: **32 kWh/d**

Shallow offshore wind: **16 kWh/d**

Hydro: **1.5 kWh/d**

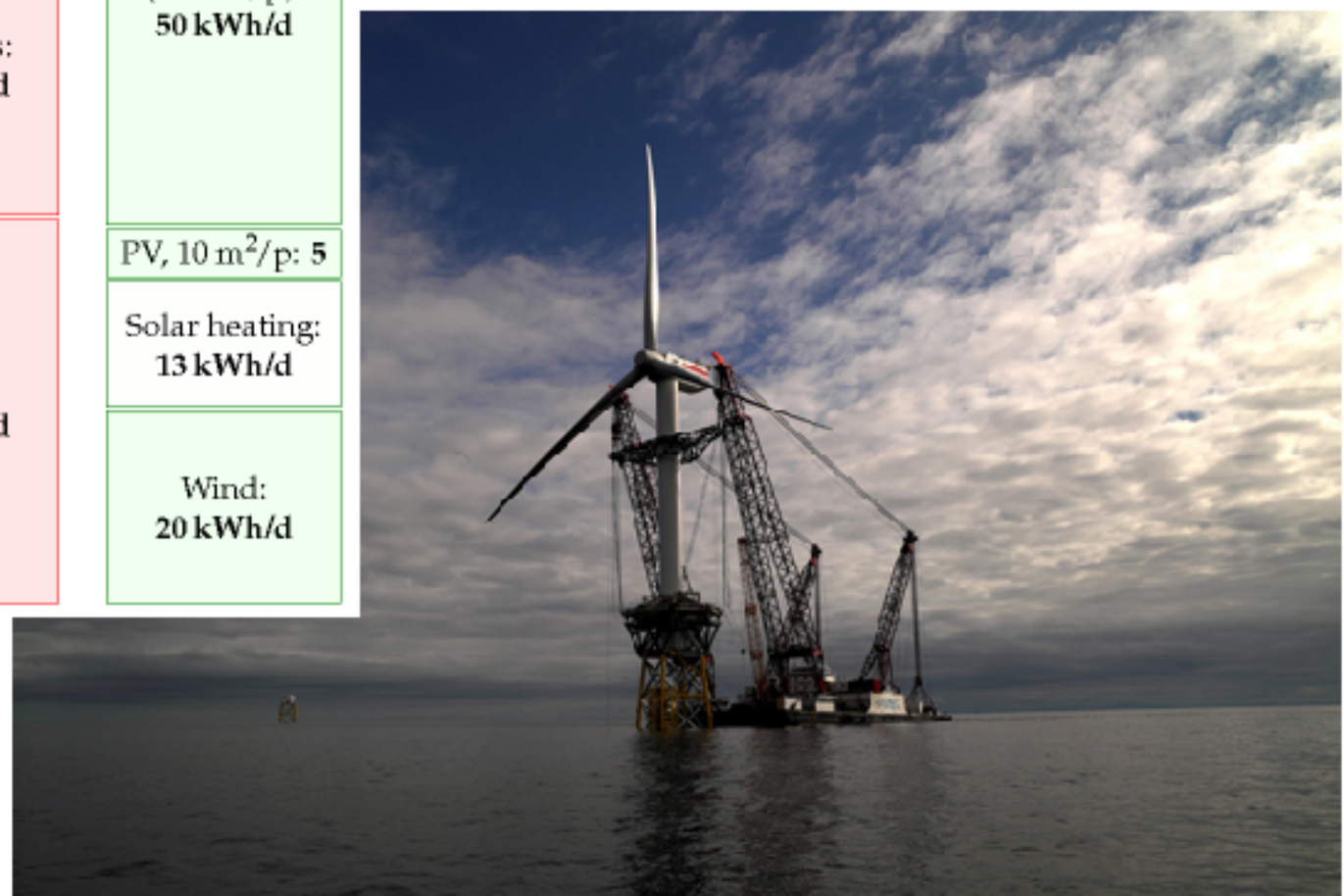
Biomass: food, biofuel, wood, waste incin'n, landfill gas: **24 kWh/d**

PV farm (200 m^2/p): **50 kWh/d**

PV, 10 m^2/p: **5**

Solar heating: **13 kWh/d**

Wind: **20 kWh/d**



Gadgets

- TV
- Computer
- Cable modem
- Mobile phones
- Bedside radio
- Other gadgets

Charger left plugged in:

0.01 kWh/d

Gadgets: **5**

Light: **4 kWh/d**

Heating, cooling: **37 kWh/d**

Jet flights: **30 kWh/d**

Car: **40 kWh/d**

Deep offshore wind: **32 kWh/d**

Shallow offshore wind: **16 kWh/d**

Hydro: **1.5 kWh/d**

Biomass: food, biofuel, wood, waste incin'n, landfill gas: **24 kWh/d**

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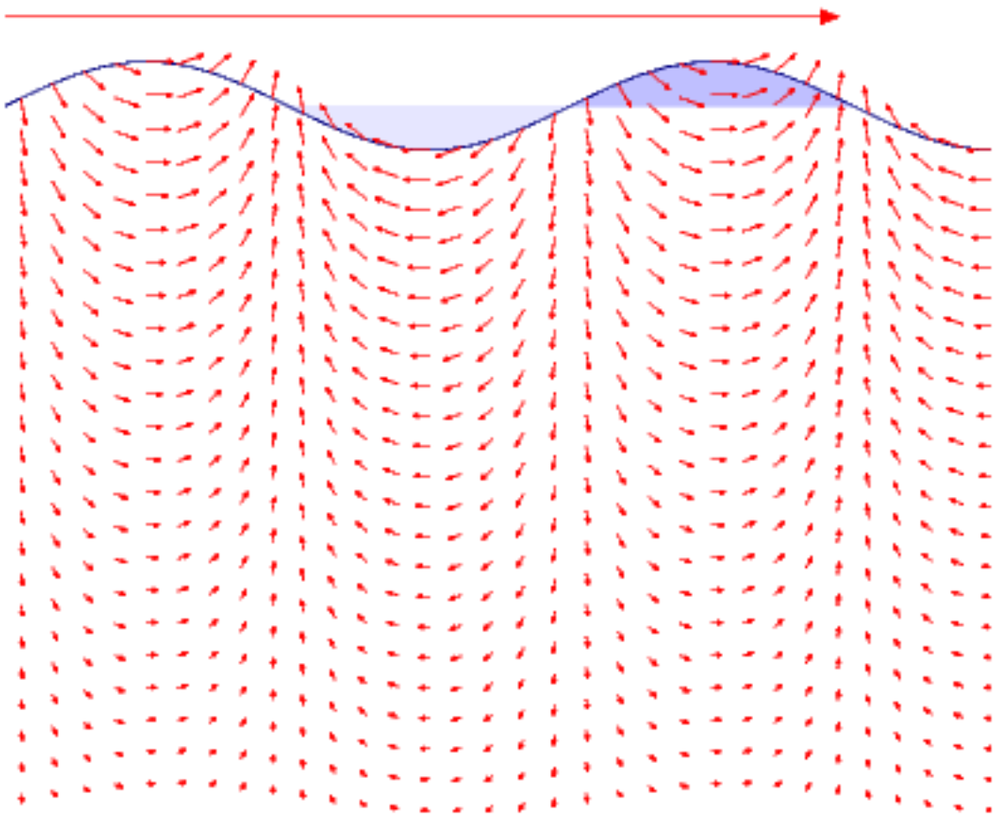
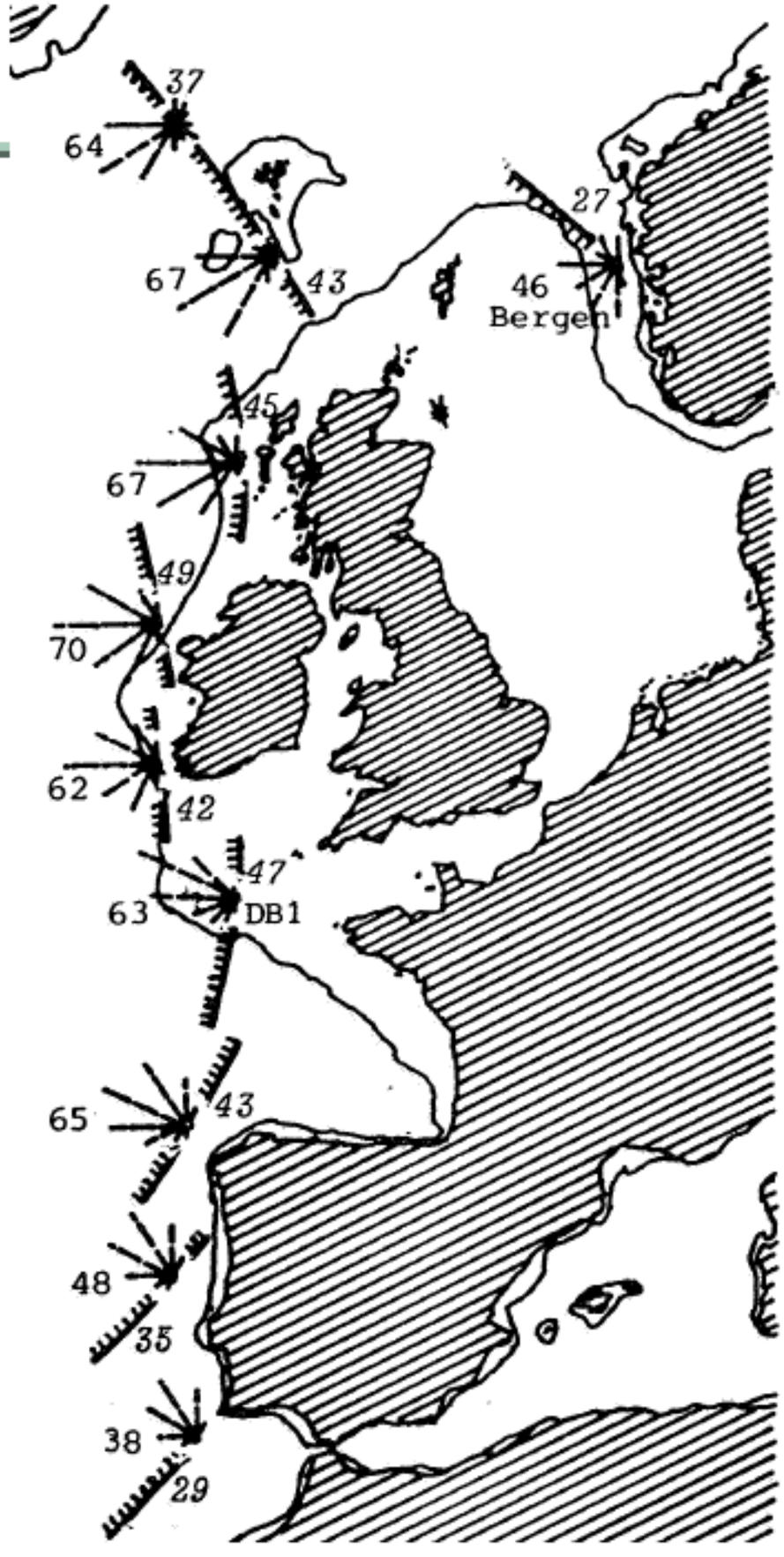
Wave





D. Mollison: Wave climate and the wave power resource (1986)

Wave

Wave: **4 kWh/d**

Deep offshore wind: **32 kWh/d**

Shallow offshore wind: **16 kWh/d**

Hydro: **1.5 kWh/d**

Biomass: food, biofuel, wood, waste incin'n, landfill gas: **24 kWh/d**

PV farm (200 m^2/p): **50 kWh/d**

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Wind: **20 kWh/d**

Gadgets: **5**

Light: **4 kWh/d**

Heating, cooling: **37 kWh/d**

Jet flights: **30 kWh/d**

Car: **40 kWh/d**

'500 kW' Limpet, Islay

Predicted average power: 200kW. Actual: 21kW.

Total incident power / population of UK

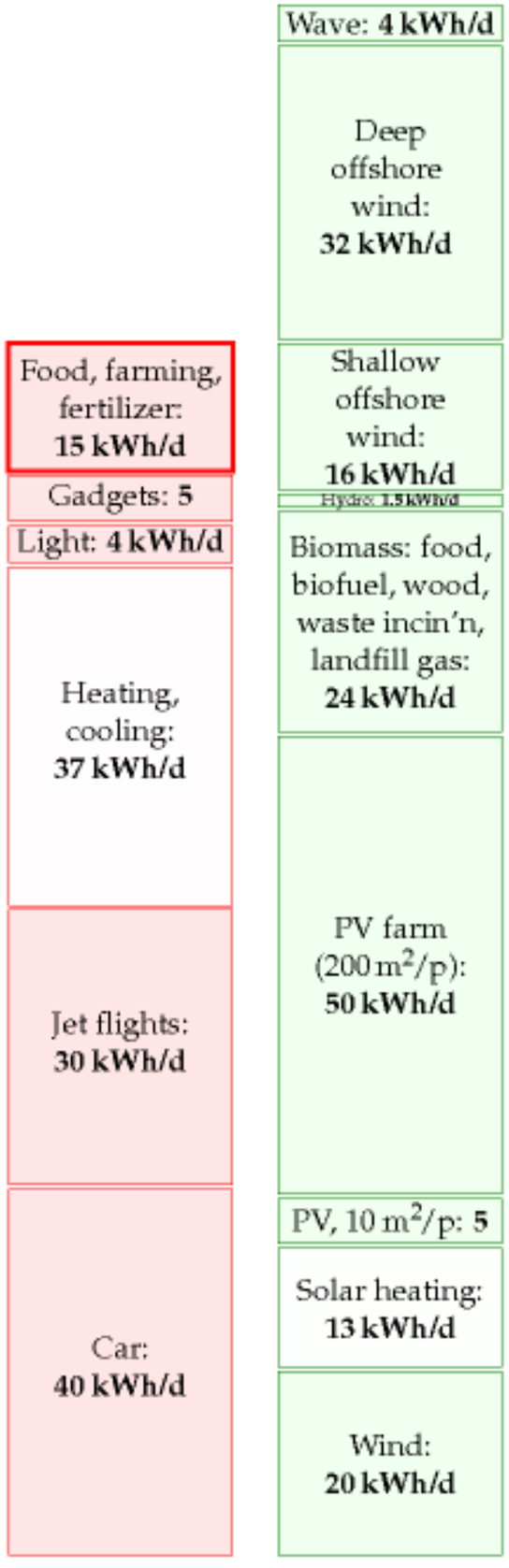
$$= \frac{40\,\text{kW/metre} \times 1000\,\text{km}}{60 \times 10^6} = 16\,\text{kWh/day}$$

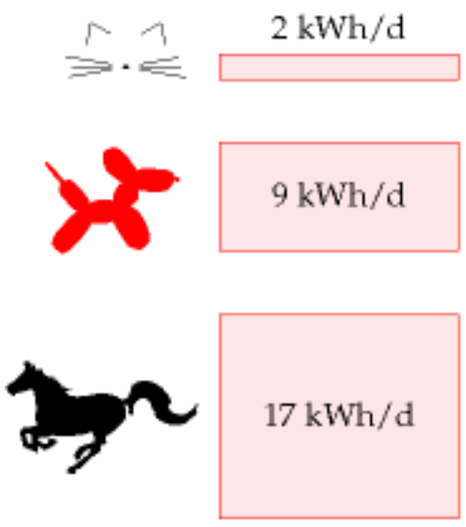
Ocean Power Delivery (ocea

Food'n'Farming

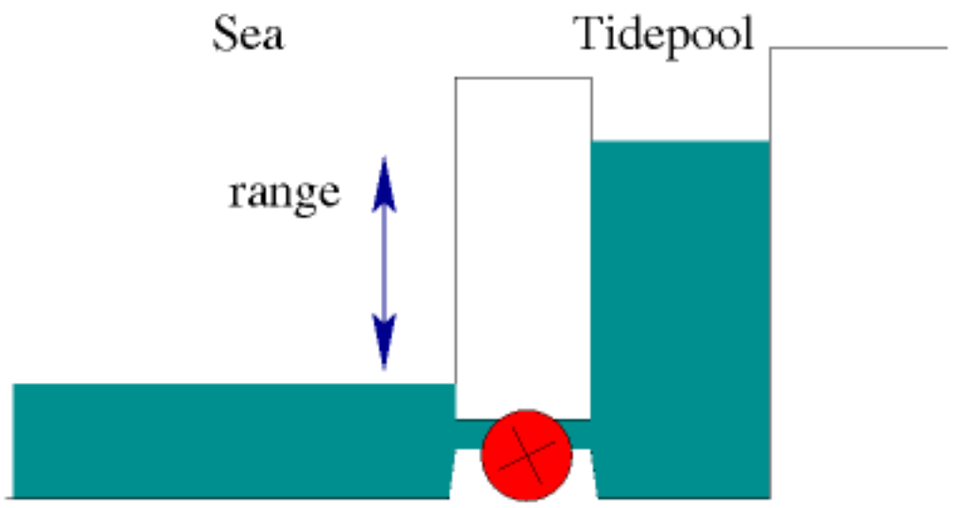
(not including energy for food delivery)

Vegans: 3 kWh/d minimum
Vegetarians: 4 kWh/d min
Carnivores: 12 kWh/d min
(260 kg of animal preparing to be eaten)



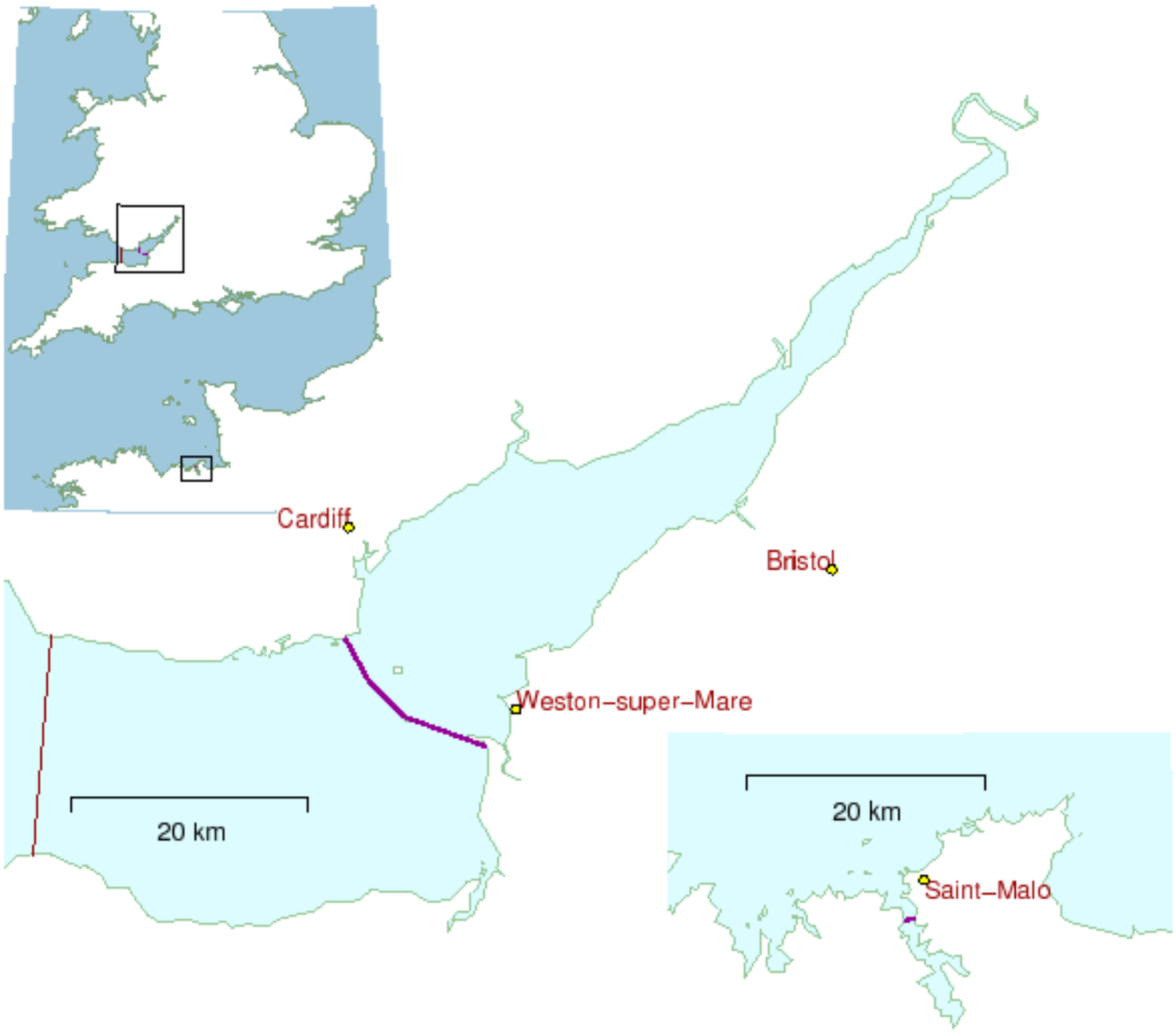


Tide - using tide pools



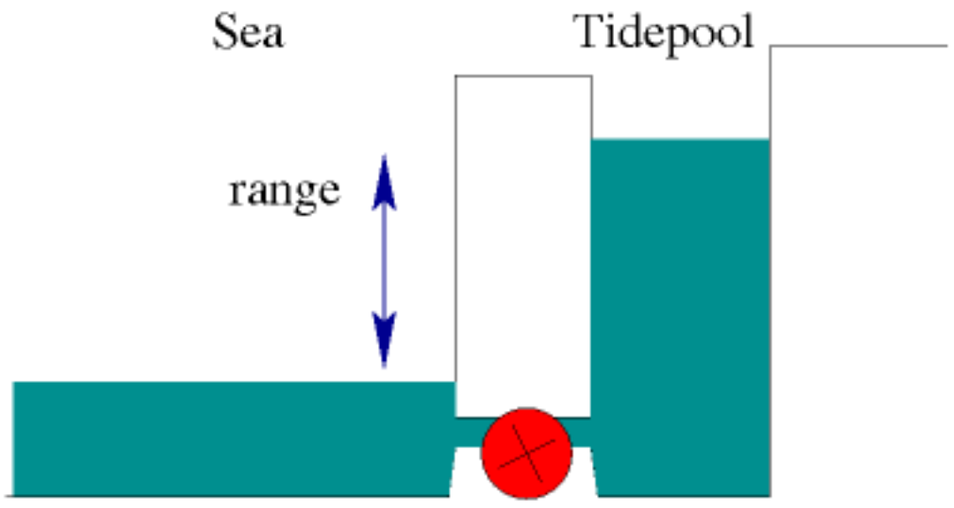
Tidal range	Power per unit area
4 m	3 W/m^2

Severn barrage and la Rance



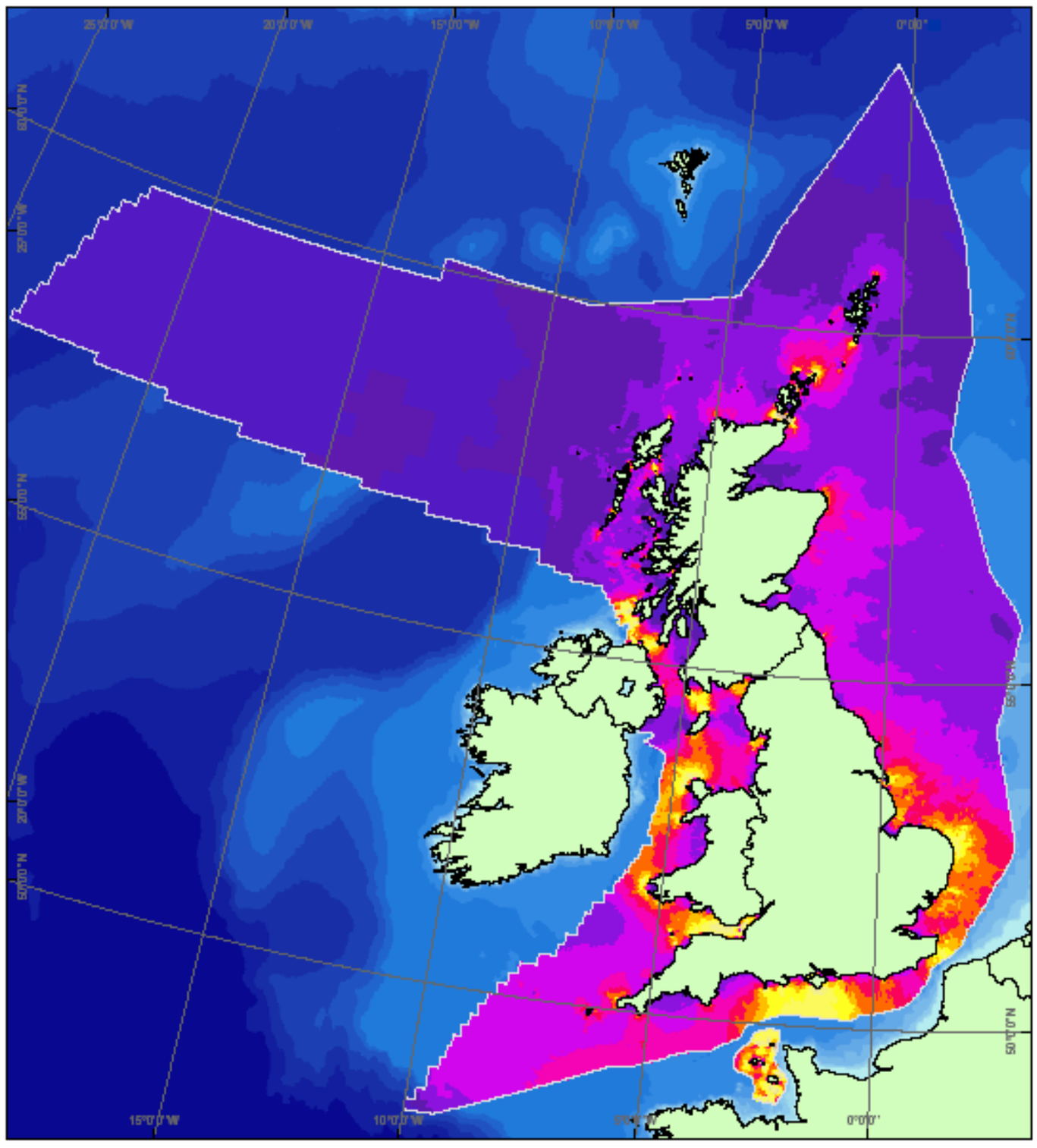
La Rance (60 MW): **2.7** W/m^2

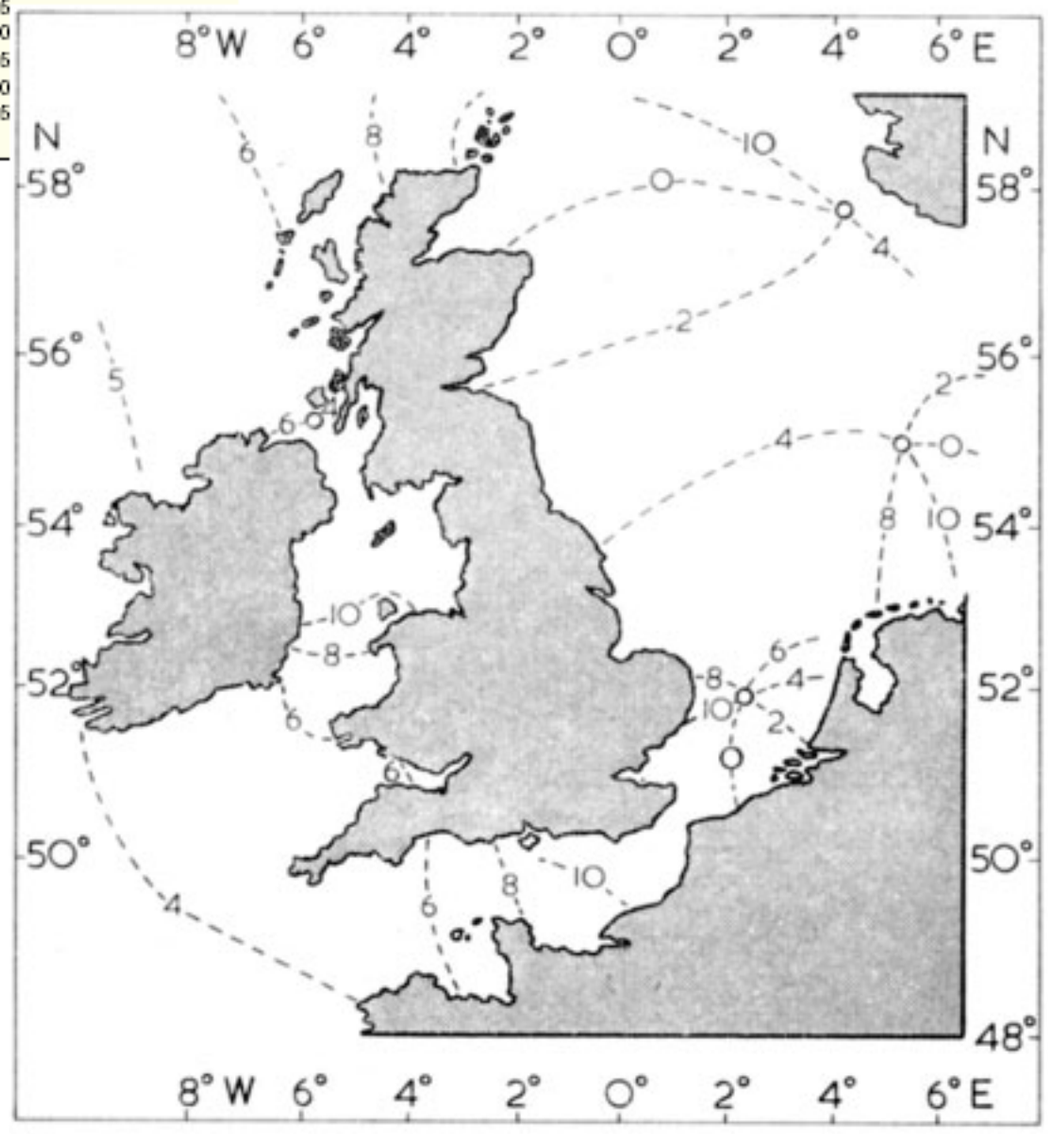
Tide - using tide pools



Tidal range	Power per unit area
4 m	3 W/m^2

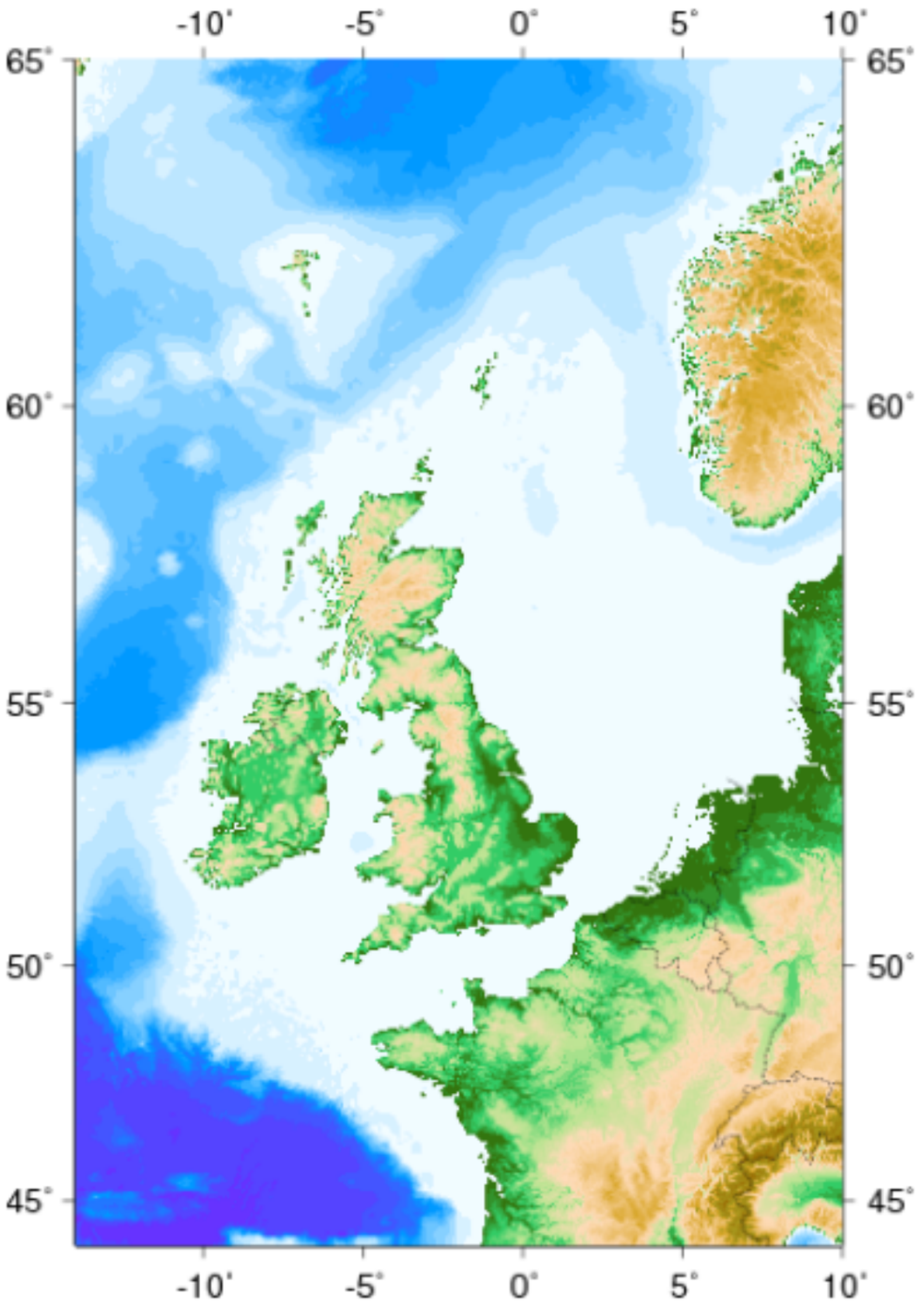
Tide


Peak Flow - (m/s)
> 4.01
3.51 - 4.00
3.01 - 3.50
2.51 - 3.00
2.01 - 2.50
1.76 - 2.00
1.51 - 1.75
1.26 - 1.50
1.01 - 1.25
0.76 - 1.00
0.51 - 0.75
0.26 - 0.50
0.11 - 0.25
< 0.10
Land
UK Continental Shelf & Channel Island Territorial Sea Limit


8° W
6°
4°
2°
0°
2°
4°
6° E
N
58°
56°
54°
52°
50°
48°

DTI

Total incoming power in 'tidal waves'

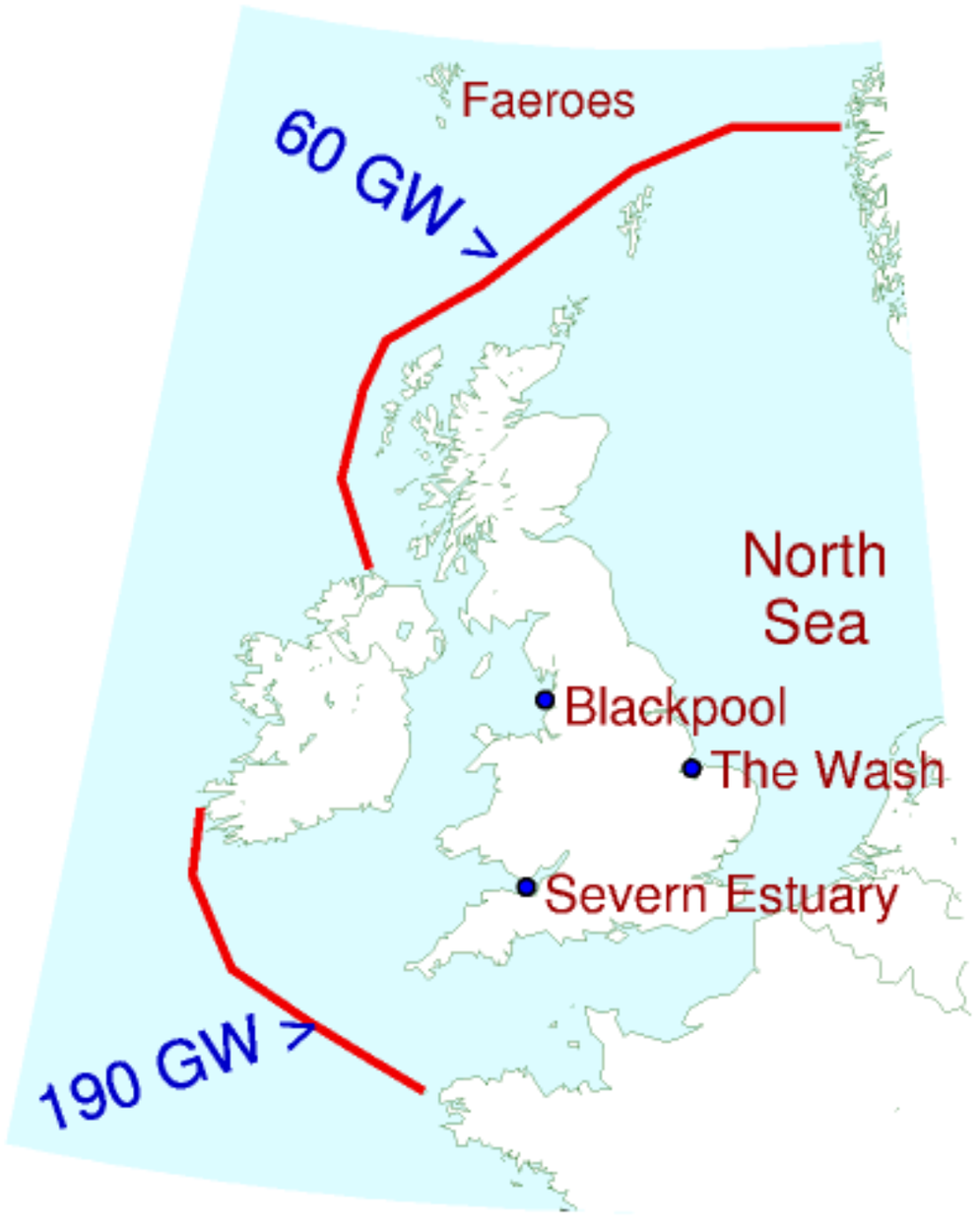


~300 kW per metre

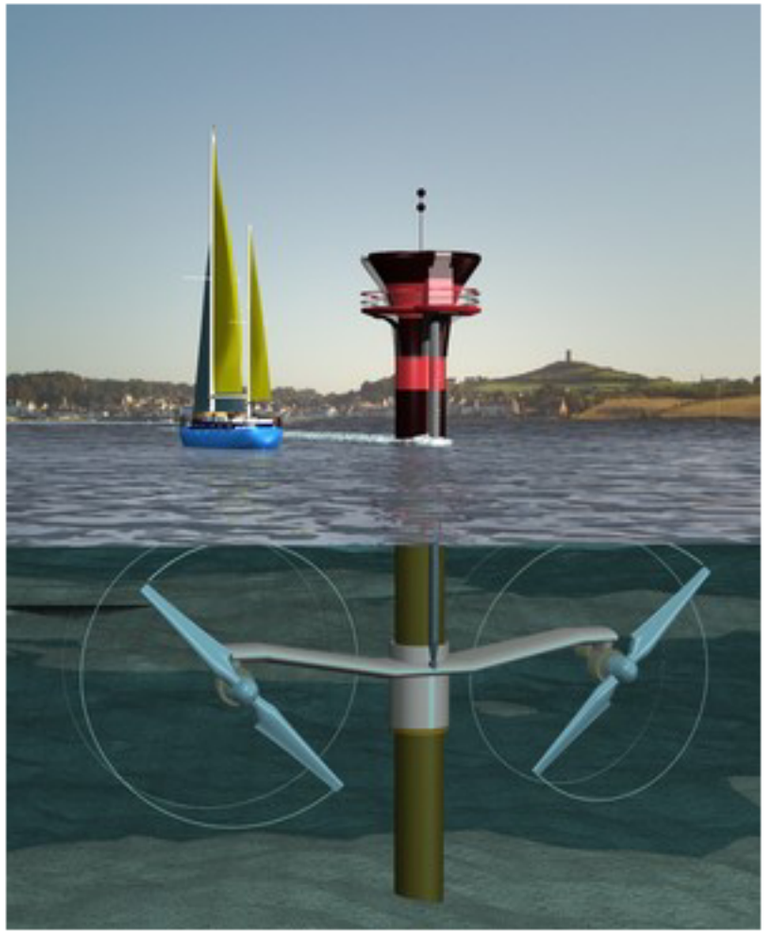
Total: 250 GW

(100 kWh/d per person)

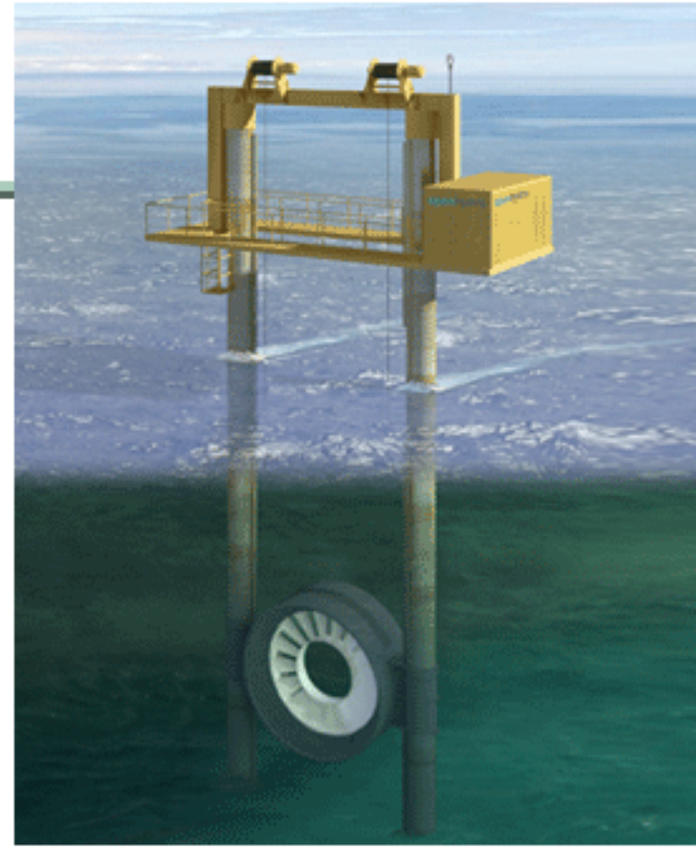
Cartwright et al (1980) Phil Trans R S Series A



Tidal stream power



marineturbines.com



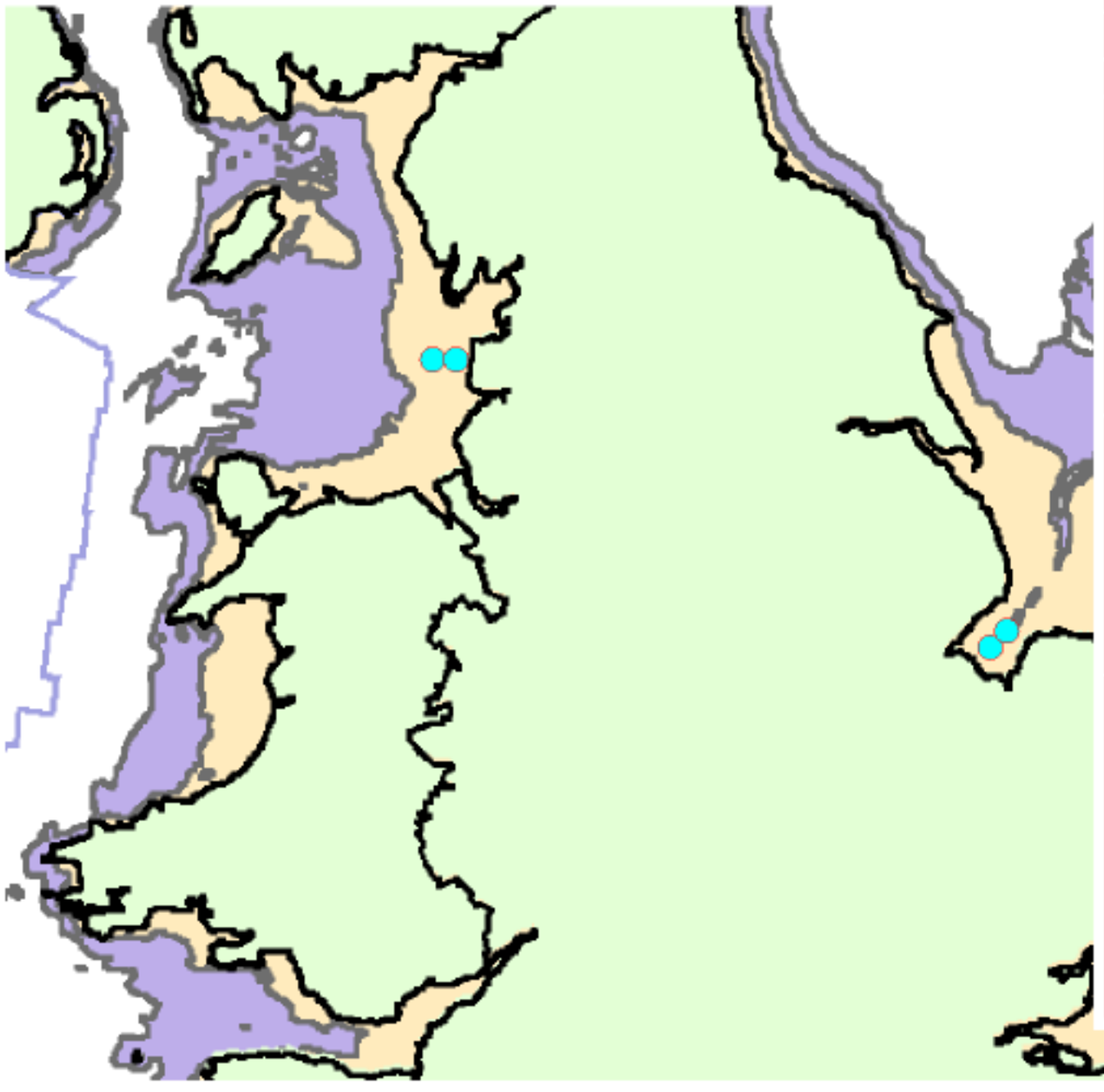
Open Hydro

1kWh/d/person
(DTI figure)

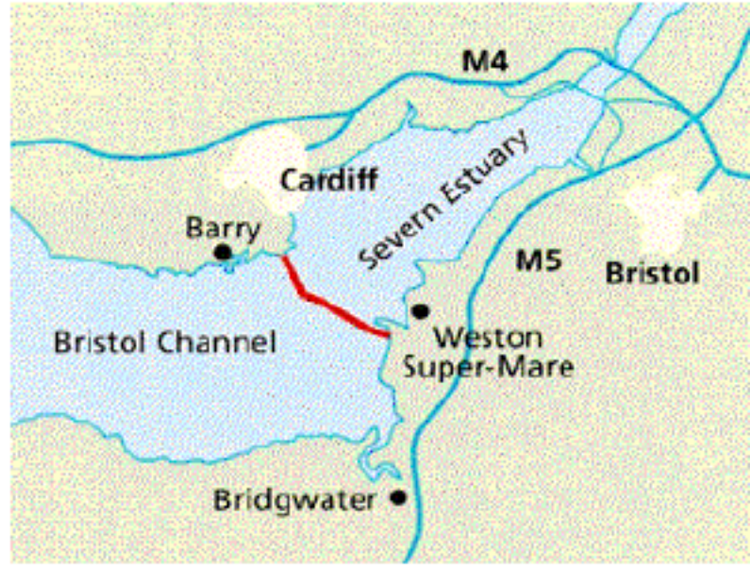
Tide

- Tide farms

- Tidal lagoons



Food, farming, fertilizer: **15 kWh/d**	Tide: **11 kWh/d**	
Gadgets: **5**	Wave: **4 kWh/d**	
Light: **4 kWh/d**	Deep offshore wind: **32 kWh/d**	
Heating, cooling: **37 kWh/d**	Shallow offshore wind: **16 kWh/d**	
	Hydro: **1.5 kWh/d**	
Jet flights: **30 kWh/d**	Biomass: food, biofuel, wood, waste incin'n, landfill gas: **24 kWh/d**	
Car: **40 kWh/d**	PV farm (200 m^2/p): **50 kWh/d**	
	PV, 10 m^2/p: **5**	
	Solar heating: **13 kWh/d**	
	Wind: **20 kWh/d**	



and barrages

0.8 kWh/d per person

Stuff

- One new computer every 2 years

Chips: **2.5 kWh/d**

Aluminium: **3 kWh/d**

Newspapers, junk mail, magazines: **2 kWh/d**

- 5 cans per day
- Stuff made in China: 12 kWh/d
- Transporting rubbish around

Road freight: **7 kWh/d**

Supermarkets: **0.5 kWh/d**

Shipping: **4**

Transporting stuff: **12 kWh/d**

Stuff: **48+ kWh/d**

Food, farming, fertilizer: **15 kWh/d**

Gadgets: **5**

Light: **4 kWh/d**

Heating, cooling: **37 kWh/d**

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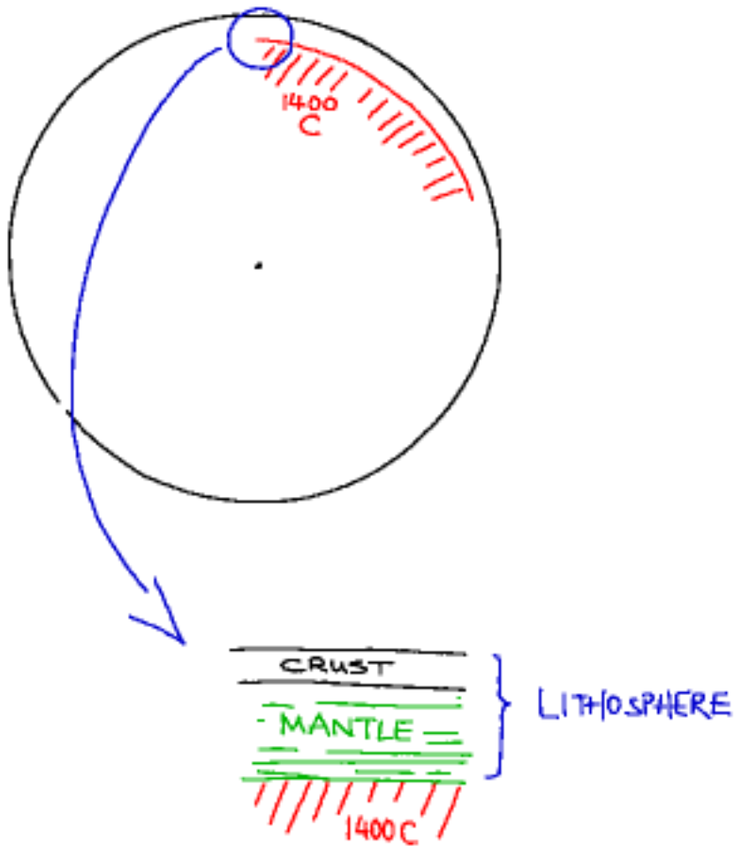
Biomass: food, biofuel, wood, waste incin'n, landfill gas: **24 kWh/d**

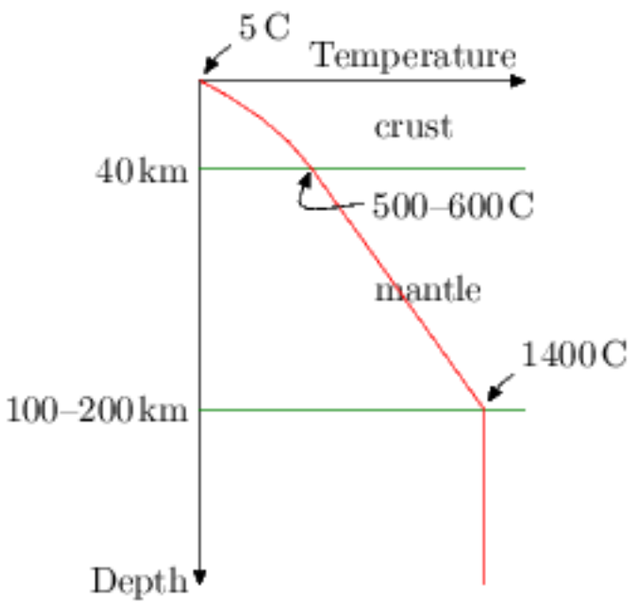
Geothermal

Nesjavellir, Iceland

Average geothermal electricity generation in Iceland in 2006 was 300 MW (24 kWh/d/person)

Geothermal





Transporting stuff: **12 kWh/d**

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Food, farming, fertilizer: **15 kWh/d**

Gadgets: **5**

Light: **4 kWh/d**

Heating, cooling: **37 kWh/d**

Jet flights: **30 kWh/d**

Car: **40 kWh/d**

Geothermal: **1 kWh/d**

Tide: **11 kWh/d**

Wave: **4 kWh/d**

Deep offshore wind: **32 kWh/d**

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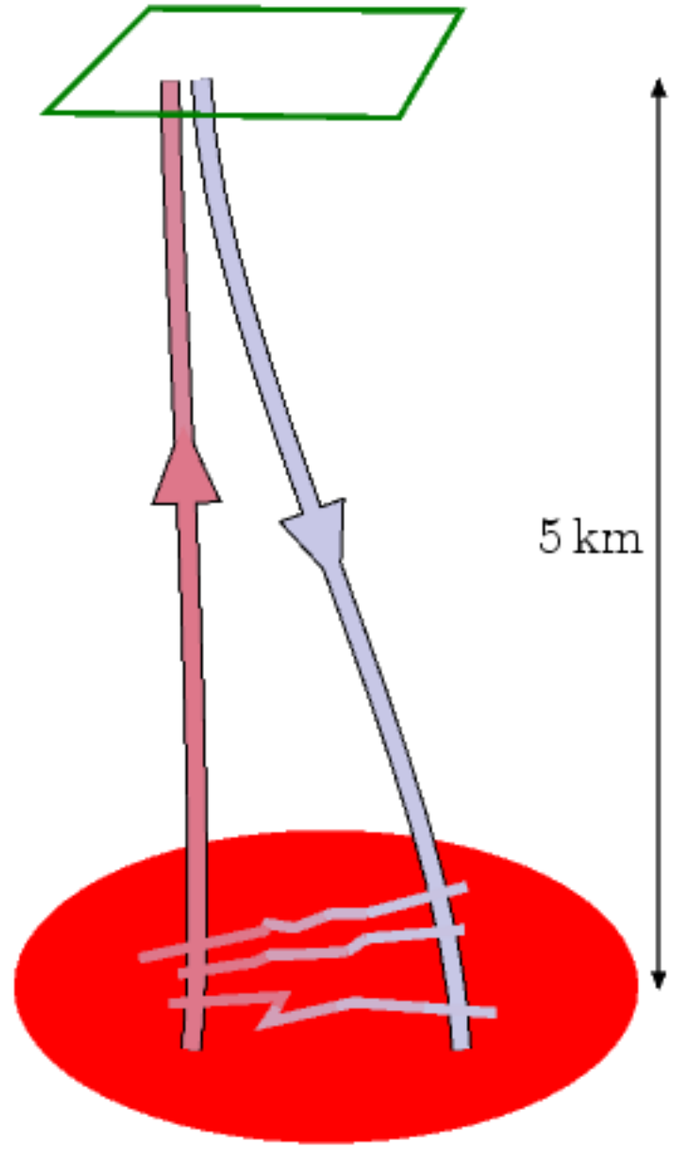
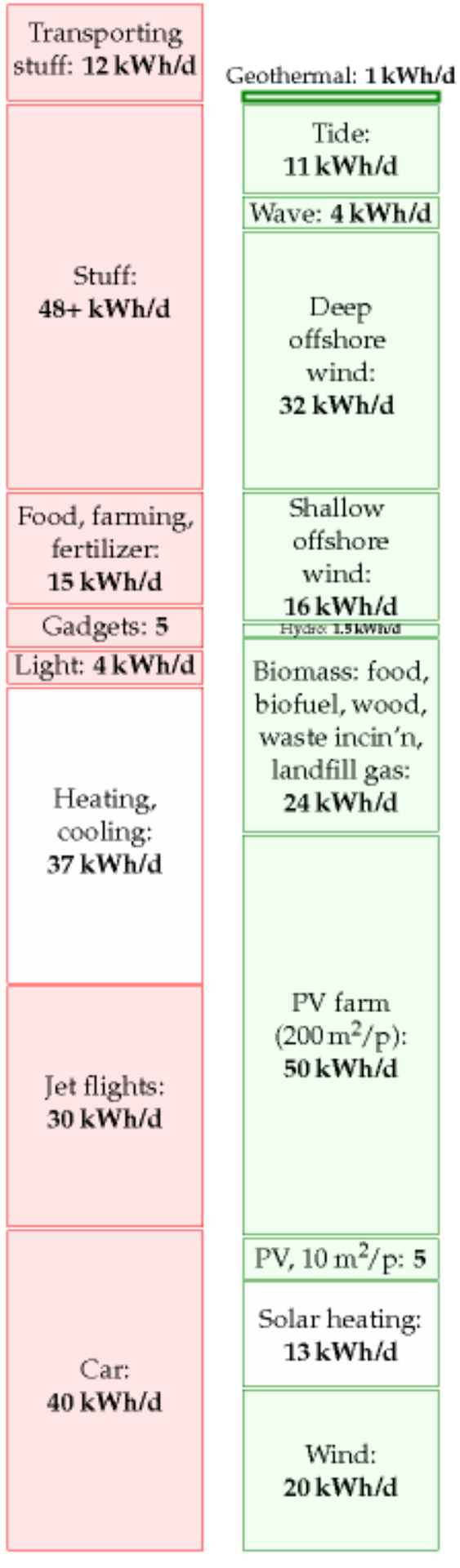


'Hot dry rock'

Still to come
on the red stack:
- industry,
- road building,
- 'defence',
- hospitals, ...



It would be very difficult to live on our own renewables

- at least, as we currently live

www.withouthotair.com

A consultation exercise in full swing


SAY NO
TO WIND TURBINES
IN BENINGTON
BENINGTON NEEDS
YOU"


SWAG
GROUP


BLOT
Belvoir Locals Oppose Turbines
www.blot-online.org


NO
YES


Maer Hills Protect


Hook Moor Wind Farm Action Group
ndfarm Developments

YMGYRCH
CEFN CROES
CAMPAIGN

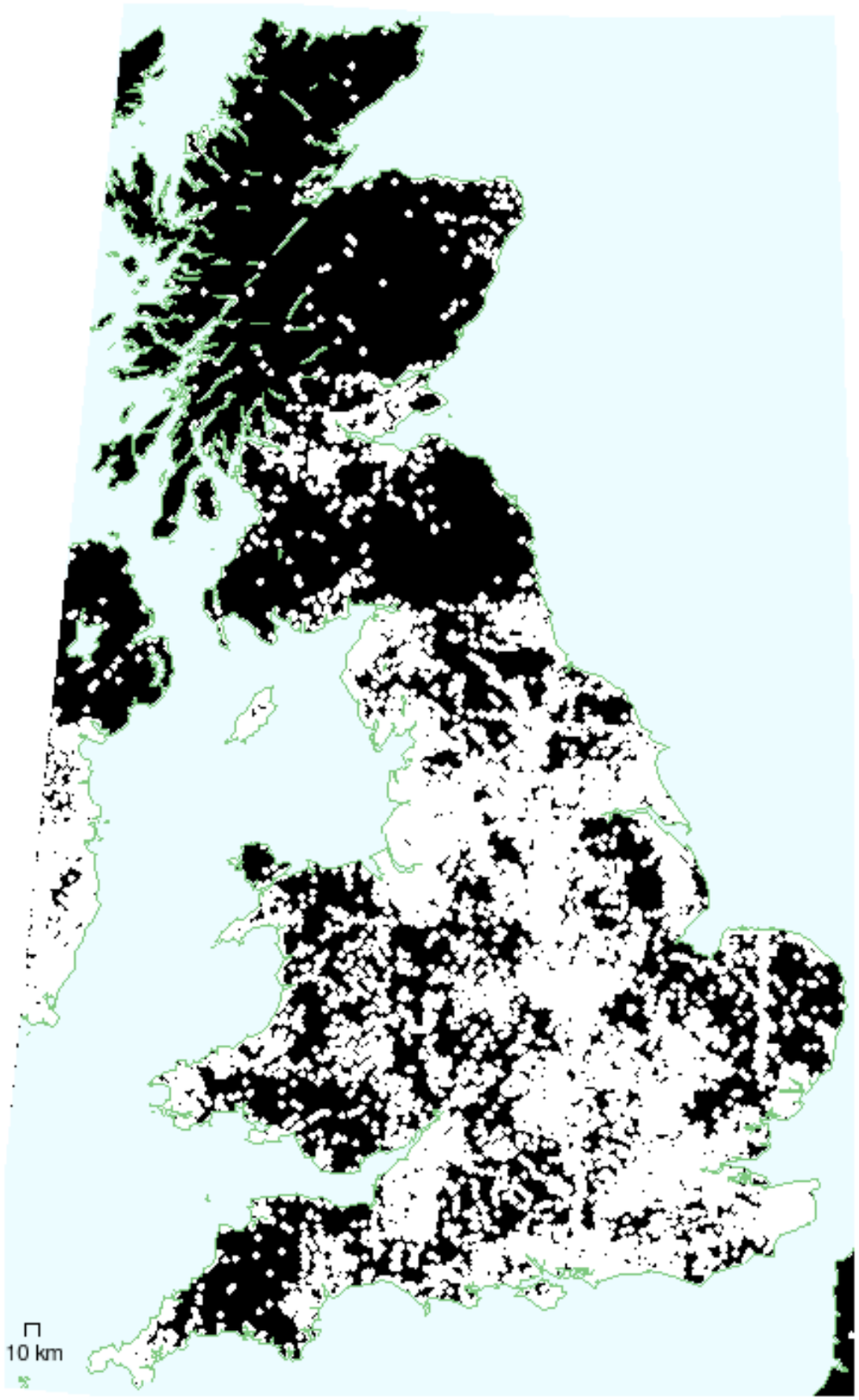

SAY
NO
TO THE
WIND FARM


www.
stopbeningtonwindfarm
.co.uk


STOP


B.A.C.K.W.A.G


STOP Lochluichart
'a windfarm too far'


10 km

Save Our Scenery -

Protecting Our Heritage Coastline

BEFORE

AFTER

FROM LLANDUDNO PROMENADE

FROM COLWYN BAY PROMENADE

saveourscenery.com

Printer friendly
Send to a friend
Tag/Bookmark

News

Giant Wind Farm Off English Coast Pits Town Against Shell, E.ON

Graveney was the site of the last combat on English soil when British forces battled a downed German bomber crew in 1940. Now the village is fighting a new enemy: the world's biggest wind farm. The local council, acting on behalf of the town's 473 residents, refused to permit a substation for the $1.5 billion London Array, which would put 271 wind turbines in the estuary of the River Thames. Royal Dutch Shell Plc and E.ON AG plan to bring power cables ashore near Graveney. "They say this is the only place they could put it — that's rubbish," said retiree George Schneider, 73, strolling on Saxon Shore Way, a rambling route across the coastal plain. "Why use a green-field site when there are other places?"

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By Rating ►

search news

are springing up on land-based
some are even becoming tourist
– proposals for offshore farms are
popular.

Estate has
ible 18
d the UK
hough each
ds to gain

ccepted by
others are
tink.

n strong
:o schemes
ms in the
and off Portstewart, near the
seway in Northern Ireland.

Surfers are worried about the impact

About News Opinions Library Press

News

Wind farm 'a threat to our airport'

Southend Airport has raised serious objections to plans to build a new wind farm – even though the turbines would be nearly 15 miles to the n experts say a wind farm next to the defunct nuclear power station, at Br air traffic control issues and might even interfere with radar. Airport mar Alistair Welch raised the concerns at a public inquiry which is being helc

June 22, 2007 in Echo

Southend Airport has raised serious objections to plans to build a new wind farm – even would be nearly 15 miles to the north.

Job creation

In Porthcawl in south Wales, a pressure group called SOS Porthcawl has been set up to oppose plans for a wind farm four miles out to sea.

The proposal is for 30 turbines on Scarweather Sands, each 453 feet high.

It could provide enough energy for more than 40,000 homes.

The production of the turbines could also create 130 jobs – they are made in Wales at Bangor and more could be produced at Port Talbot.

Tourism

But SOS Porthcawl says the turbines will be noisy and visible from beauty spots, which would deter tourists.

Protesters target wind farm plans

Plans of how the wind farm will look are on display

Porthcawl is a popular spot for surfers

Local people opposing plans to build one of the UK's big
south Wales coast met on Friday. Residents in Porthcaw
to highlight their opposition to the proposed 30-turbine
Sands.

SOS Porthcawl was set up by campaigners in the town v
say the wind farm will adversely affect the holiday reso
which attracts surfers and tourists from all over the UK
demonstration coincides with a public consultation into
project by developers United Utilities Green Energy.
Four-times British surf champion, Simon Tucker said the
was a lot of feeling against the proposals within the tow
"This demonstration is to ask the developers not to dest
the very environment they claim they are trying to prote
he said. Mr Tucker said the turbines, which are taller th
the Statue of Liberty in New York, will destroy the pano
views and also have an impact on the sea.

"The turbines will change the shape of the sandbanks a
the waves," he said. "If the waves are changed and peop
sport because of the turbines then the town is going to
company behind the £100m scheme say the turbines, wh
sea level, will generate enough power for 86,000 homes
The site, which is to the west of Porthcawl, is approxima
the nearest household.

Project - Is This A New Klondyke?

y Herald (linked above) talks about the views
and disappearing as we used to know them - vast
st as they had been for hundreds of years and
n industrial scene. As we watch the first massive
aithness and Sutherland coast are we watching
other aspect of our scenery - the coastal views?
another hazard for fishing boats and vessels to
view now of anyone on the east of Caithness are
thers as we face up to rising oil prices and the
. We already see oil rigs with in view. Will wind
ut at sea than on our hills and mountains?

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Last Updated: Friday, 28 May, 2004, 16:58 GMT 17:58 UK

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Fishermen oppose wind farm plans

Hundreds of fishermen gathered in the Wash to protest against plans to build offshore wind turbines.

The men from Boston, Skegness and King's Lynn are unhappy at government proposals to erect 250 wind turbines in the Greater Wash.

If it goes ahead, the facility would be part of one of the largest wind farms in the world.

Planning permission has already been granted for 60 turbines on two sites off the south Lincolnshire coast.

Hundreds of turbines could be built about five miles off the coast

Project 'impractical'

Andy Roper, who organised the protest, emphasised the fishermen's livelihoods are being threatened.

From The Times

November 23, 2002

Winds of change will mean giant sea turbines

By Anthony Browne, Environment Editor

DOZENS of wind farms, each with hundreds of turbines up to 500ft high, are to be given the go-ahead off the coast between Scotland and Wales, around the Wash in East Anglia and in the Thames Estuary.

Yesterday's announcement was welcomed by some environmental groups; others have given warning that it will ruin views and damage sea life. Fishermen have said that they will be forced out of business.

Brian Wilson, the Energy Minister, said: "In theory, these areas could source enough electricity to power the whole of Britain, albeit intermittently. There is no doubt

From The Times

February 4, 2008

Wind farms 'a threat to national security'

Magnus Linklater and Dominic Kennedy

Ambitious plans to meet up to a third of Britain's energy needs from offshore wind farms are in jeopardy because the Ministry of Defence objects that the turbines interfere with its radar.

The MoD has lodged last-minute objections to at least four onshore wind farms in the line of sight of its stations on the east coast because they make it impossible to spot aircraft, *The Times* has learnt. The same objections are likely to apply to wind turbines in the North Sea, part of the massive renewable energy project announced by John Hutton, the Energy Secretary, barely two months ago. They would be directly in line with the three principal radar defence stations, Brizlee Wood, Saxton Wold and Trimingham on the Northumberland, Yorkshire and Norfolk coasts.

Wind power 'a security ris

02 November 2007 08:15

Defence chiefs threw the future of East Anglia's wind energy industry into confu
last night after claiming that wind turbin
could be a threat to national security.

Experts say the MoD now objects to abou
50pc of applications to build onshore wir
turbines because of concerns they affect
performance of military radar.

Transporting stuff: **12 kWh/d**

Stuff: **48+ kWh/d**

Food, farming, fertilizer: **15 kWh/d**

Gadgets: **5**

Light: **4 kWh/d**

Heating, cooling: **37 kWh/d**

Jet flights: **30 kWh/d**

Car: **40 kWh/d**

~~Geothermal: 1 kWh/d~~

Tide: **11 kWh/d**

~~Wave: 4 kWh/d~~ too expensive!

~~Deep offshore wind: 32 kWh/d~~ not near my radar!

~~Shallow offshore wind: 16 kWh/d~~ not near my birds!

~~[illegible]~~ not in my valley!

~~Biomass: food, biofuel, wood, waste incin'n, landfill gas: 24 kWh/d~~ not in my countryside!

~~PV farm (200 m^2/p): 50 kWh/d~~ too expensive!

~~PV: 10 m^2/p: 5~~ too expensive!

~~Solar heating: 13 kWh/d~~ not on my street!

~~Wind: 20 kWh/d~~ not in my back yard!

Transporting stuff: **12 kWh/d**		
Stuff: **48+ kWh/d**	Geothermal: ~~1 kWh/d~~	too immature!
	Tide: **11 kWh/d**	
	Wave: ~~4 kWh/d~~	too expensive!
	Deep offshore wind: **32 kWh/d**	not near my radar!
Food, farming, fertilizer: **15 kWh/d**	Shallow offshore wind: **16 kWh/d**	not near my birds!
Gadgets: **5**	~~Hydro: 4 kWh/d~~	not in my valley!
Light: **4 kWh/d**	Biomass: food, biofuel, wood, waste incin'n, landfill gas: **24 kWh/d**	not in my countryside!
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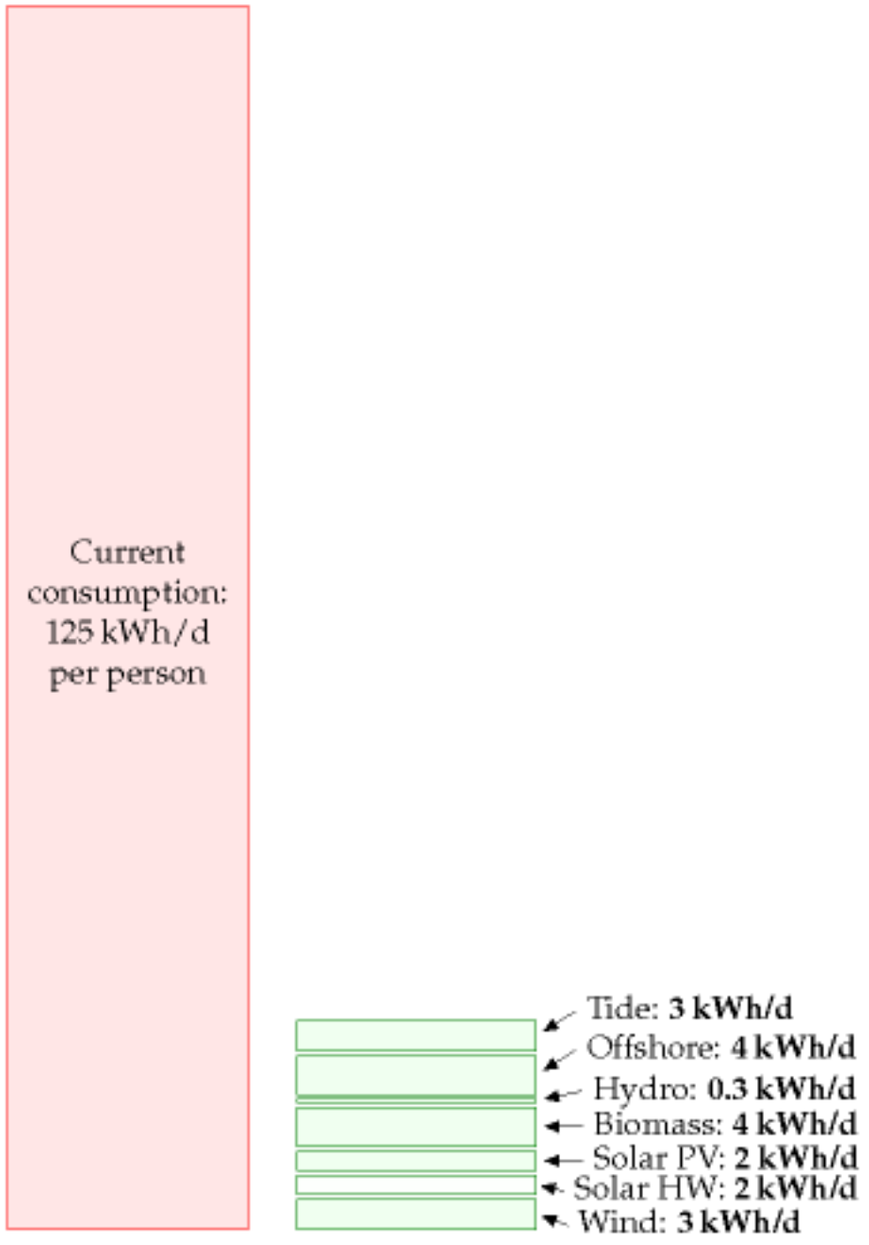
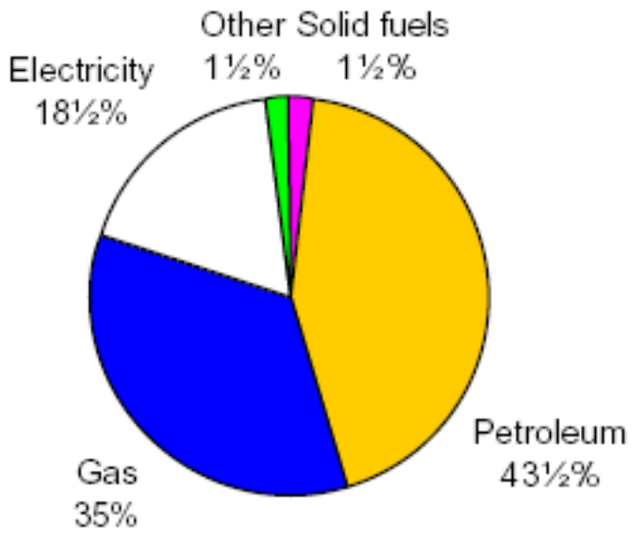
	Solar heating: **13 kWh/d**	not on my street!
	Wind: **20 kWh/d**	not in my back yard!

after the great British consultation exercise...

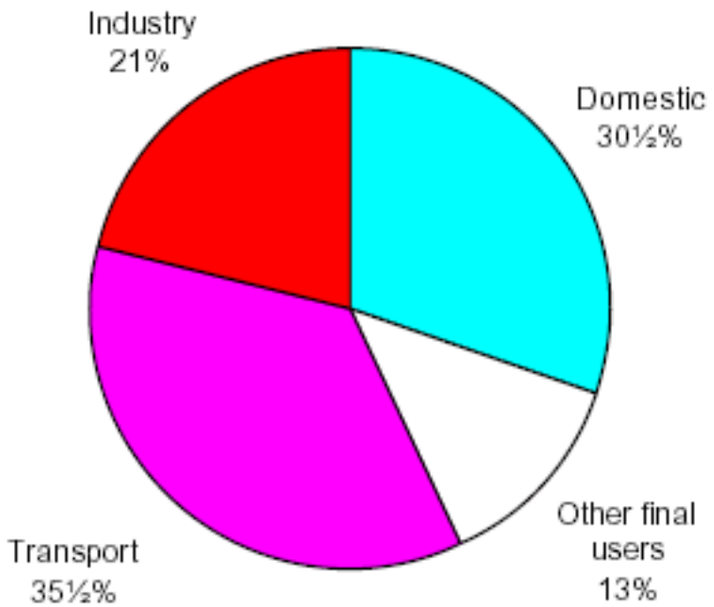


This would be a 15-fold increase of renewables

Average power consumption, UK: 125 kWh/d/p



2004



www.dti.gov.uk

Transport
35%

Hot air
26%

Hot water
8%

Lighting,
appliances 6%

Process
10%

Other
15%

'primary consumption'

125 kWh/day (Europe)

250 kWh/day (USA)

(doesn't include imports,
nor solar energy in food)

For CO_2 pollution, divide by 10:

100 kWh/day $\simeq$ 10 tonnes CO_2/yea

Conclusions - part I

A country like Britain

can't live on

its own renewables

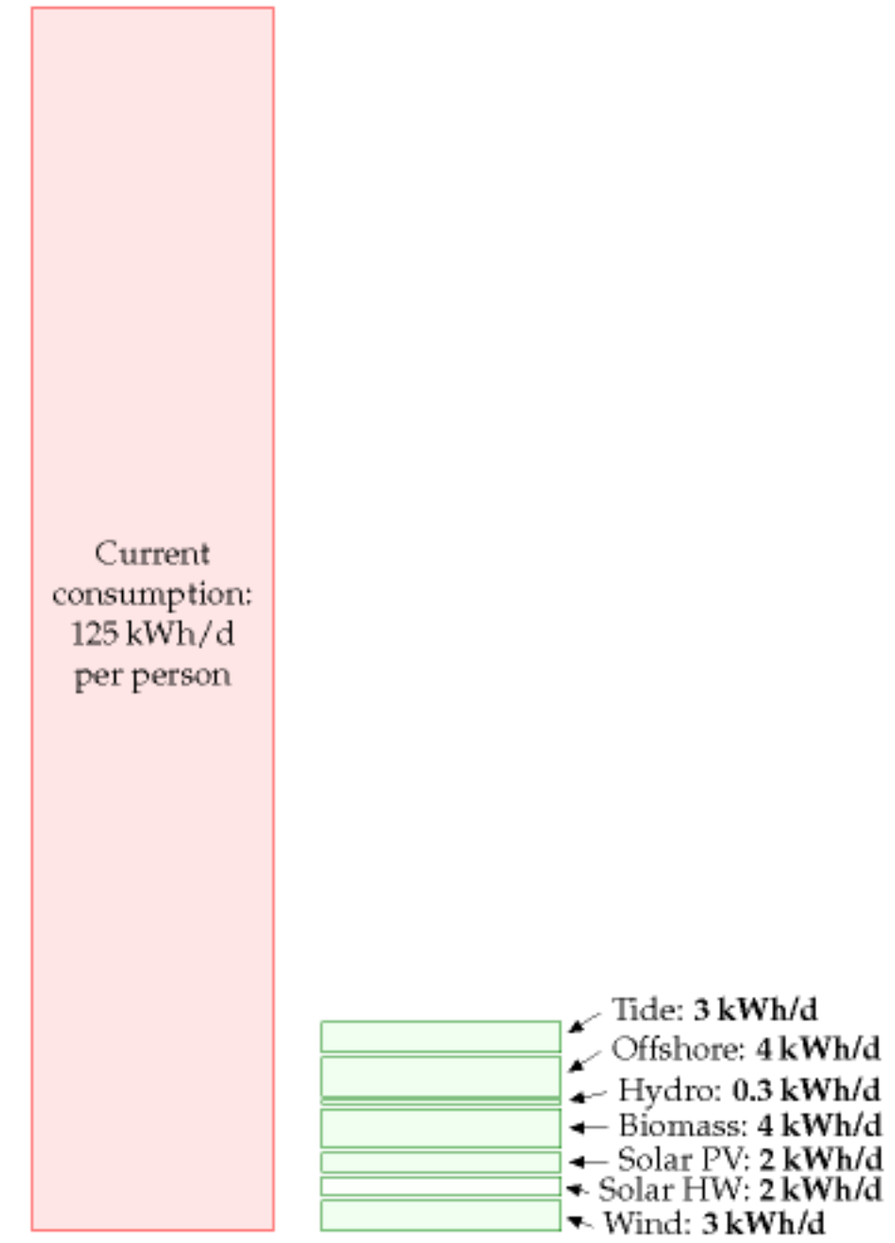
- at least,

not as we currently live

To make a difference,

renewables have to be

country-sized



Renewables are diffuse

	Power per unit land area
Wind	$2\,\mathrm{W/m^2}$
Offshore wind	$3\,\mathrm{W/m^2}$
Tidal pools	$3\,\mathrm{W/m^2}$
Tidal stream	$8\,\mathrm{W/m^2}$
Solar PV panels	5–$20\,\mathrm{W/m^2}$
Plants	$0.5\,\mathrm{W/m^2}$
Solar chimney (Spain)	$0.1\,\mathrm{W/m^2}$
Concentrating solar power (desert)	15–$20\,\mathrm{W/m^2}$
Ocean thermal	$5\,\mathrm{W/m^2}$
Rain-water (highlands)	$0.24\,\mathrm{W/m^2}$
Rain-water (lowlands)	$0.02\,\mathrm{W/m^2}$

- To make a difference, renewable facilities have to be country-sized

Block

News

News
England
Northern Ireland
Scotland
Wales
International
RSS feeds

PRINT
Block

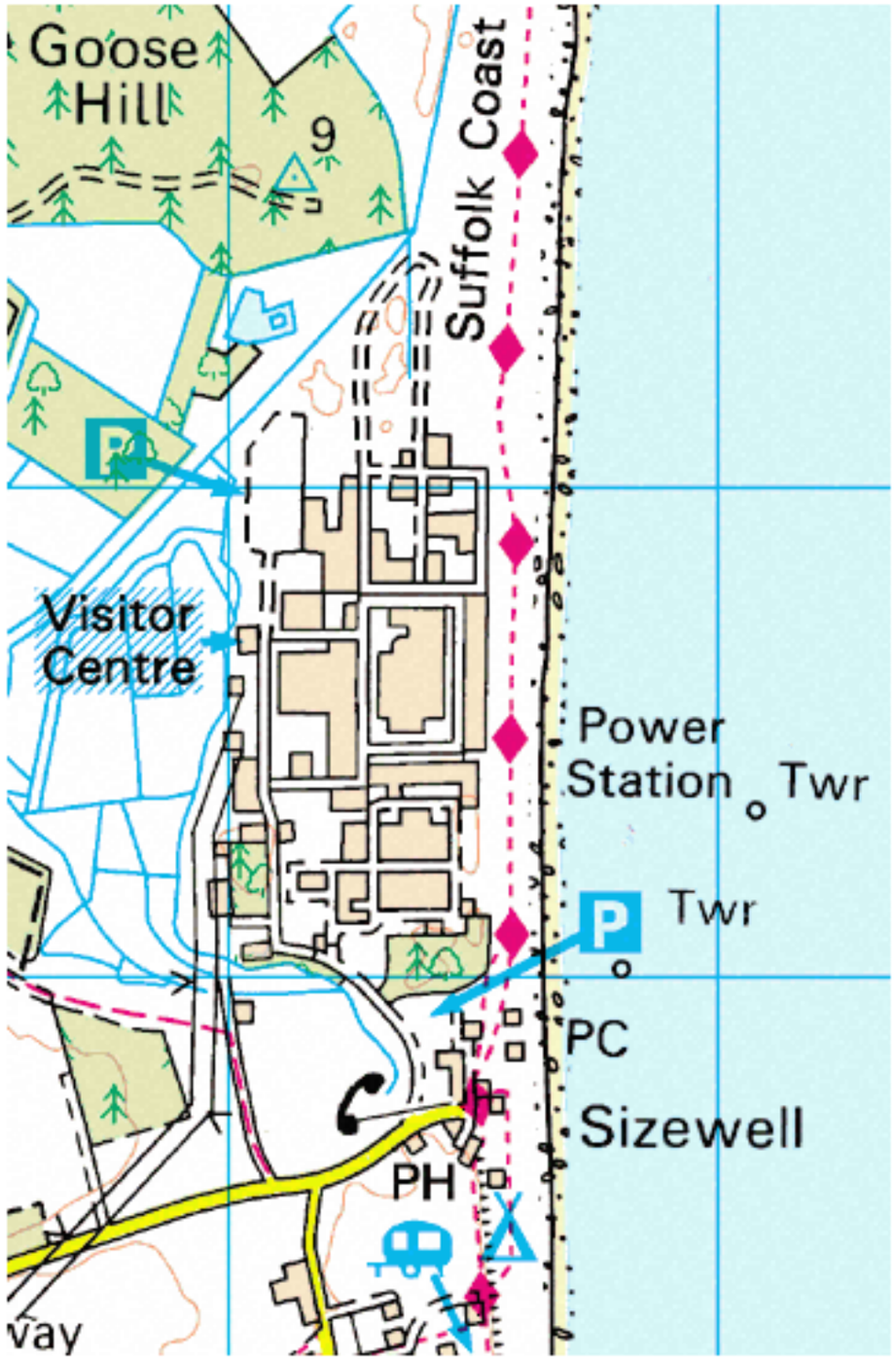
No green light for Severn barrage

Last modified: 01 October 2007

Europe's most dynamic estuary will be destroyed by the construction of a barrage across the Severn while other less striking measures would cost less and could do more to cut carbon emissions.

"other less striking measures"?

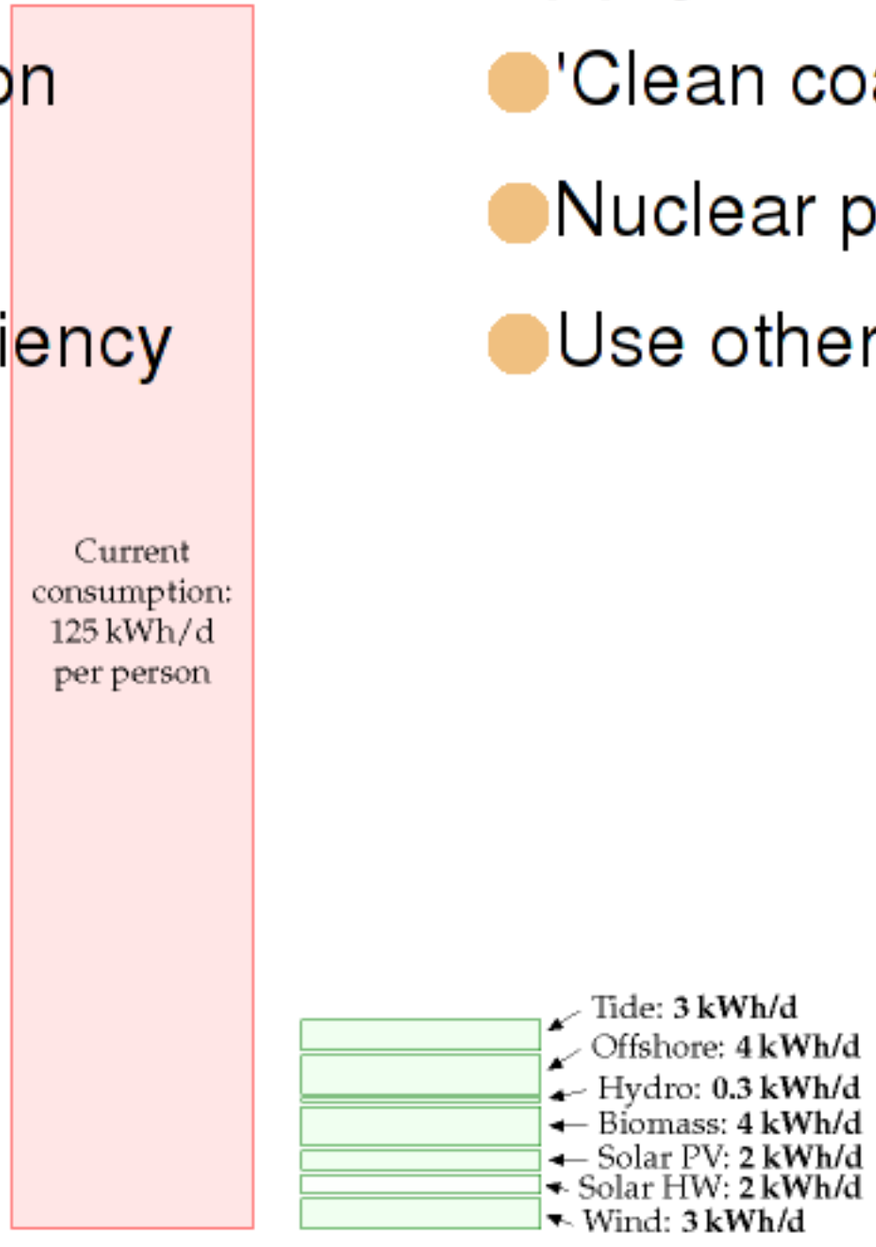
To make a difference, renewable facilities have to be country-sized



Nuclear	
Fission	$1000\,\mathrm{W/m^2}$

How to make an energy plan that adds up

- Demand-side
  - Reduce population
  - Change lifestyle
  - Technology, efficiency
- Supply-side
  - 'Clean coal'
  - Nuclear power
  - Use other countries' renewables



A Mitsubishi Warrior, yesterday

Amazing acts of testosterone-fuelled bravery

Efficiency - for transport

- "Baby on board"

80 kWh per 100 person-km (1 person)

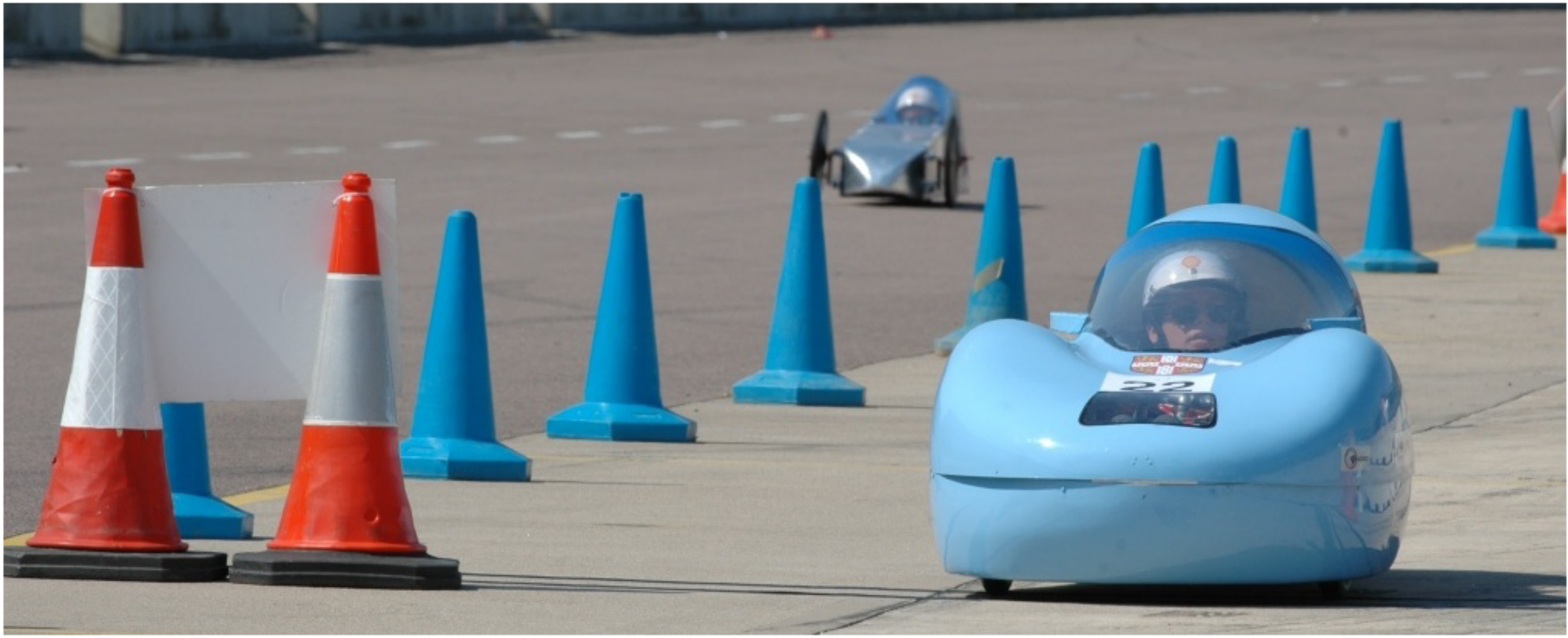
How can this consumption be reduced?

1 kWh per 100 person-km (3 people)

6 kWh per 100 person-km average (electric)

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

Eco-car



1.3 kWh per 100 person-km (takes 1 teenager)

[2200 mpg]

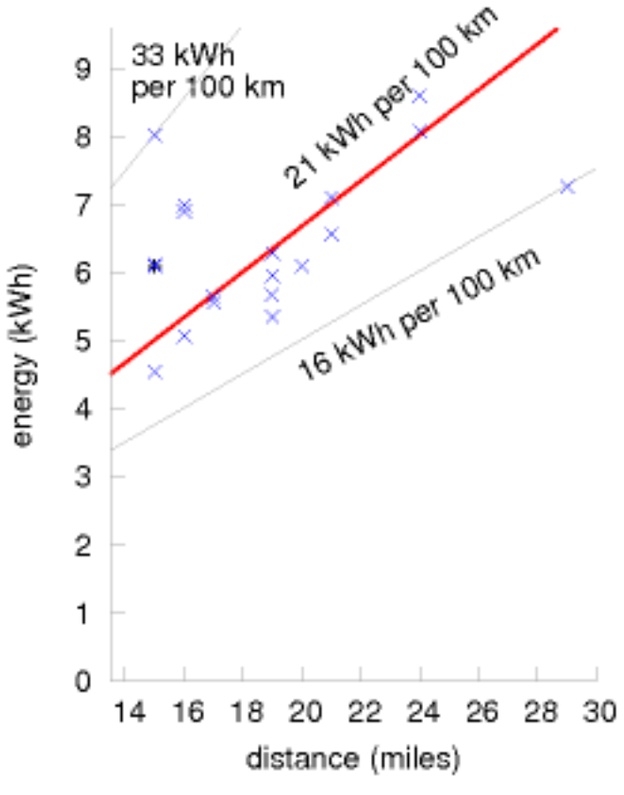
at 15 mph

http://www.teamcrocodile.com/

Electric cars

21 kWh per 100 km (solo)

equivalent to 125 miles per gallon



data from Kele Baker

G-Wiz

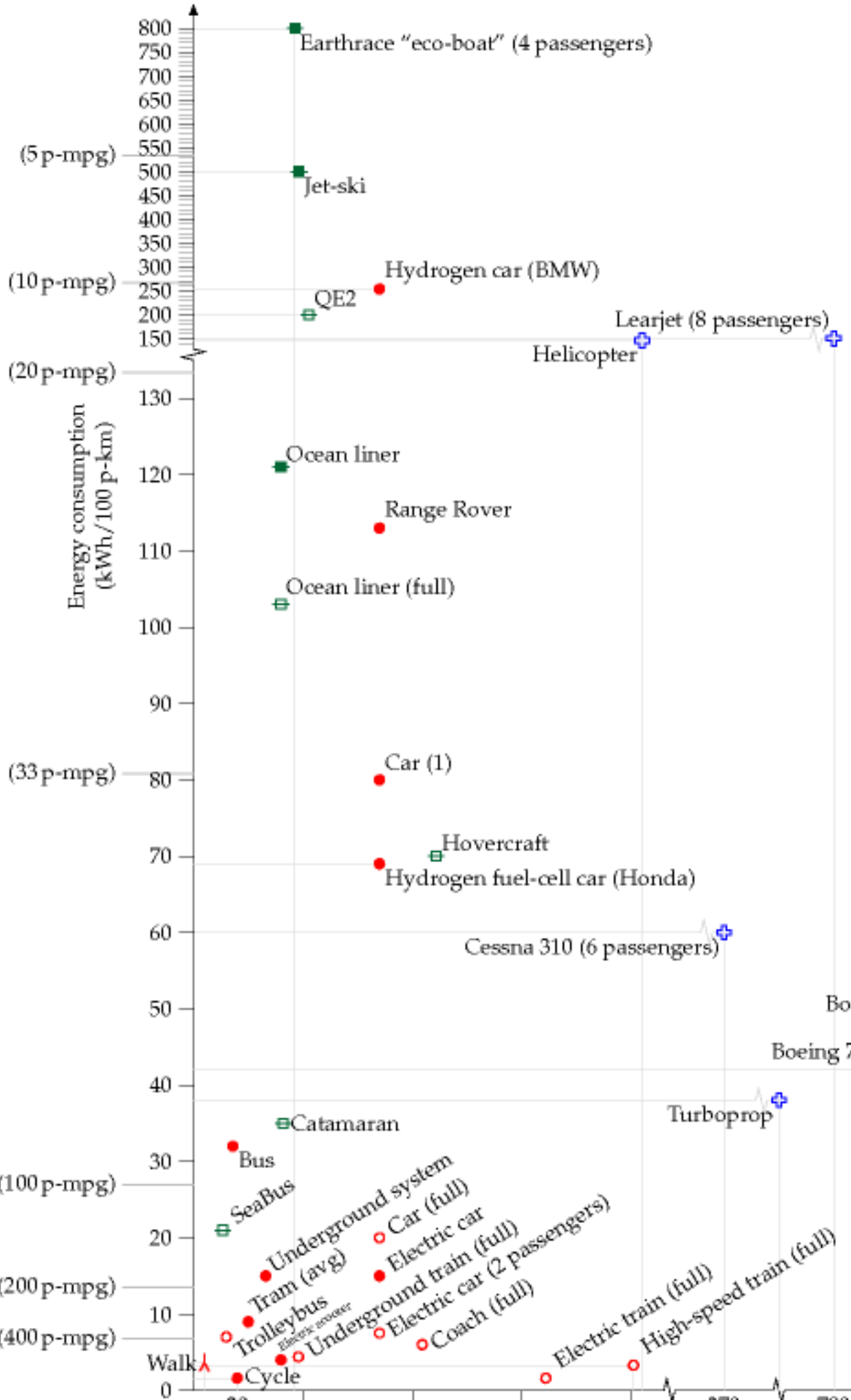
6 kWh per 100 km

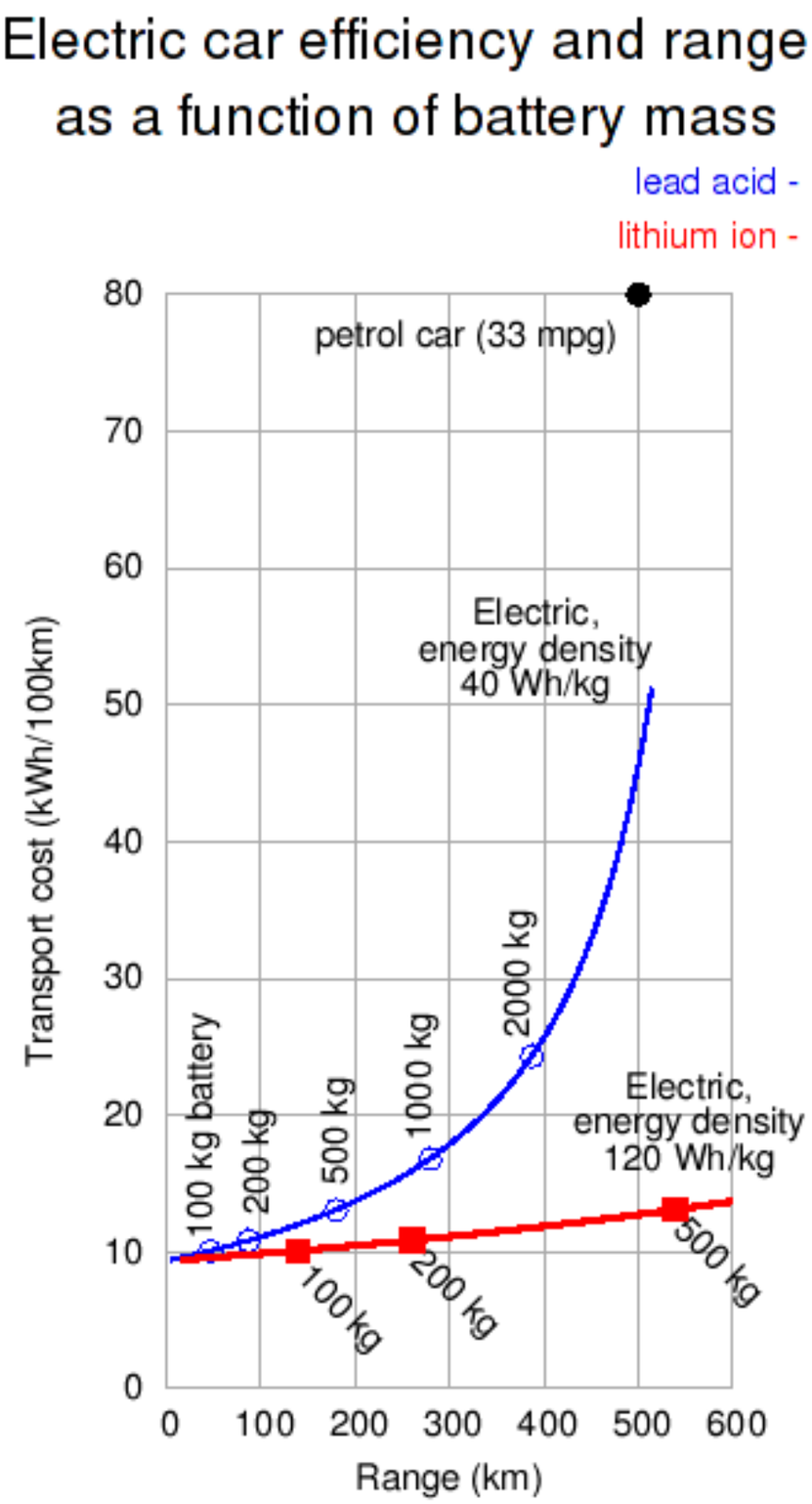
Electric scooters

3 kWh per 100 km

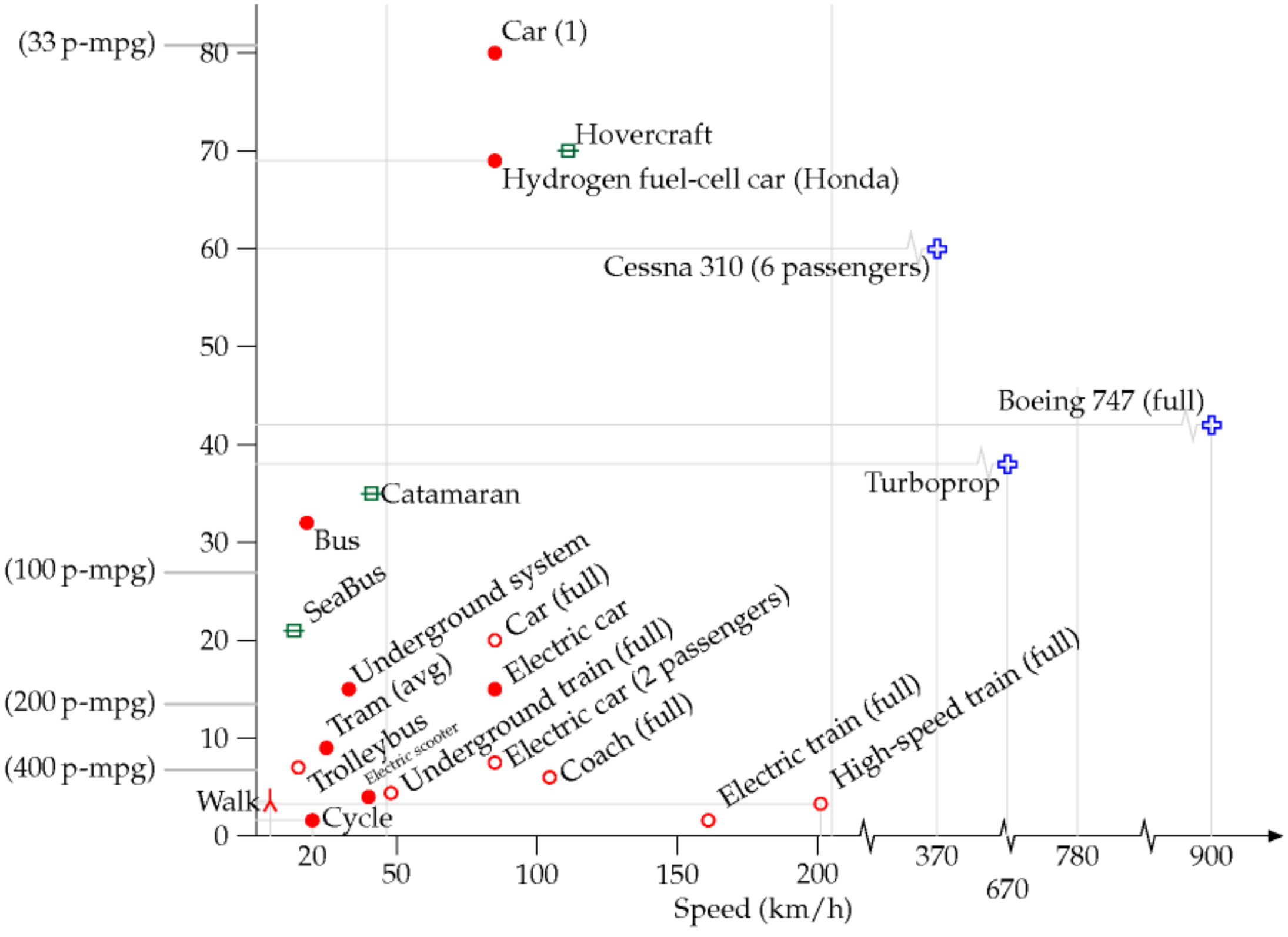
http://www.vectrix.com/

Electric trains


Energy consumption (kWh/100 p-km)
800
750
700
650
600
550
500
450
400
350
300
250
200
150
130
120
110
100
90
80
70
60
50
40
30
20
10
0
(5 p-mpg)
(10 p-mpg)
(20 p-mpg)
(33 p-mpg)
(100 p-mpg)
(200 p-mpg)
(400 p-mpg)
Earthrace "eco-boat" (4 passengers)
Jet-ski
Hydrogen car (BMW)
QE2
Learjet (8 passengers)
Helicopter
Ocean liner
Range Rover
Ocean liner (full)
Car (1)
Hovercraft
Hydrogen fuel-cell car (Honda)
Cessna 310 (6 passengers)
Boeing 747
Boeing 747 (full)
Turboprop
Catamaran
Bus
SeaBus
Underground system
Tram (avg)
Trolleybus
Car (full)
Electric car
Underground train (full)
Electric car (2 passengers)
Coach (full)
Electric train (full)
High-speed train (full)
Walk
Cycle


Electric car efficiency and range as a function of battery mass
lead acid -
lithium ion -
Transport cost (kWh/100km)
80
70
60
50
40
30
20
10
0
0
100
200
300
400
500
600
Range (km)
petrol car (33 mpg)
Electric, energy density 40 Wh/kg
100 kg battery
200 kg
500 kg
1000 kg
2000 kg
Electric, energy density 120 Wh/kg
100 kg
200 kg
500 kg

Energy consumption (kWh per 100 passenger-km)



Efficiency II

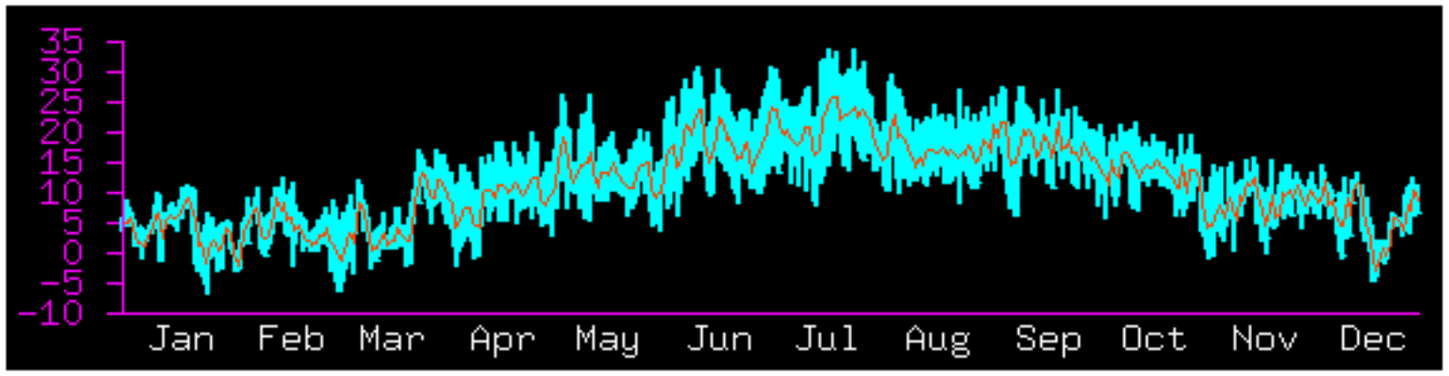
- Heating

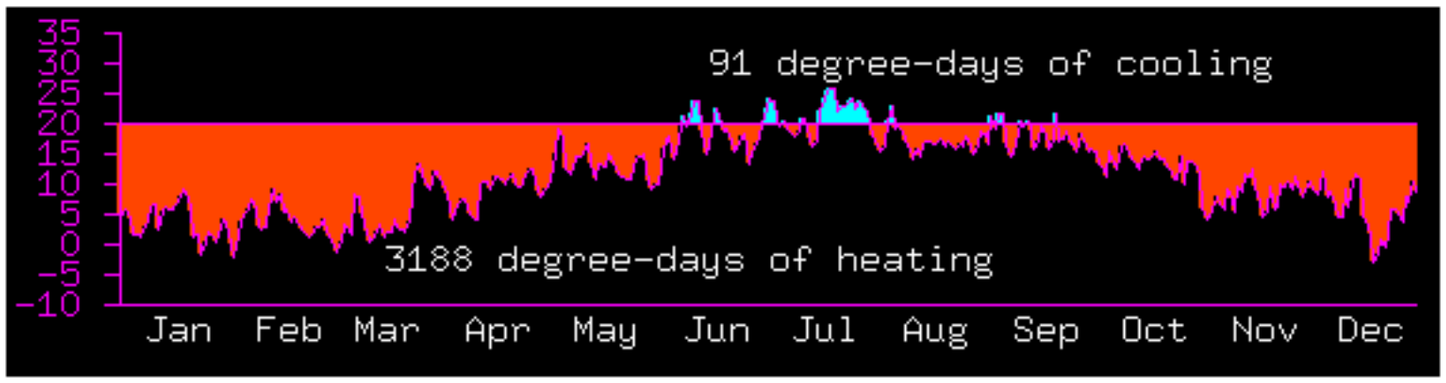
$$\underbrace{\boxed{\text{Heat loss}}}_{\text{(kWh/d)}} = \underbrace{\text{Leakiness}}_{\text{(kWh/d/°C)}} \times \underbrace{\text{Average temperature difference}}_{\text{(°C)}}$$

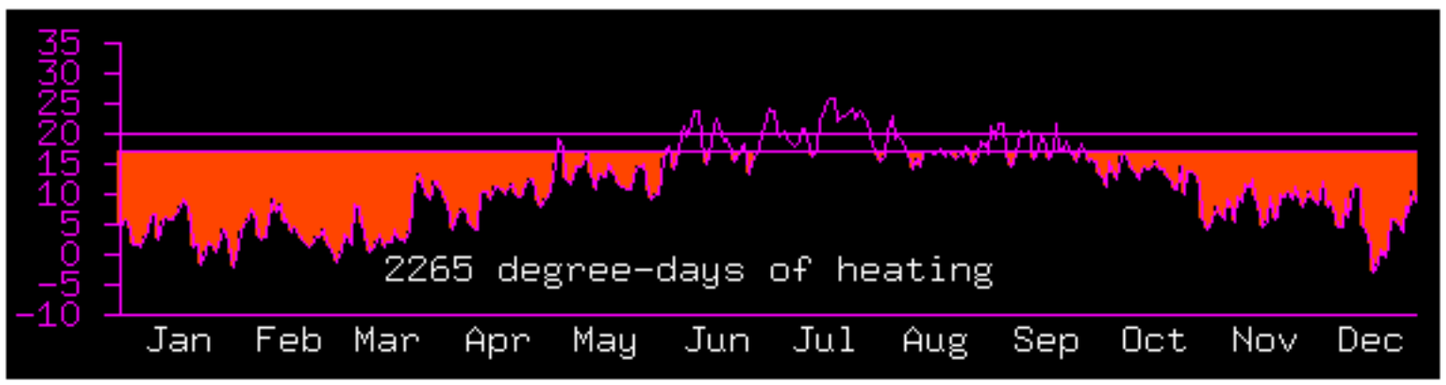
$$\text{Power required} = \boxed{\text{Heat loss}} \Big/ \text{Coefficient of performance of heat-creation}$$

Turn the thermostat down

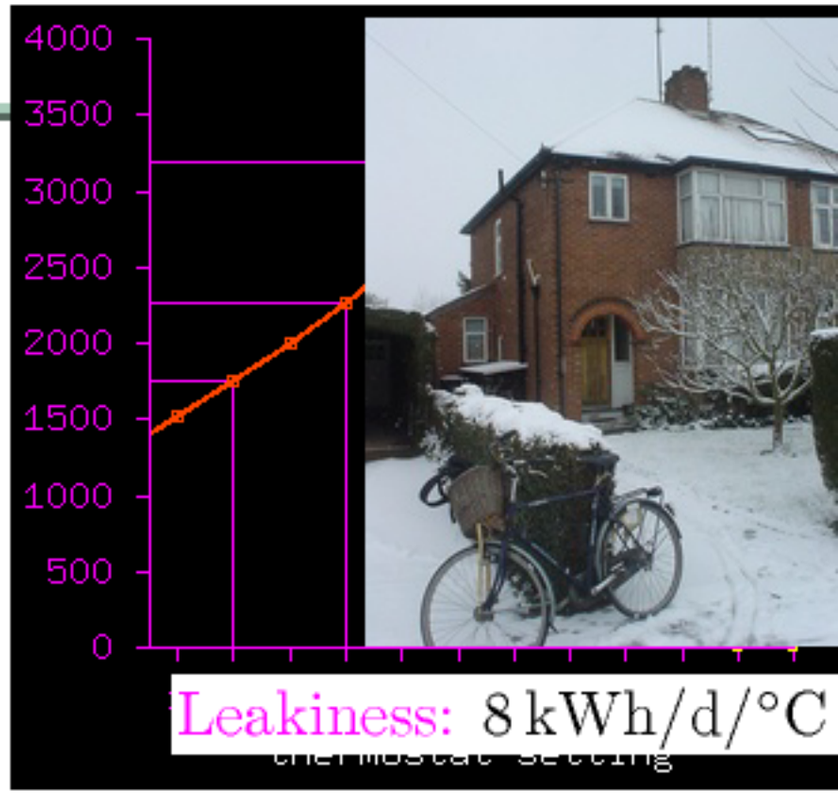
$$\underset{\text{(kWh/d)}}{\boxed{\text{Heat loss}}} = \underset{\text{(kWh/d/°C)}}{\text{Leakiness}} \times \underset{\text{(°C)}}{\text{Average temperature difference}}$$



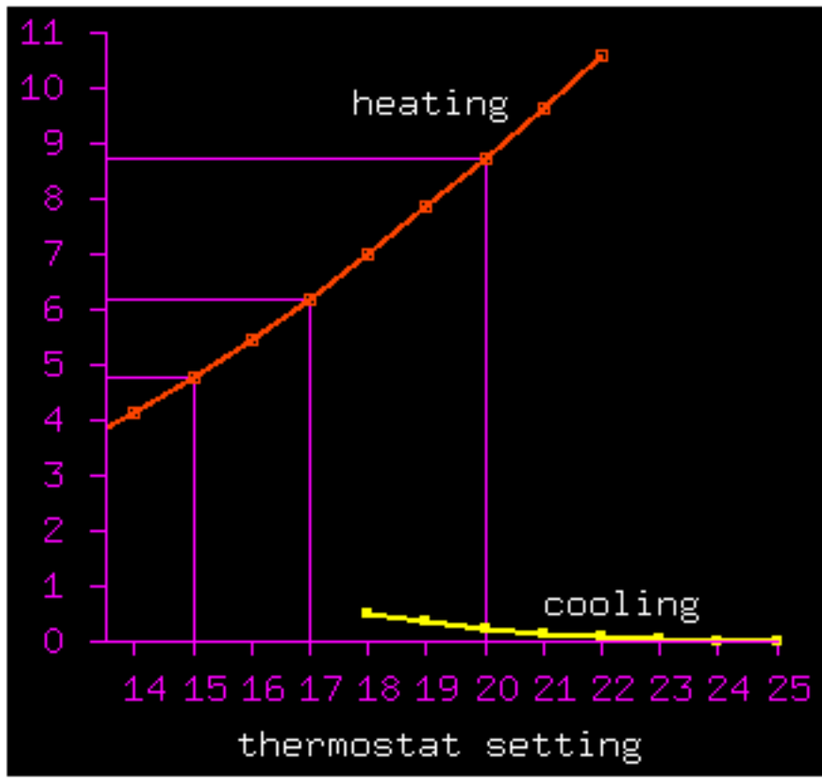




Temperature demand, in degree-days per year



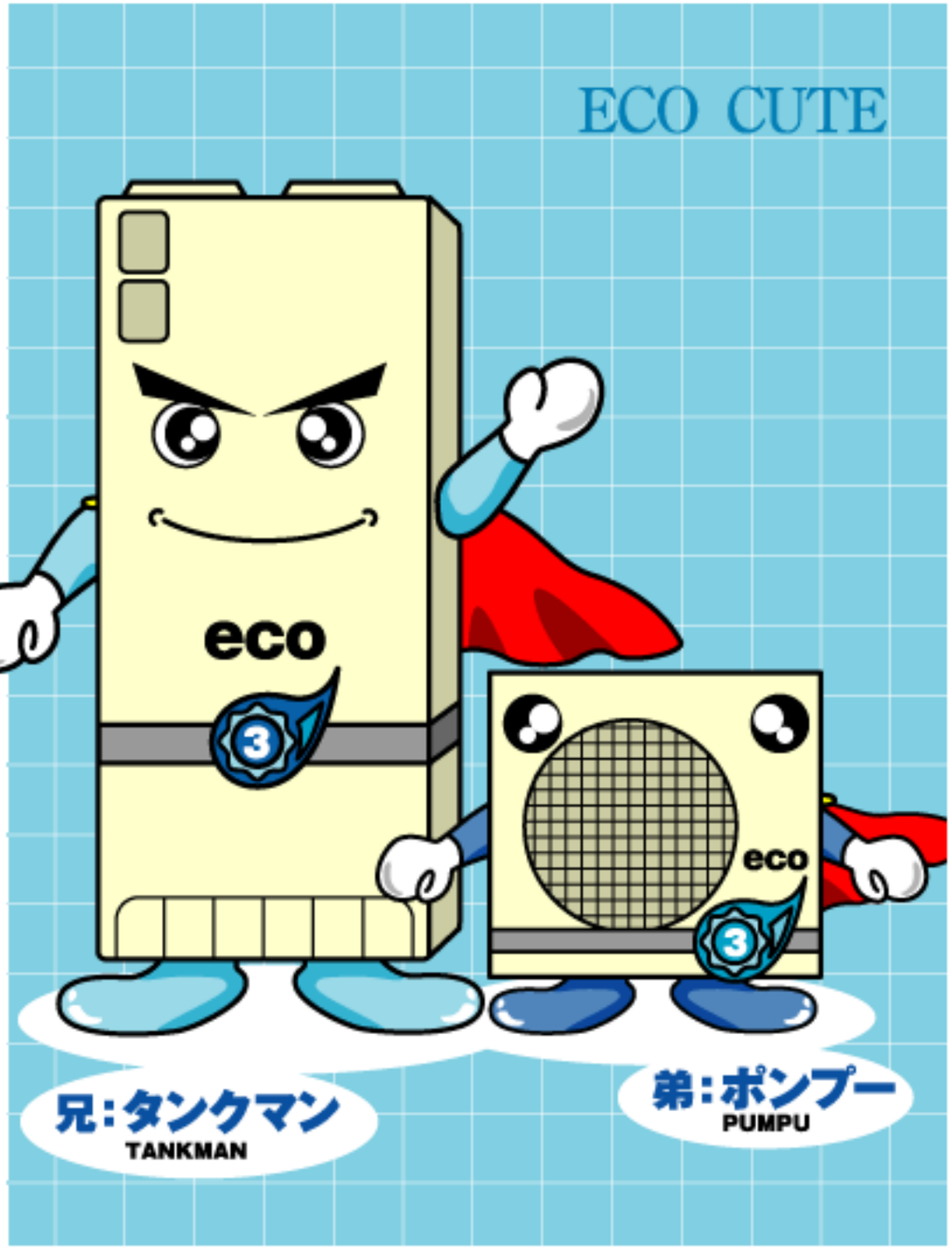
Average temperature difference



Reduce leakiness

New leakiness: 6 kWh/d/°C

Increase coefficient of performance - use Heat pumps



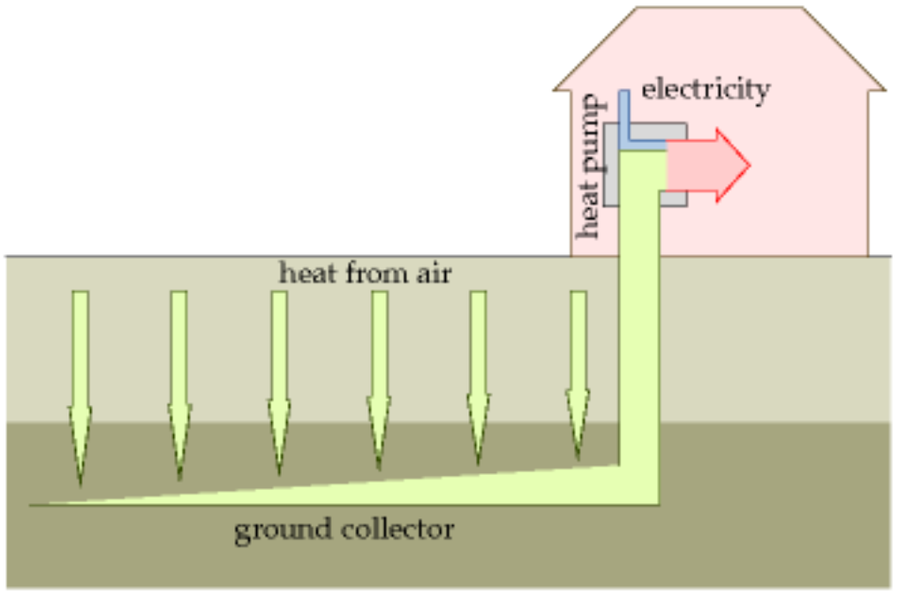
http://www.ecosystem-japan.com/

EcoCute water heater - CoP = 4.9!

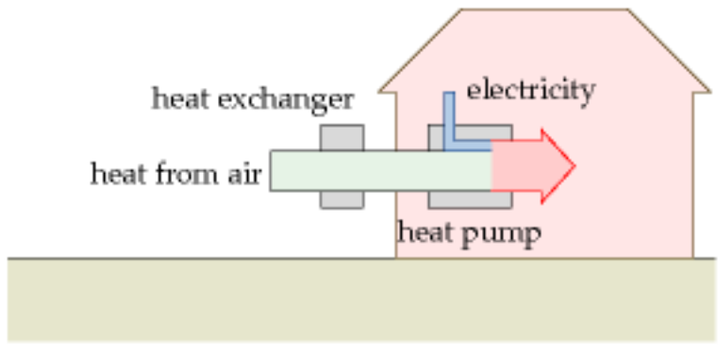
$$\text{Power required} = \boxed{\text{Heat loss}} \Big/ \begin{array}{c}\text{Coefficient of performance}\\ \text{of heat-creation}\end{array}$$

Heating without fossil fuels

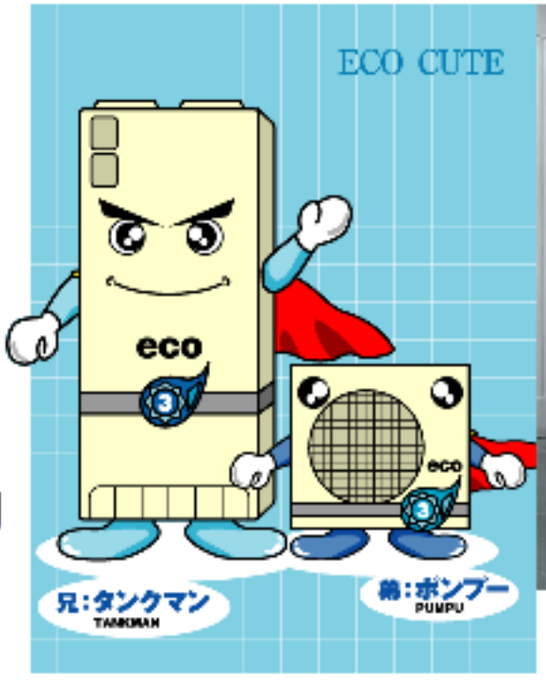
- Heat pumps, powered by electricity
  - Ground-source heat pumps



  - Air-source heat pumps

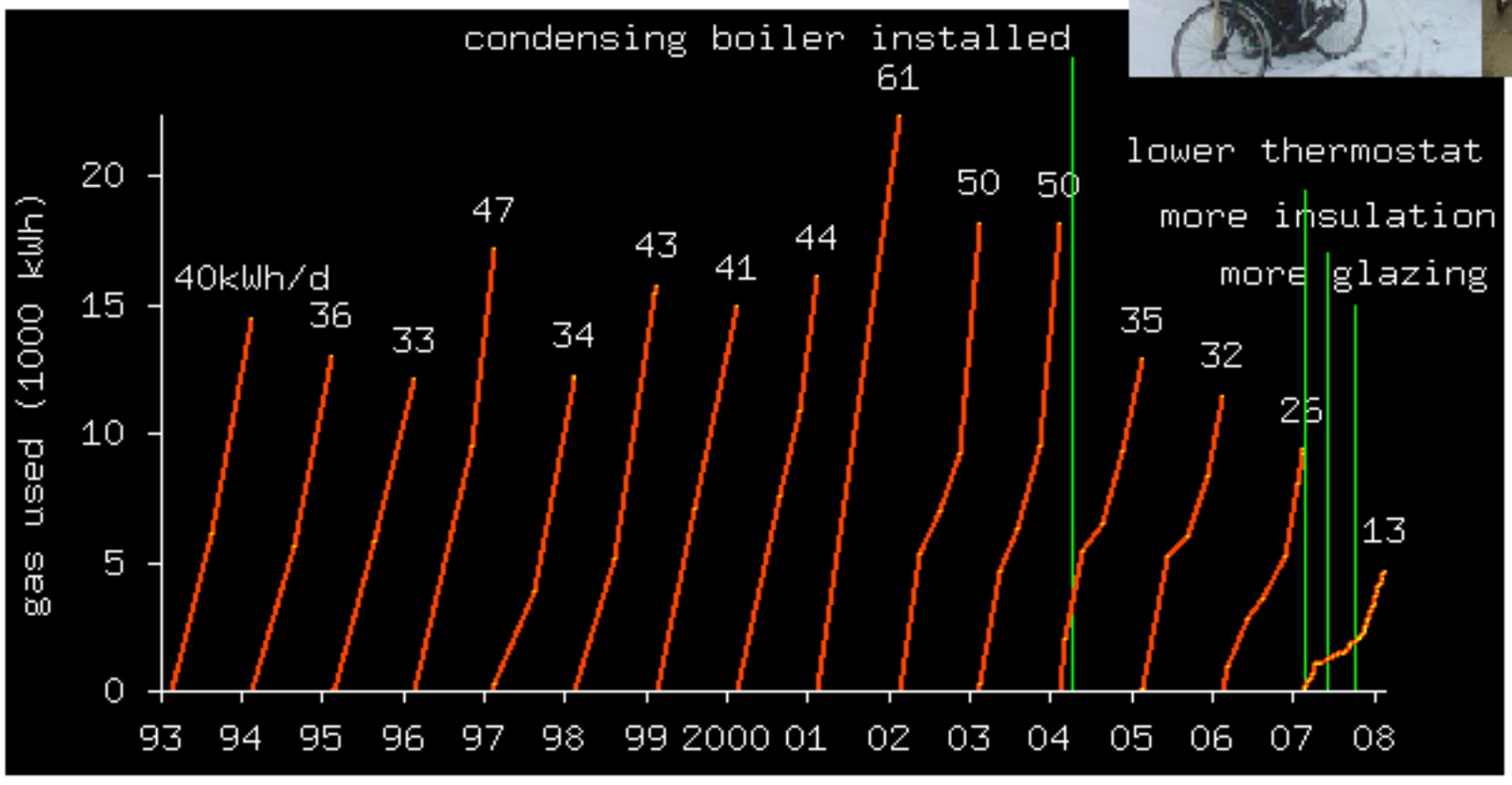


4 times more efficient than ordinary electric heating

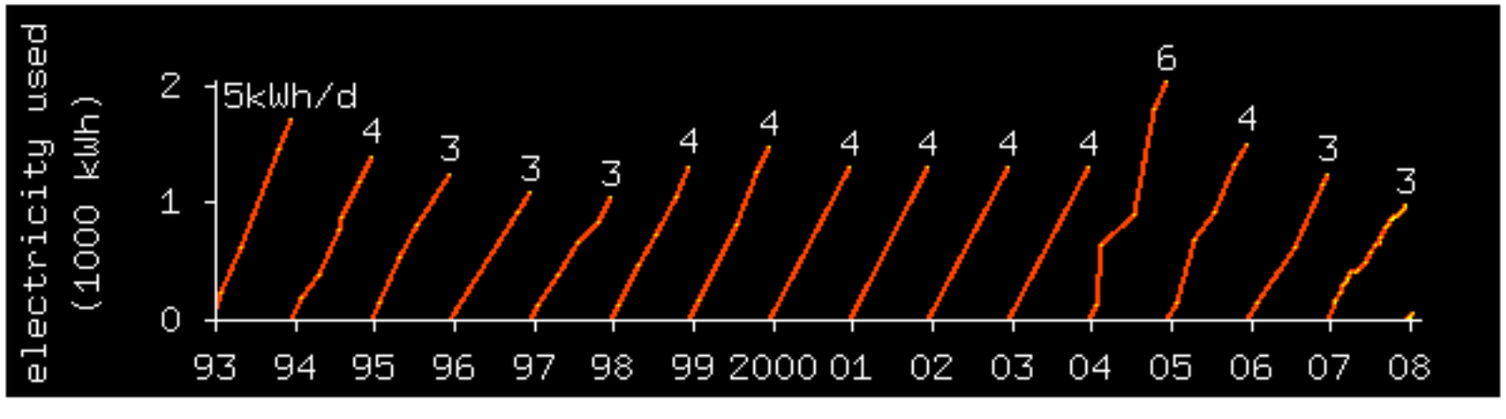


Read your meters!

- Gas

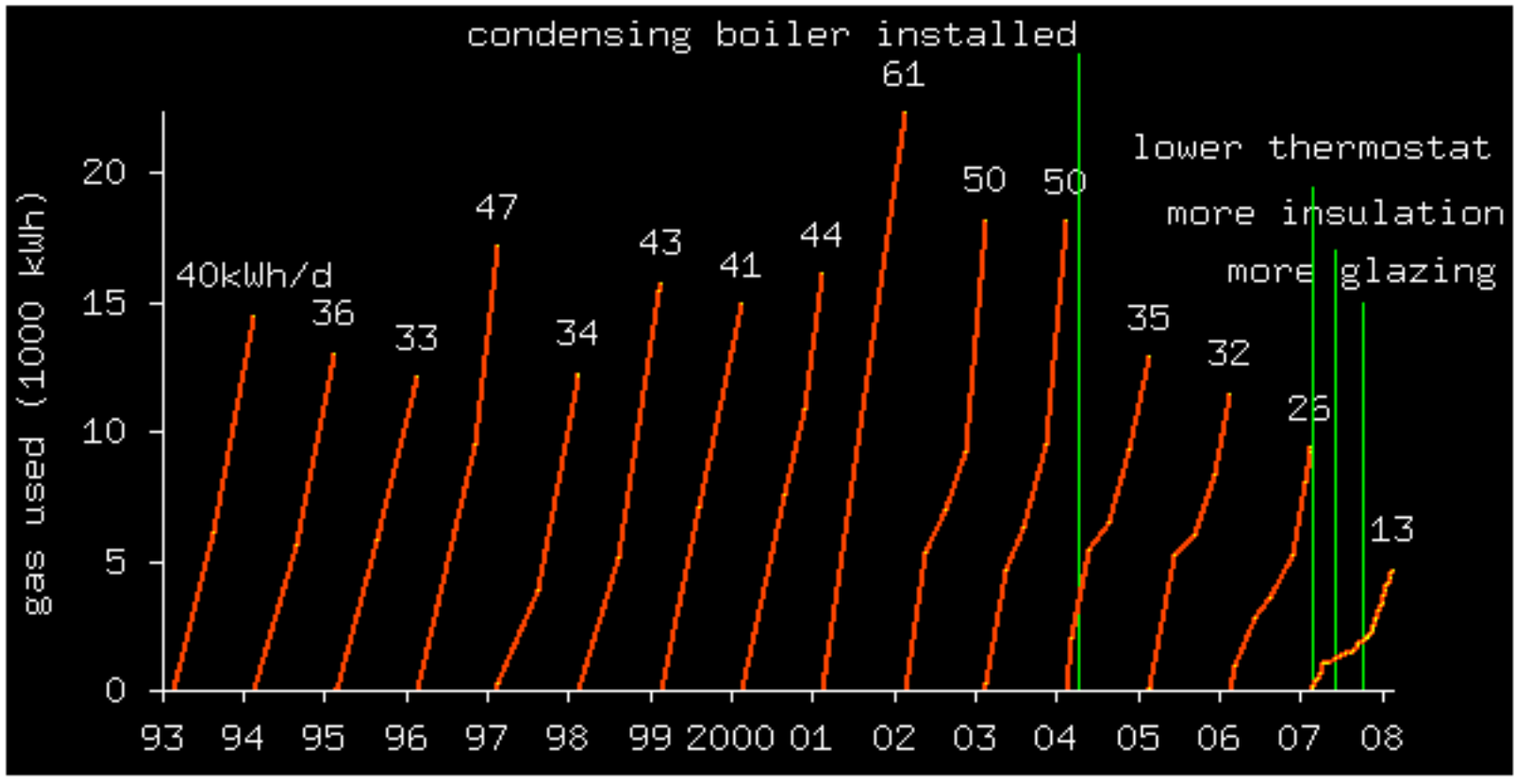


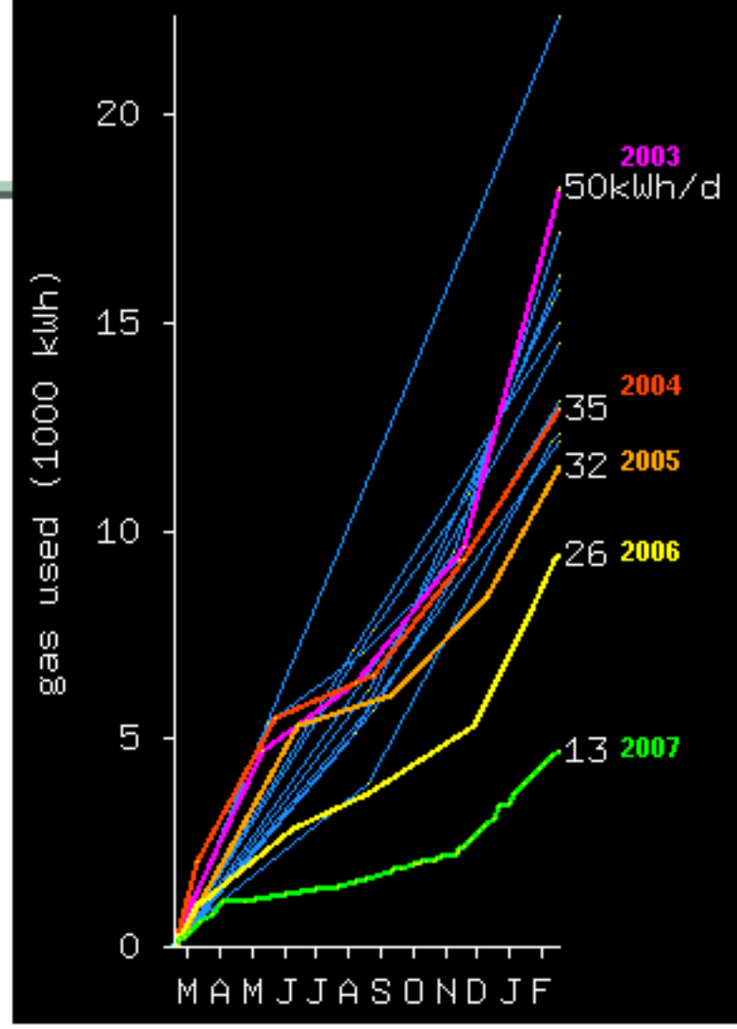
- Electricity



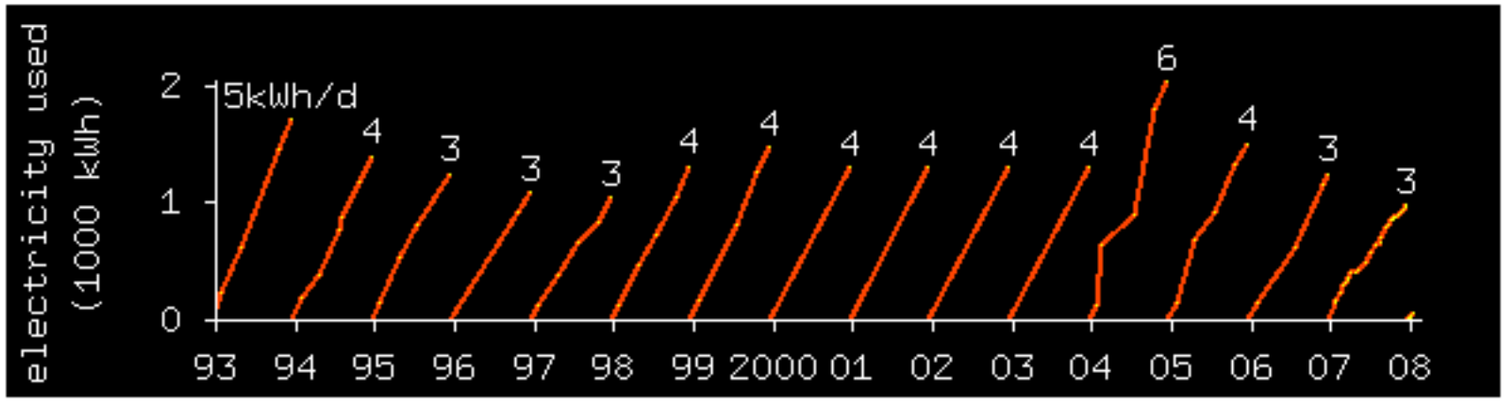
Read your meters!

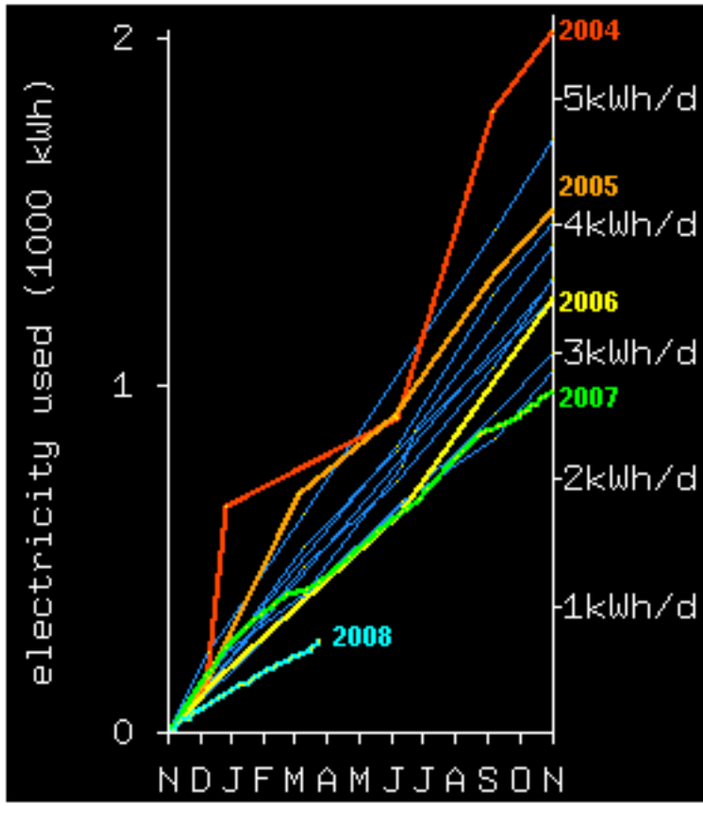
Gas





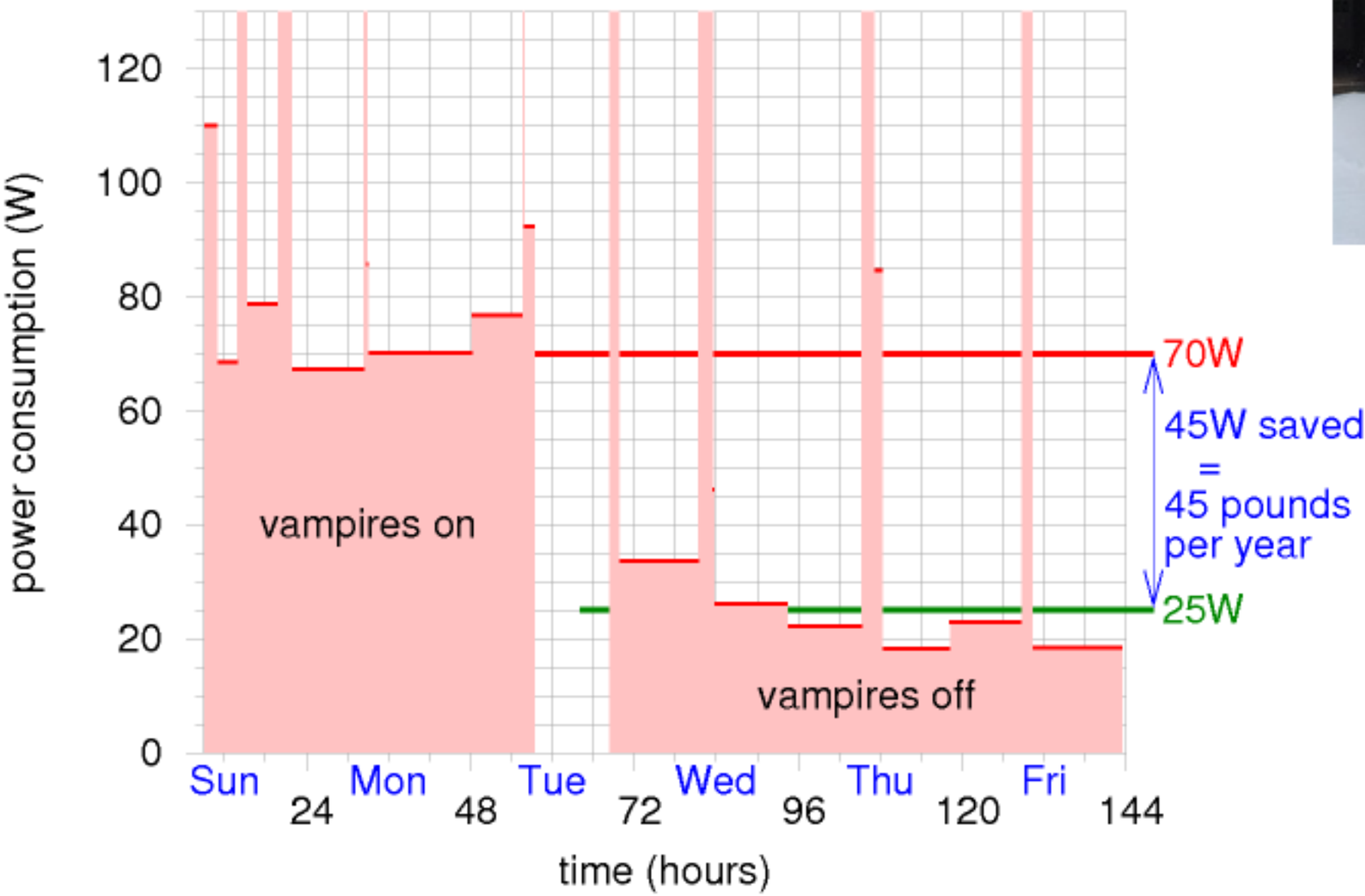
Electricity





Efficiency in the offing

Electricity



Efficiency and technology

- Jevons' paradox

"as technological improvements increase the efficiency with which a resource is used, total consumption of that resource may increase, rather than decrease."

For example, from 1900 to 2000, passenger transportation in the USA became 5 times more energy-efficient; but nowadays, the average person travels 50 times further.

World Business Council for Sustainable Development

DEDICATED TO MAKING A DIFFERENCE

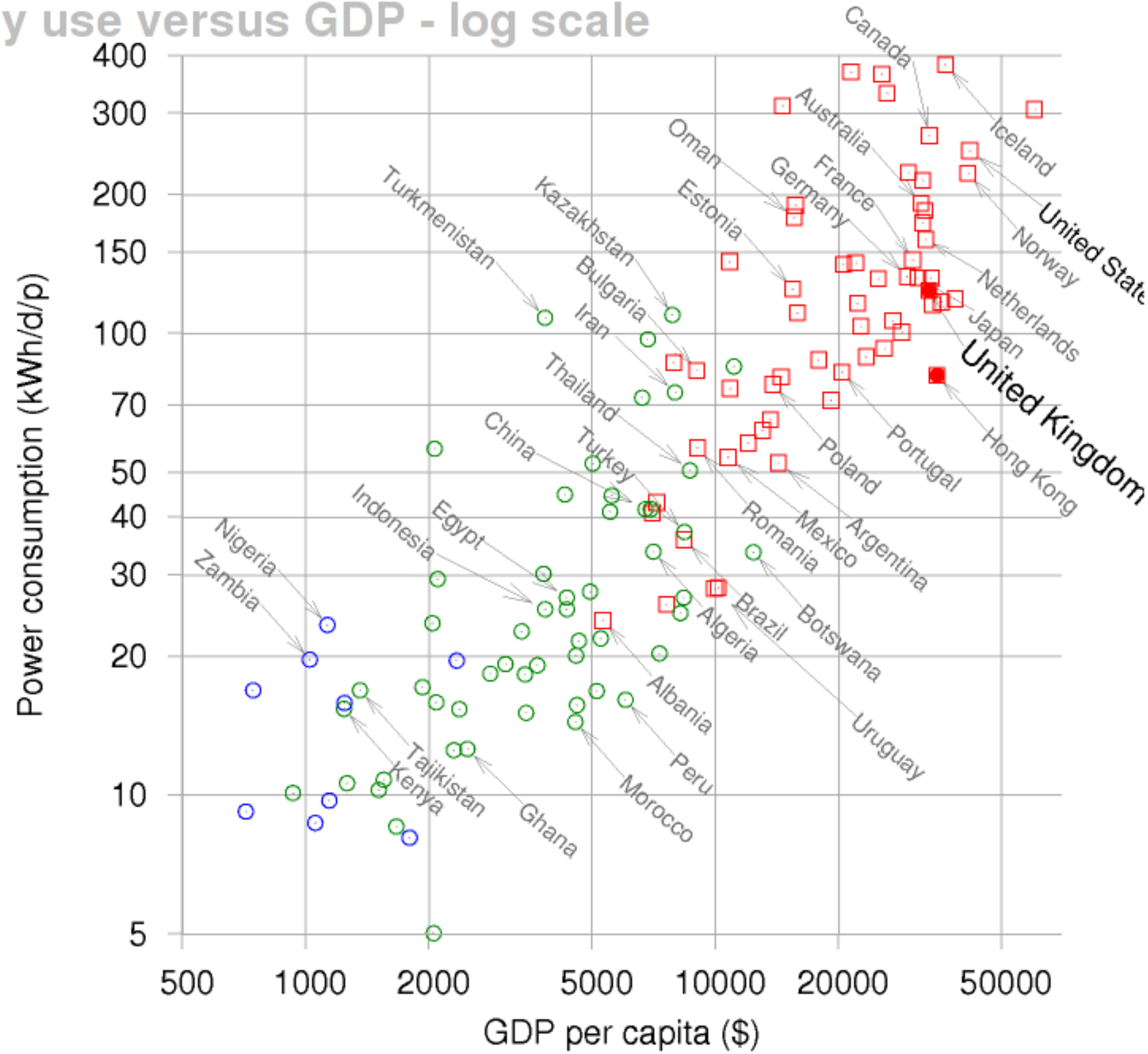
Energy and climate change

"A reduction in growth is not an acceptable path to a lower-carbon world."

"the truth is no country is going to cut its growth or consumption substantially in light of a long-term environmental problem"

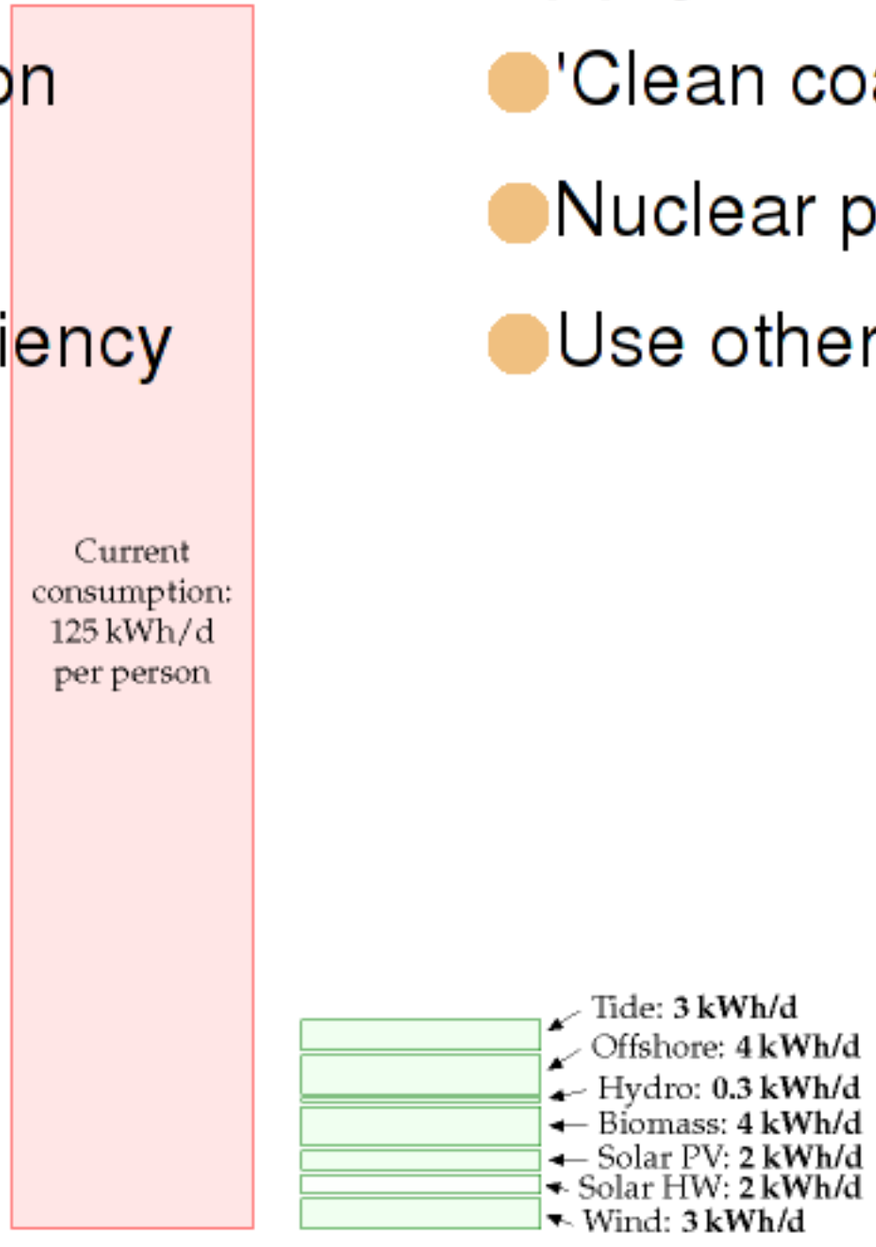
Sept 15 2005

Energy use versus GDP - log scale



How to make an energy plan that adds up

- Demand-side
  - Reduce population
  - Change lifestyle
  - Technology, efficiency
- Supply-side
  - 'Clean coal'
  - Nuclear power
  - Use other countries' renewables



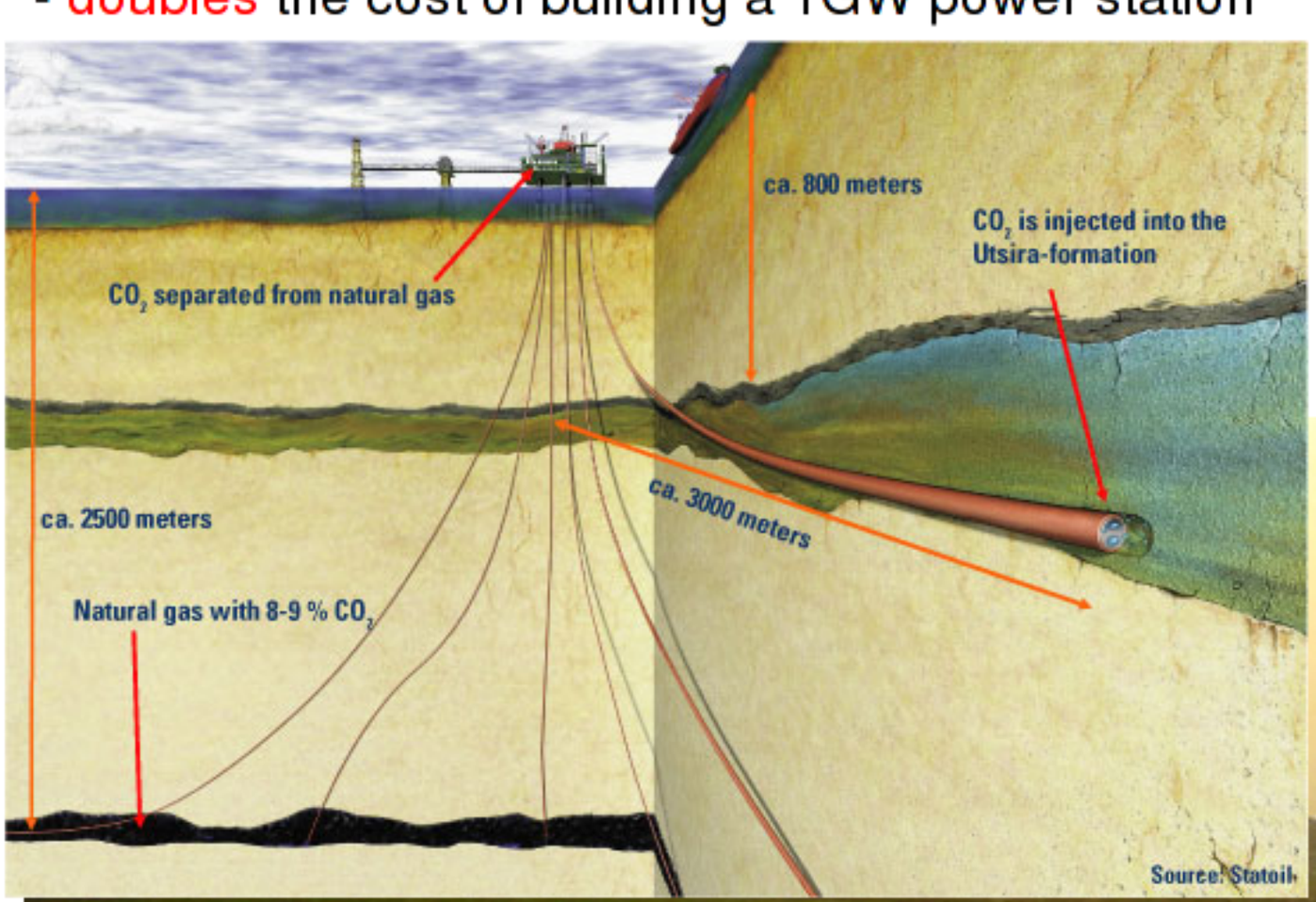
'Sustainable fossil fuels'

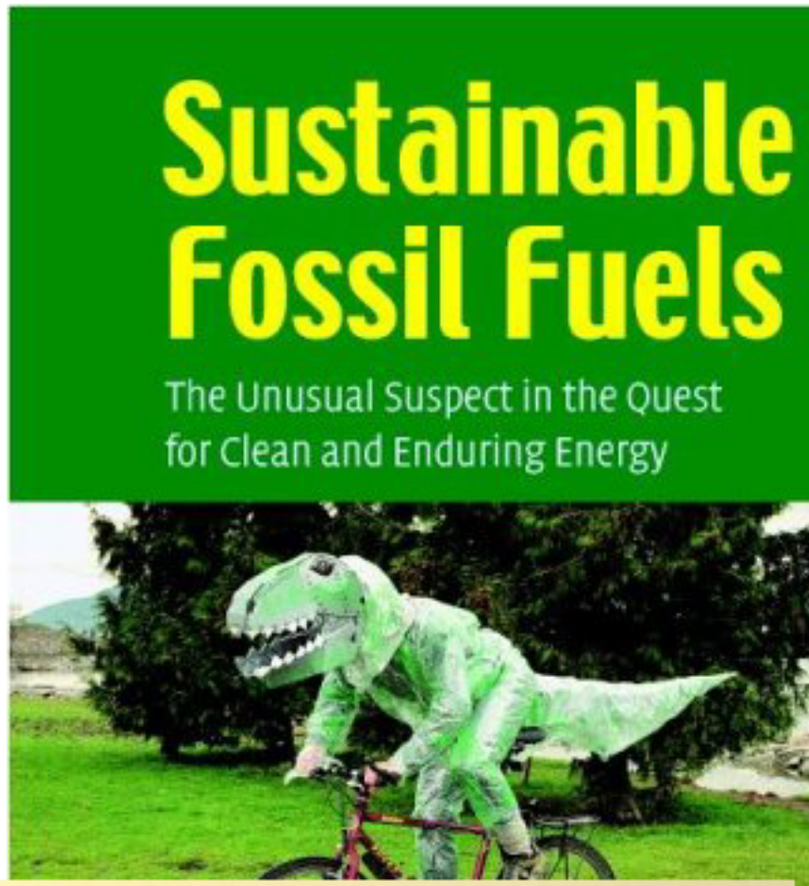
$$\frac{1600\ \text{Gt of coal}}{6\ \text{billion people}} \Big/ 1000\ \text{years} \times 8000\ \text{kWh per tonne} = 6\,\text{kWh per day per person}$$

Coal:
6 kWh/d

Carbon capture and storage

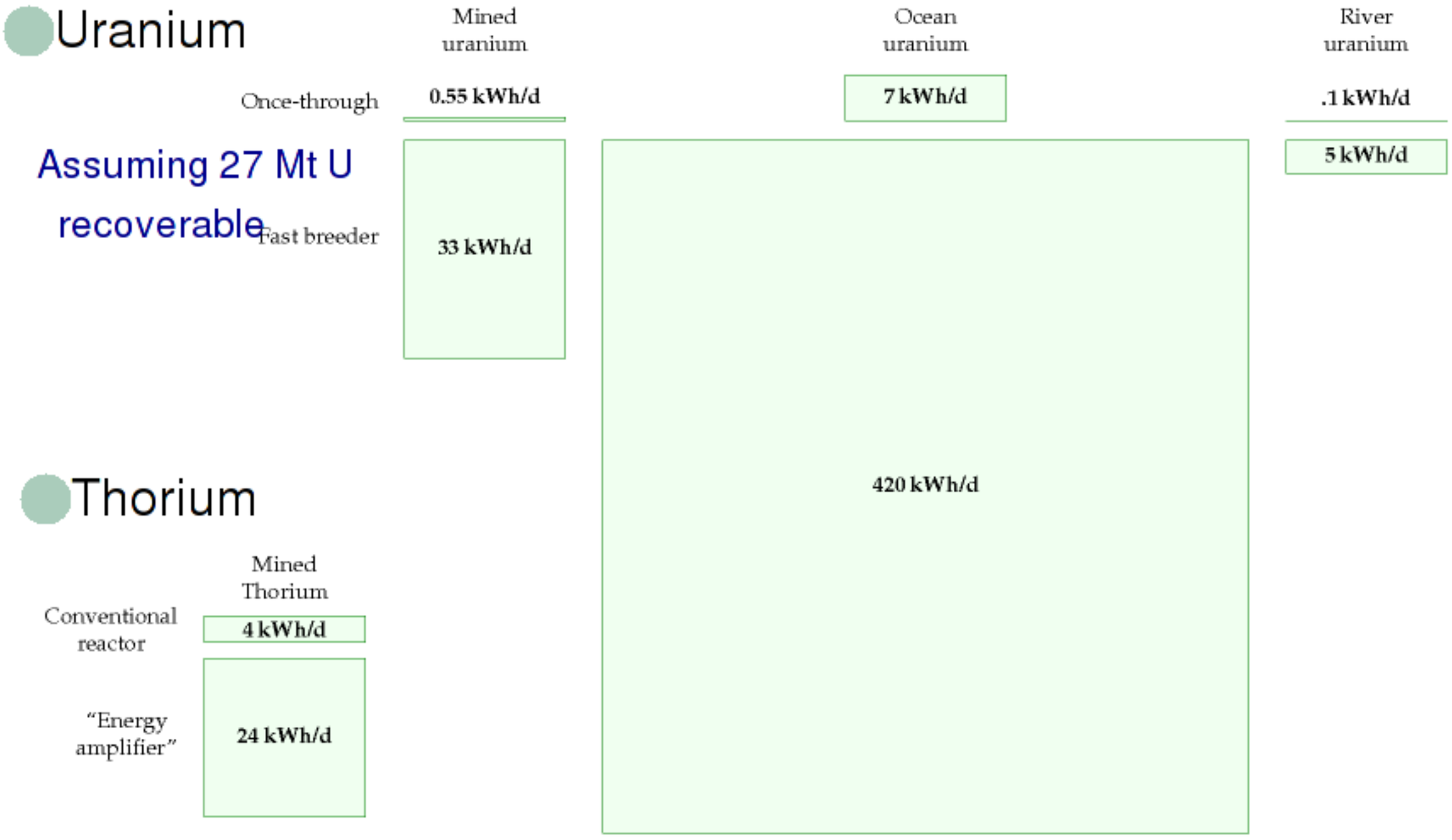
- requires 25% of the generated energy
- doubles the cost of building a 1GW power station





Nuclear Fission ('sustainable' = 1000 years)

Uranium



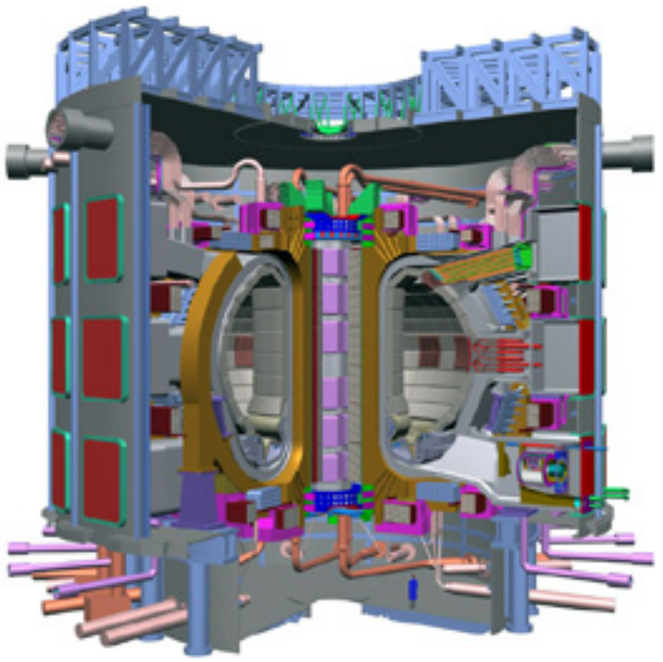
Assuming 27 Mt U recoverable

Thorium

Assuming 1.6 Mt Th recoverable

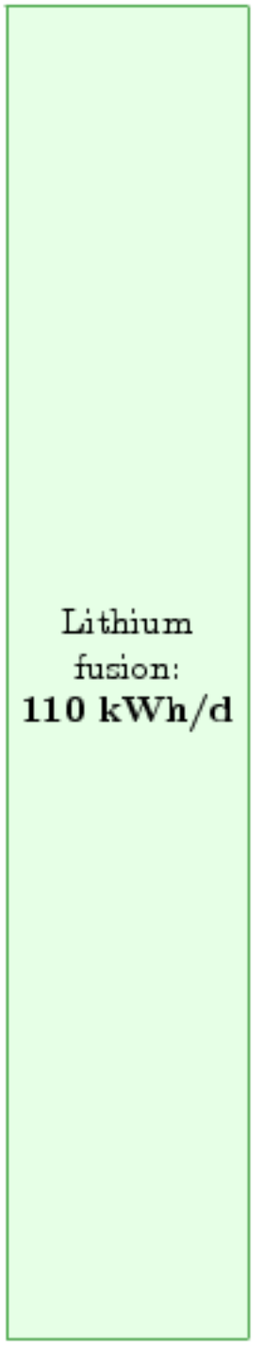
Nuclear Fusion

- Not a sure thing
  - a gamble



- DT reaction
  - requires Lithium and Deuterium
- DD reaction
  - requires Deuterium

(Mined Lithium; there's lots more in seawater)



DD reaction

D lasts ~ 1 billion years

How to make an energy plan that adds up

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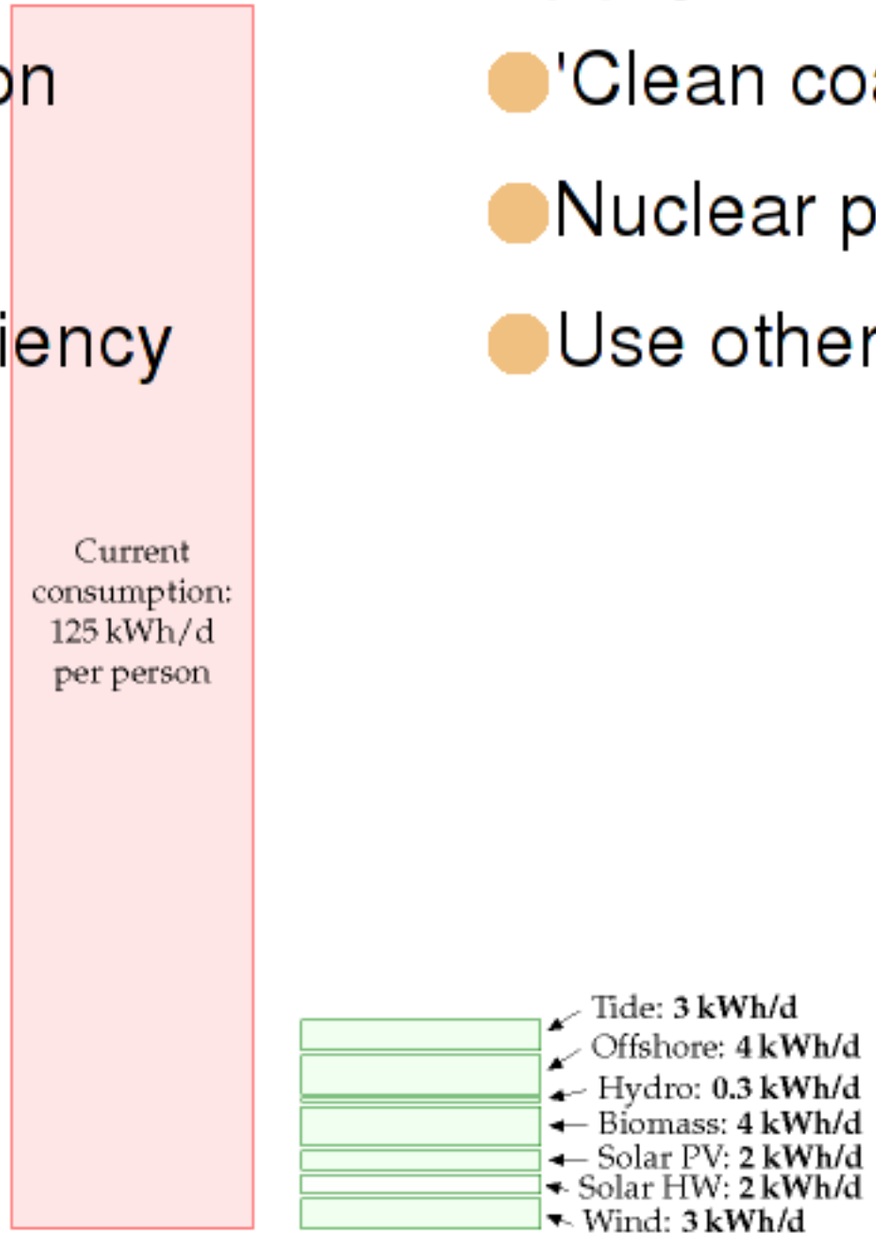
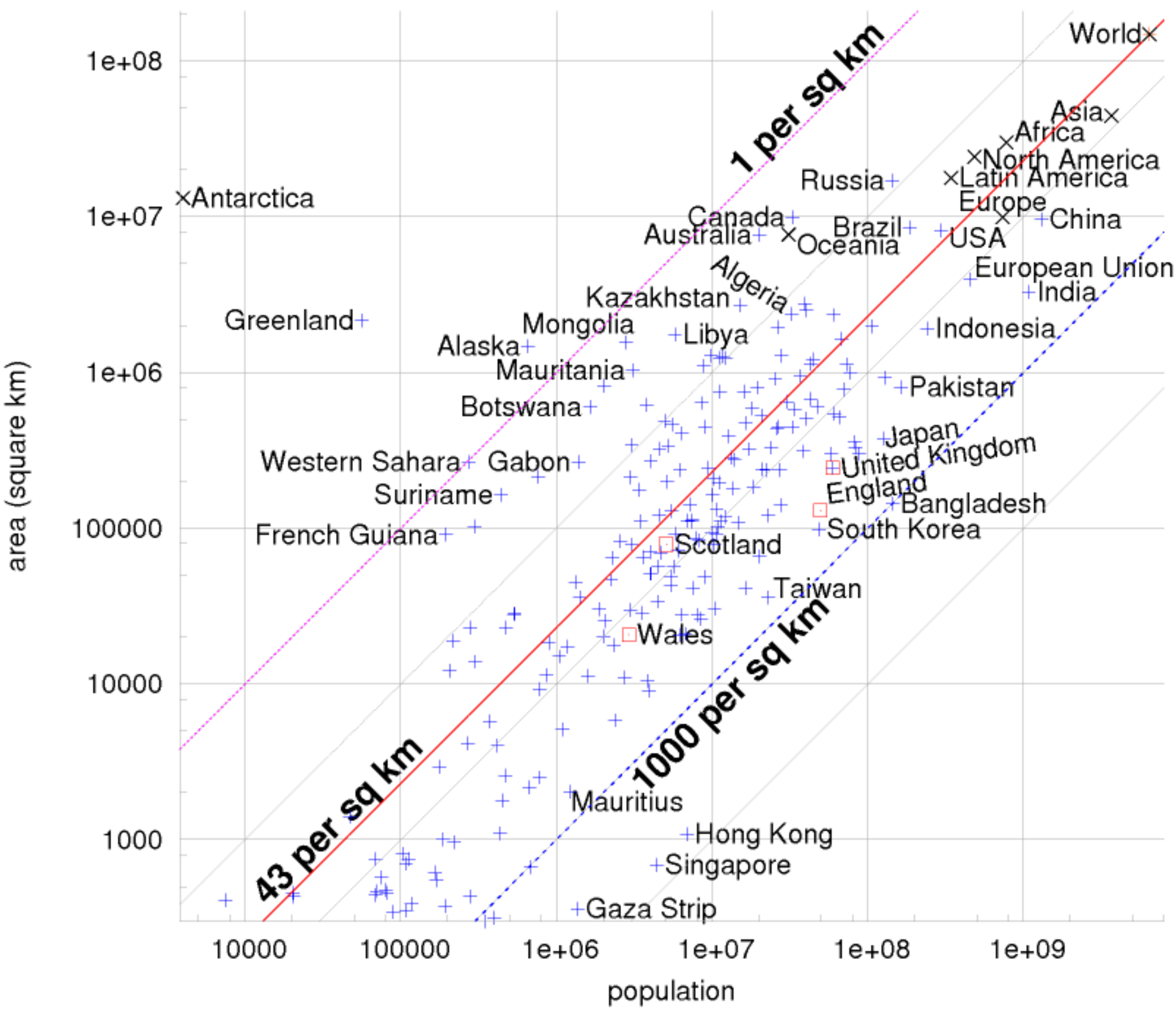
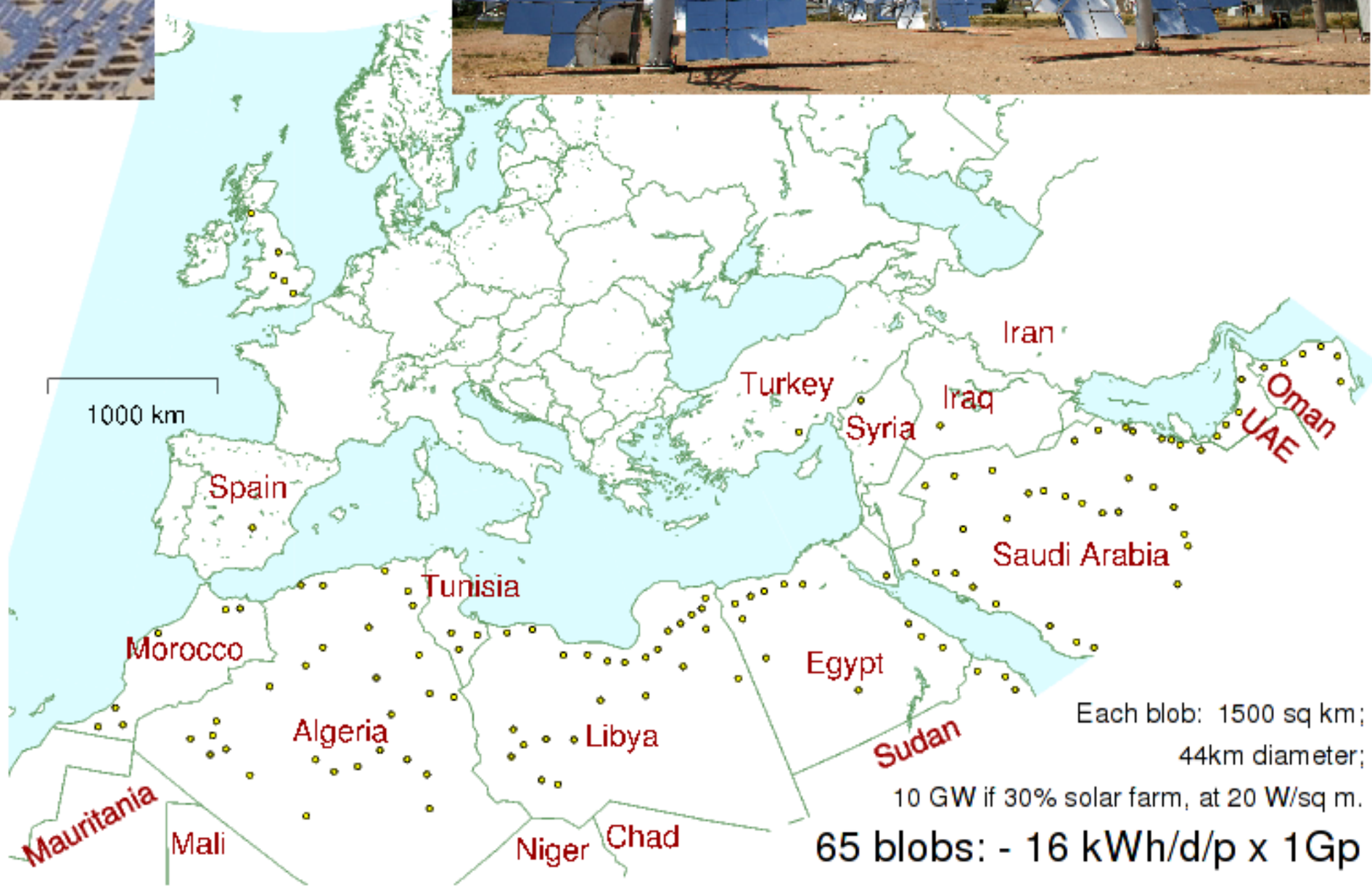



1e+08
1e+07
1e+06
100000
10000
1000
area (square km)
10000
100000
1e+06
1e+07
1e+08
1e+09
population
1 per sq km
43 per sq km
1000 per sq km
World
Asia
Africa
North America
Latin America
Europe
Russia
Canada
Australia
Oceania
Brazil
USA
China
European Union
India
Indonesia
Pakistan
Japan
United Kingdom
England
Bangladesh
South Korea
Taiwan
Wales
Antarctica
Greenland
Alaska
Mauritania
Botswana
Western Sahara
Gabon
Suriname
French Guiana
Scotland
Algeria
Kazakhstan
Mongolia
Libya
Mauritius
Hong Kong
Singapore
Gaza Strip

International options



Spain

1000 km

Morocco

Tunisia

Algeria

Libya

Mauritania

Mali

Niger

Chad

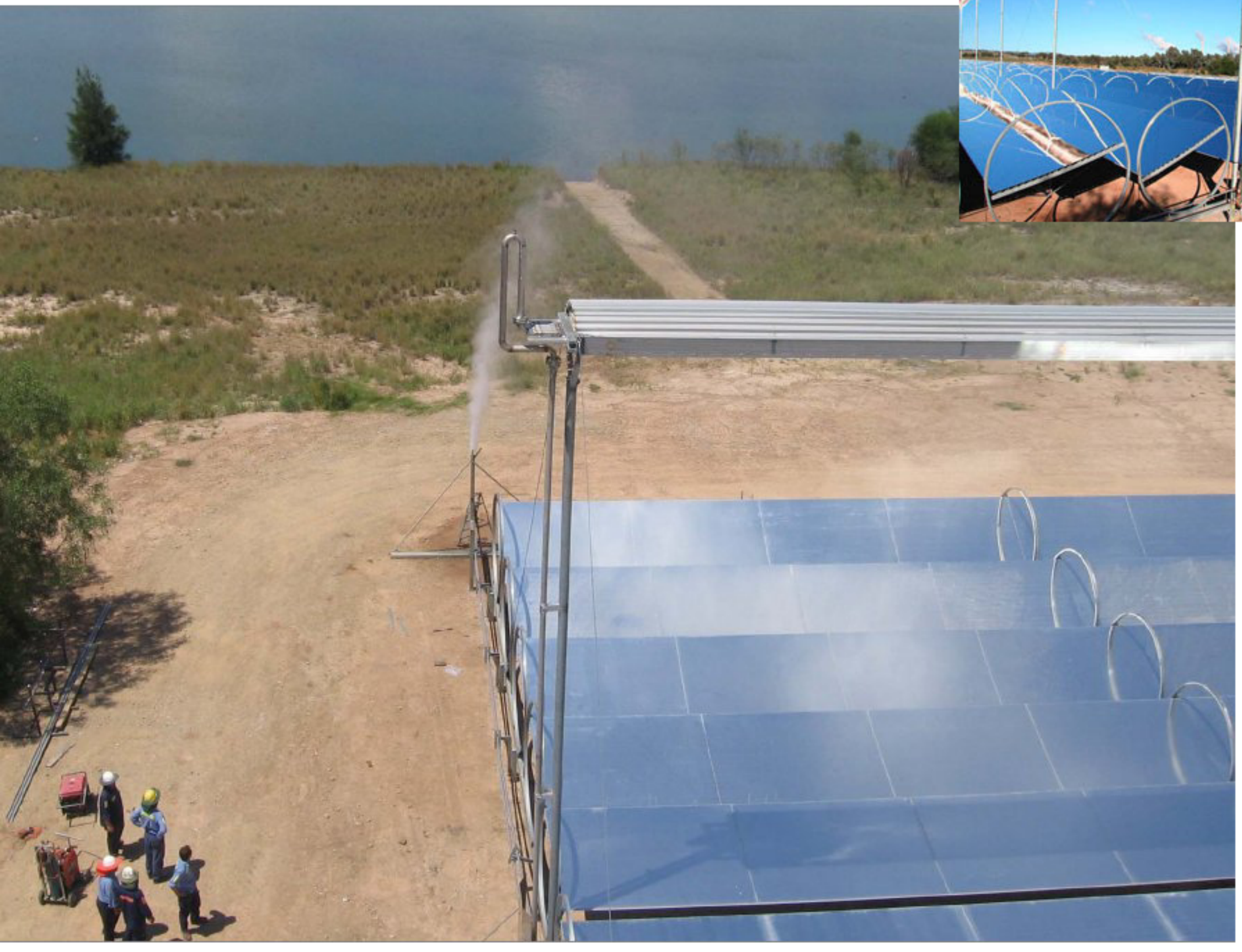
Each blob: 1500 sq km;

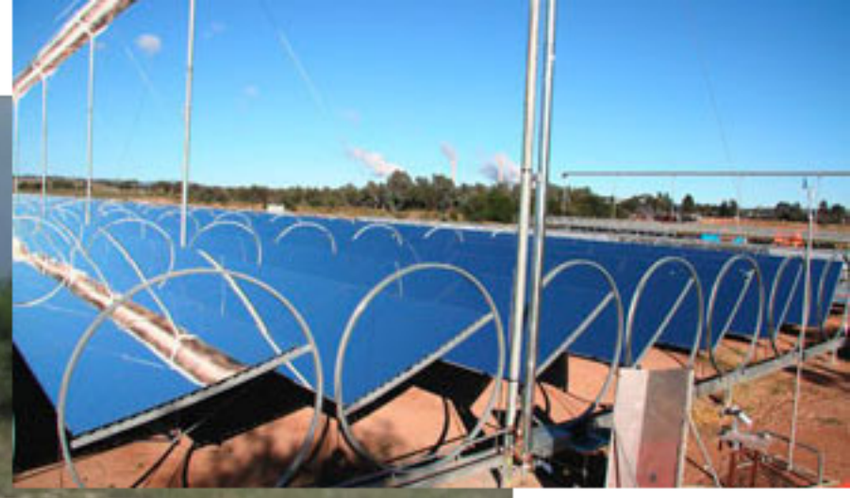
44km diameter;

10 GW if 30% solar farm, at 20 W/sq m.

65 blobs: - 16 kWh/d/p x 1Gp

www.stirlingenergy.com





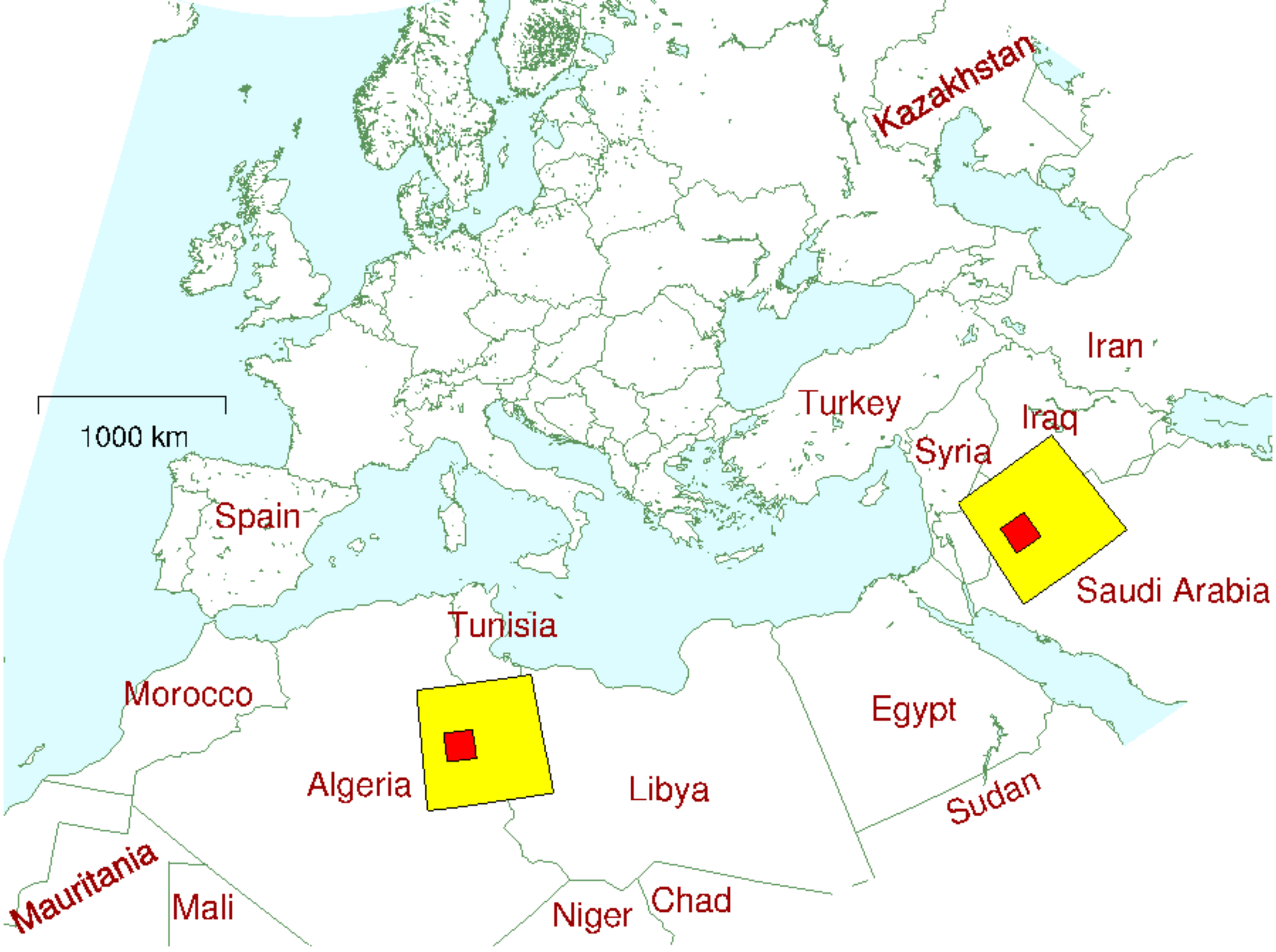
Andasol, Spain

$10\ \mathrm{W/m^2}$

PS10, Solucar

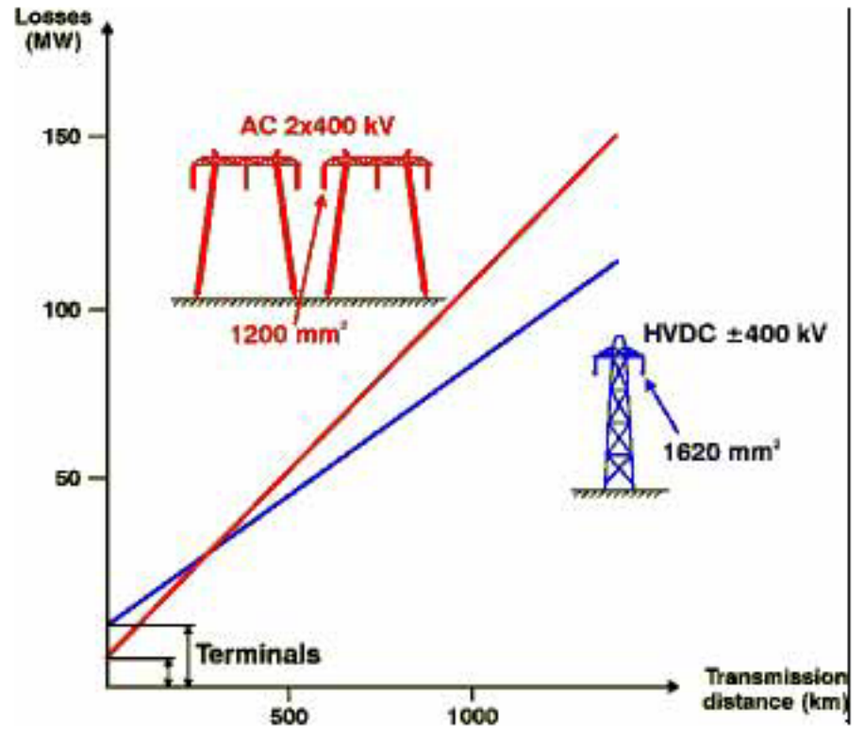
$5\ \mathrm{W/m^2}$

Photo by afloresm



Yellow: 125 kWh/d/p for 1 billion people; Red: 125 kWh/d/p for 60 million people

HVDC transmission



Photos and diagrams: ABB

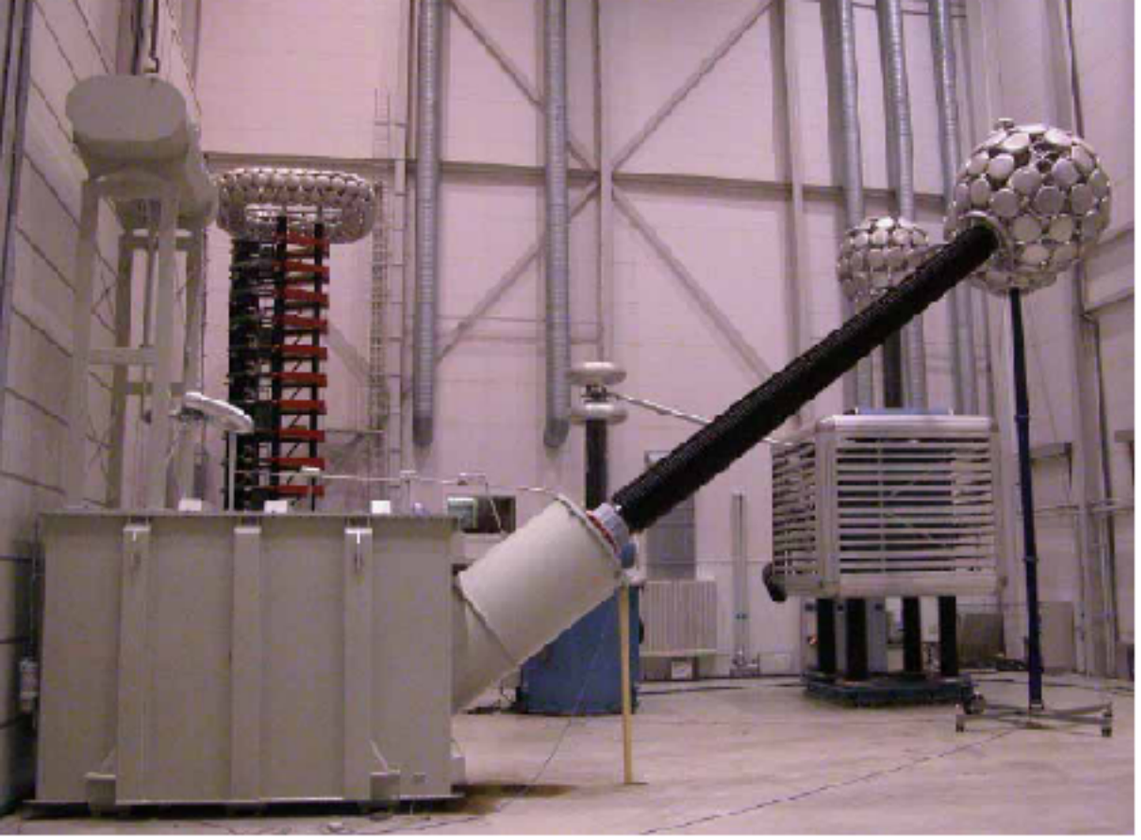
2GW -->

3.1GW, 1360km

1.9GW, 1420km

Mozambique - South Africa

0.7GW, 580km



Photos: ABB

Finland - Estonia:
One pair of cables
transmit 350 MW

How to make an energy plan that adds up

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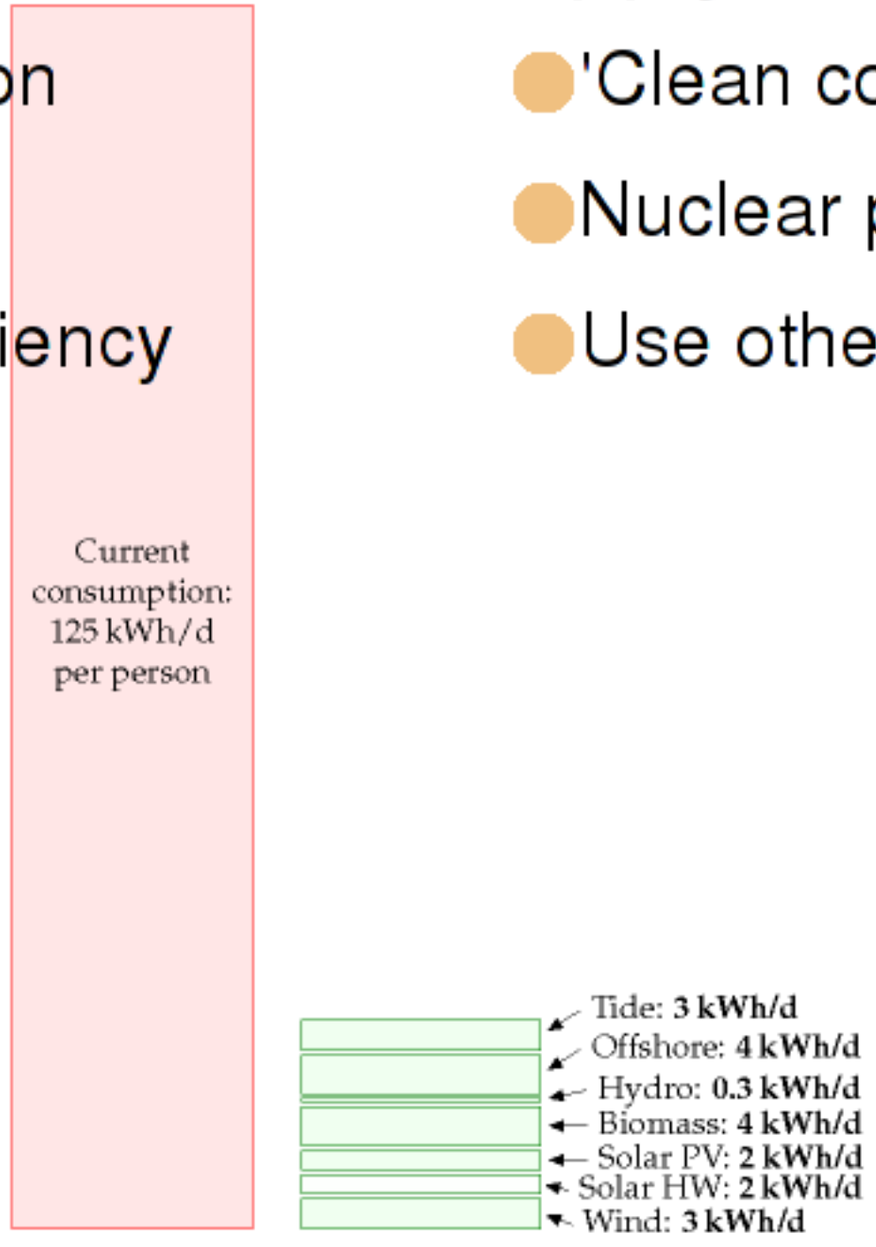
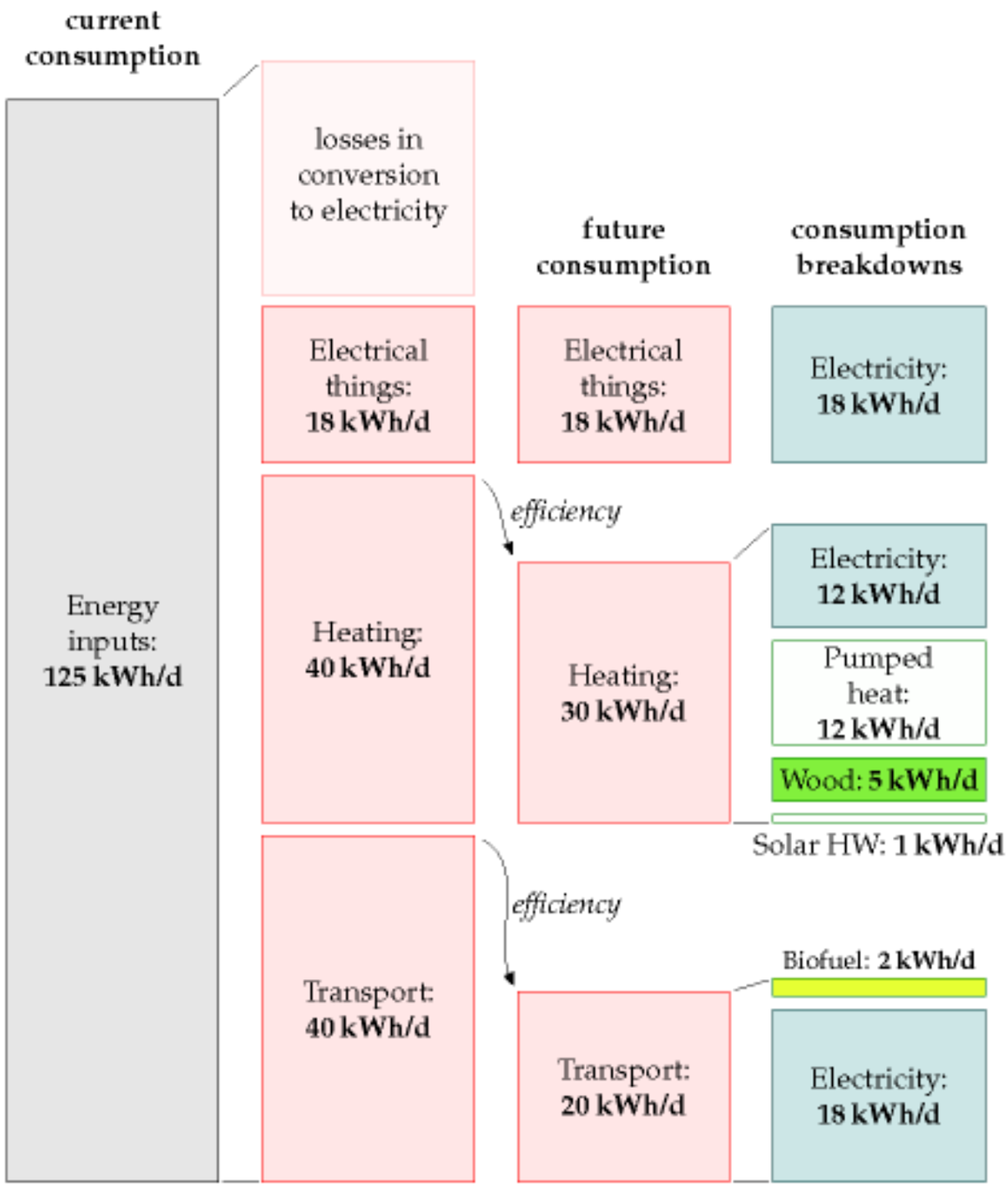


How to get the UK off fossil fuels

- Transport, Heating, Electricity
  - Electrify all transport
  - Insulate all buildings; read all meters
  - Electrify all building-heating
    - air-source or ground-source heat pumps
    - (not combined heat and power)

- Our renewables
- Nuclear? (stop-gap?)
- 'Clean coal'? (stop-gap)
- Other people's renewables

One cartoon plan



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

tidal stream farms

100 sq km wind farms

Loch Shin

Loch Maree

Loch Ness

Foyers

Loch Morar

Biofuels

Loch Shiel

Loch Ericht

Blackwater

Loch Rannoch

65km wave farm

Loch Tay

Cruachan

Loch Awe

Loch Katrine

Loch Sloy

Loch Leven

Wood/Miscanthus

100 km

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

Sellafield

Wood/Miscanthus

Heysham

100 km

Drax

Ferrybridge

Wylfa

tidal lagoons

Dinorwig

Ffestiniog

Trawsfynydd

Sizewell

Bradwell

Berkeley

Oldbury

Didcot

65km wave farm

Kingsnorth

Hinkley Point

Dungeness

HVDC power lines

Photovoltaics

Solar power in deserts

This plan's mix

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**

Four Londons' worth

Use for cofiring biomass with CCS

40GW - four-fold increase

Jack-up barges cost 60M

25% of UK - forests, willow, miscanthus

1 sq m per person HW

12% of UK for biofuels

Half of all roofs

33-fold increase in wind capacity

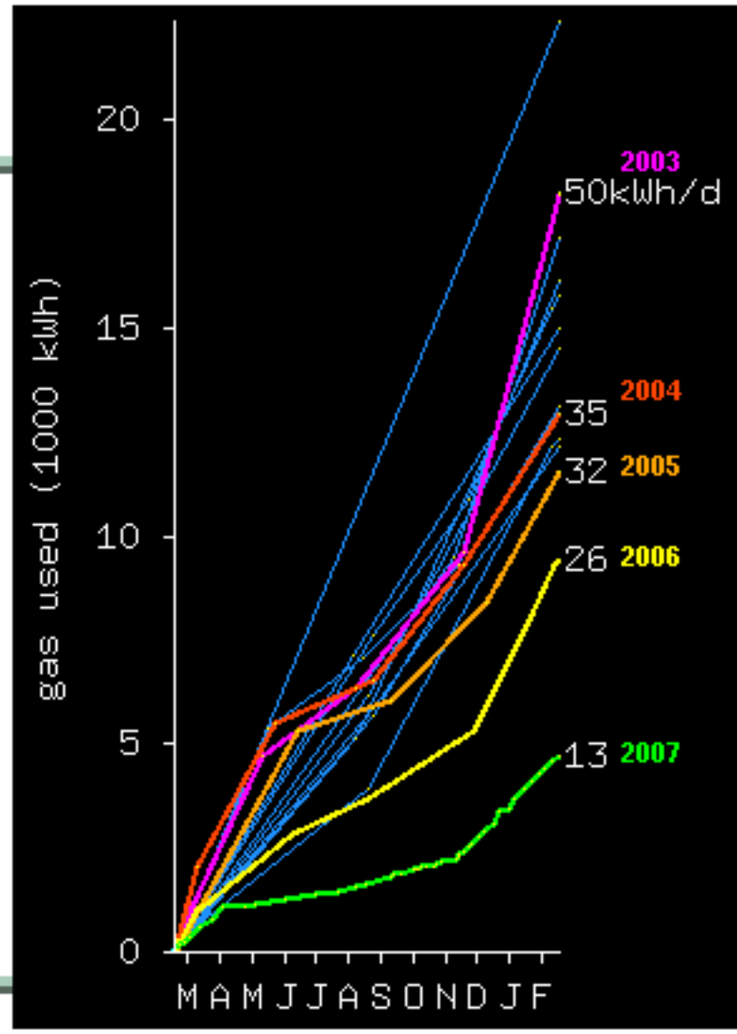
[Jet flights: 5kWh/d/p, while oil lasts]

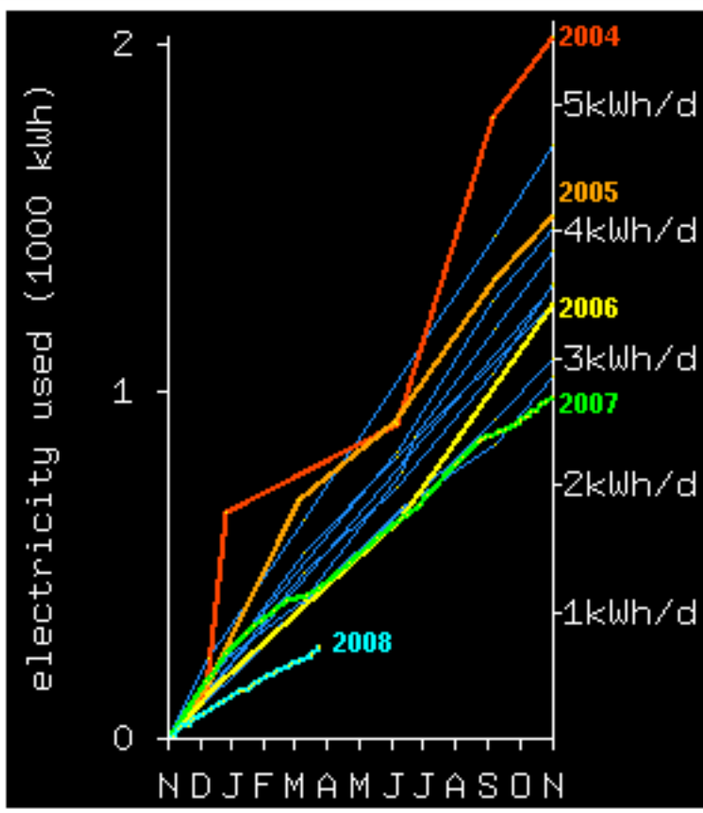
What society must do

- A plan that adds up
- Carbon tax
  - upstream, stable
- Carbon capture at all coal power stations

What individuals can do

- Read meters
- Say yes to plans that add up





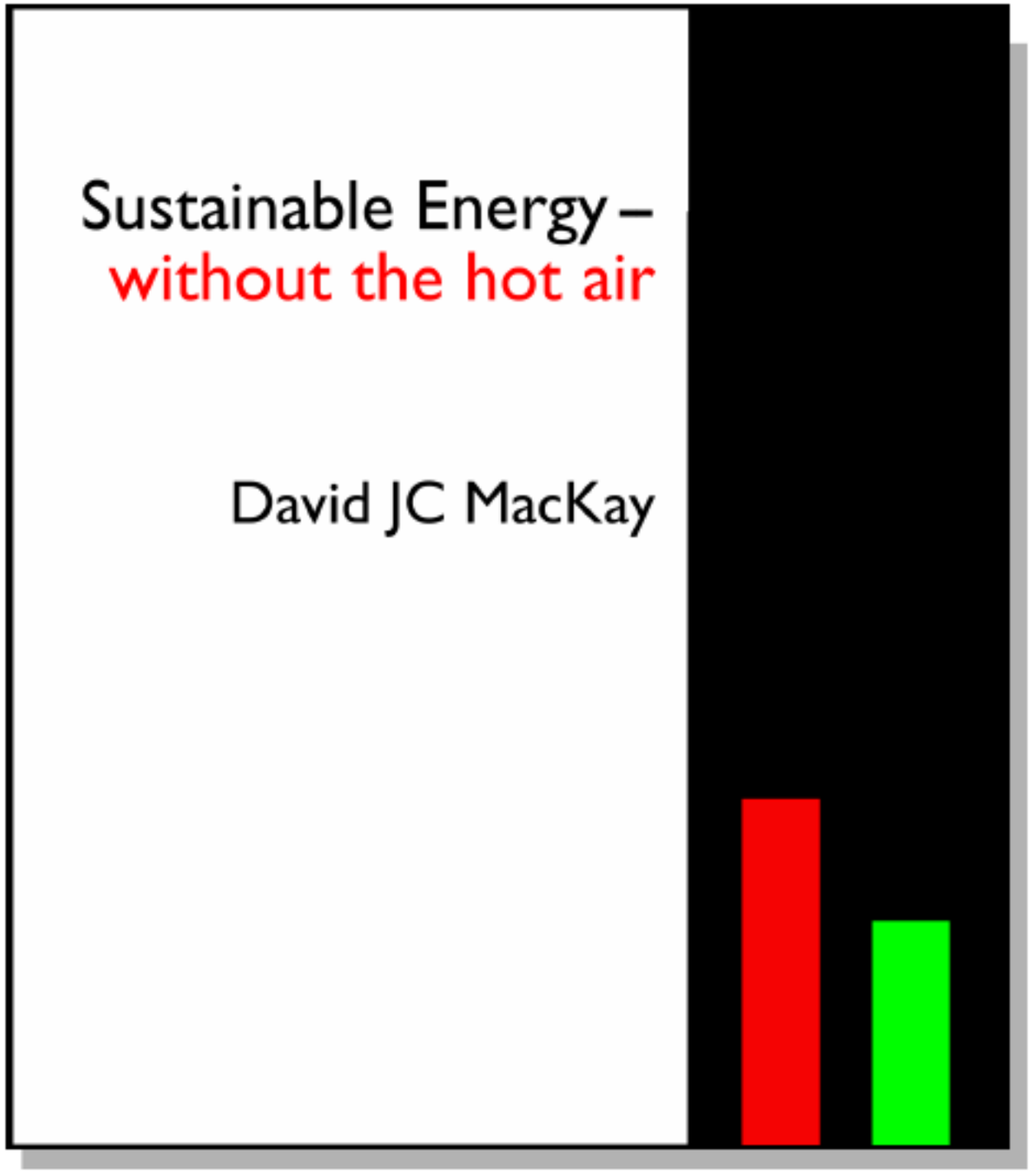
Getting off fossil fuels is not easy, but it is possible

- A Plan that adds up must have some or all of:
  - country-sized renewable facilities
  - renewables from other people's countries
  - lots of nuclear power
- And efficiency too of course

'Okay - it's agreed; we announce - "to do nothing is not an option!" then we wait and see how things pan out...'

Sustainable Energy – without the hot air

David JC MacKay



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