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ZERO CARBON BRITAIN
Rethinking the Future

Balancing variability in a 100% renewable scenario

Alice Hooker-Stroud
alice.hooker-stroud@cat.org.uk

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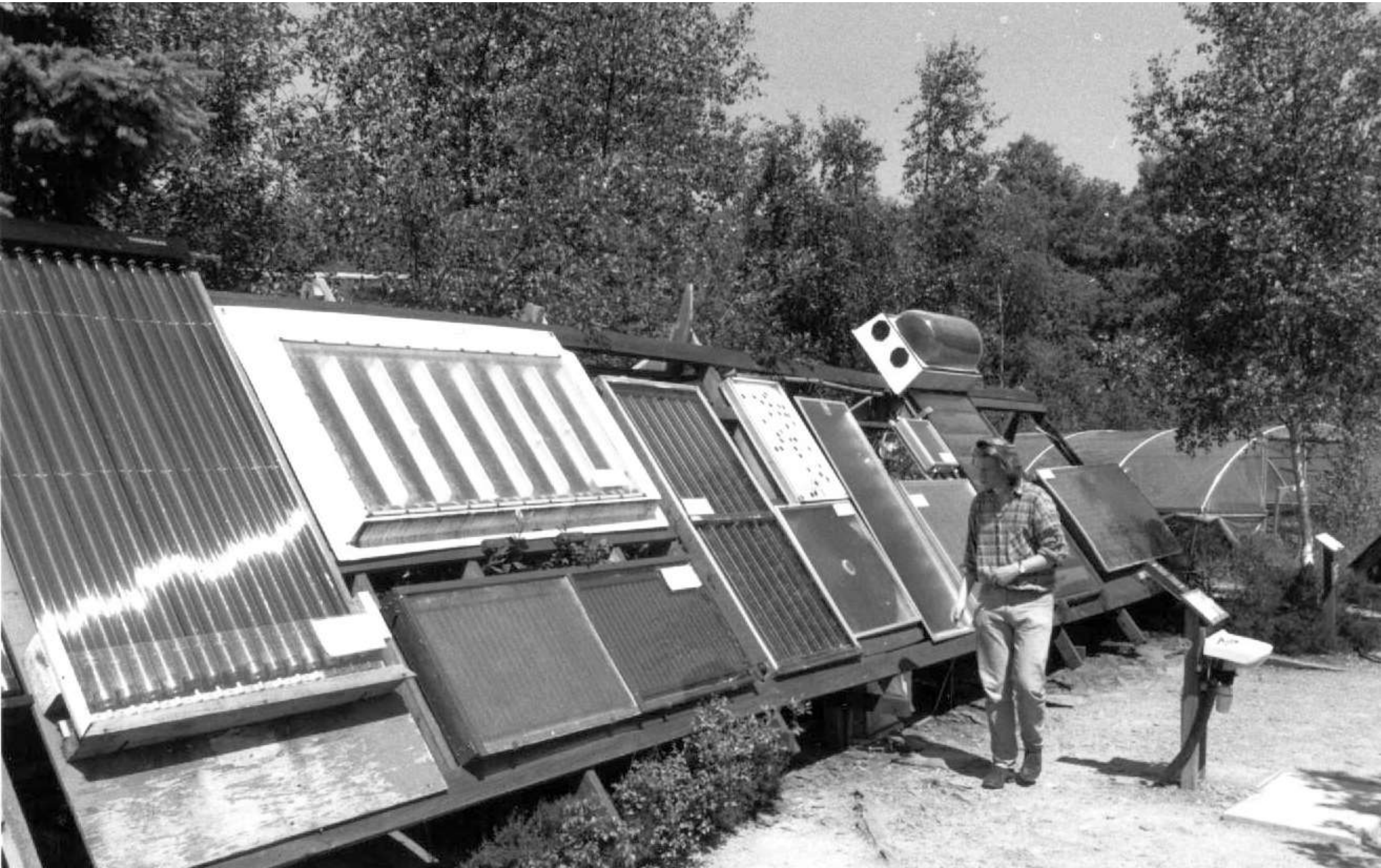
Canolfan y Dechnoleg Amgen (1973)

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Weller

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Performance
Building Solutions
&
Breathability


Marmot

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Rethinking the Future

Less ‘hand on’, more sitting at a desk...

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Rethinking the Future

A technically robust scenario in which the UK has risen to the challenge of climate change.

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Rethinking the Future

“Dear Santa…”

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Some assumptions

- ‘Physically realistic’ approach (no BAU available)

Where we're heading today

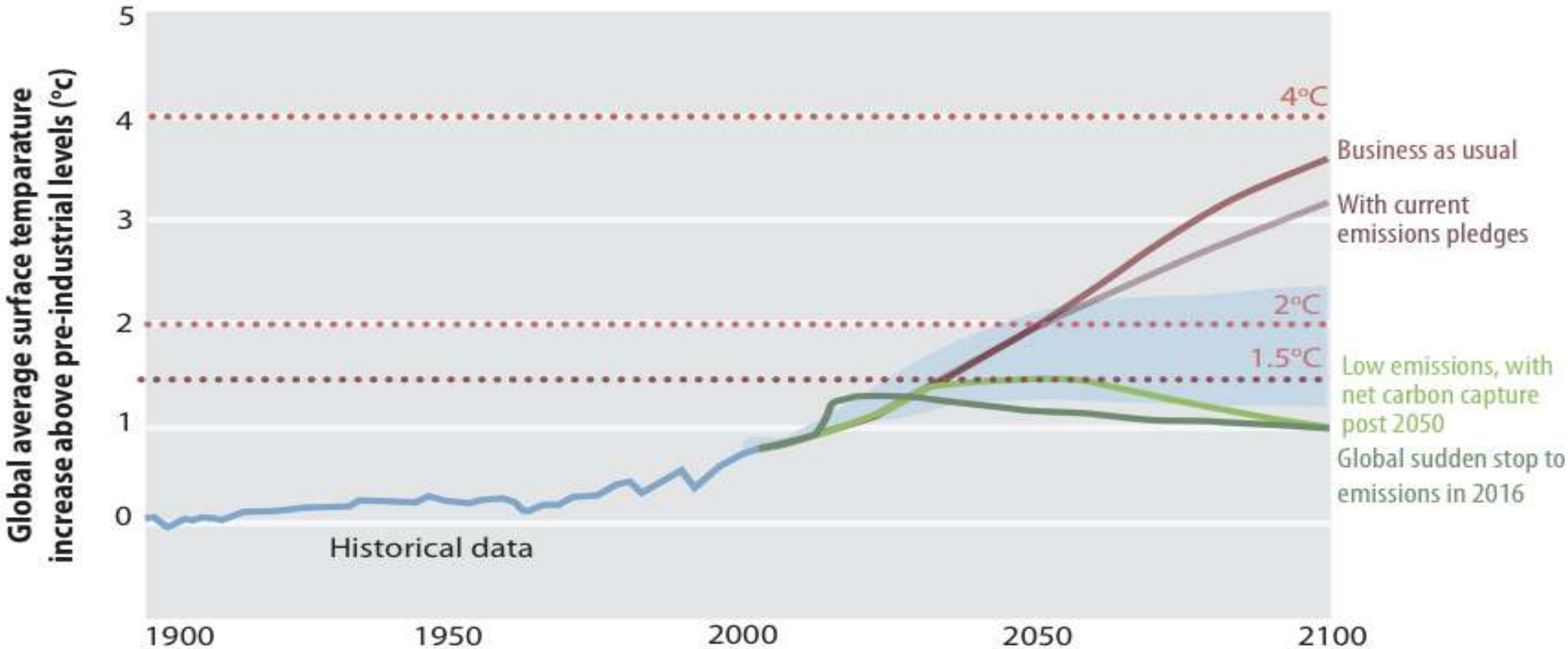

Figure 2.4: Temperature changes expected under different emissions scenarios. Adapted from World Bank (2012).

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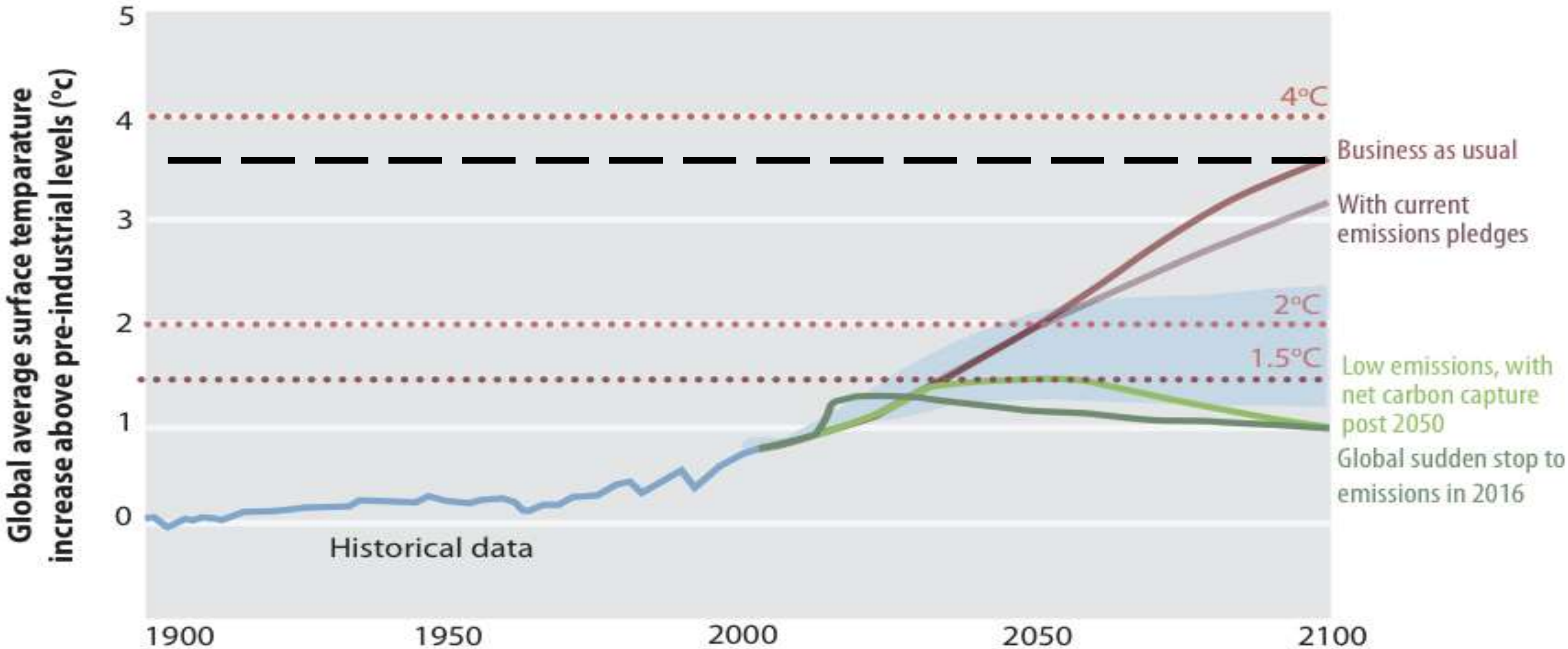
Where we're heading today



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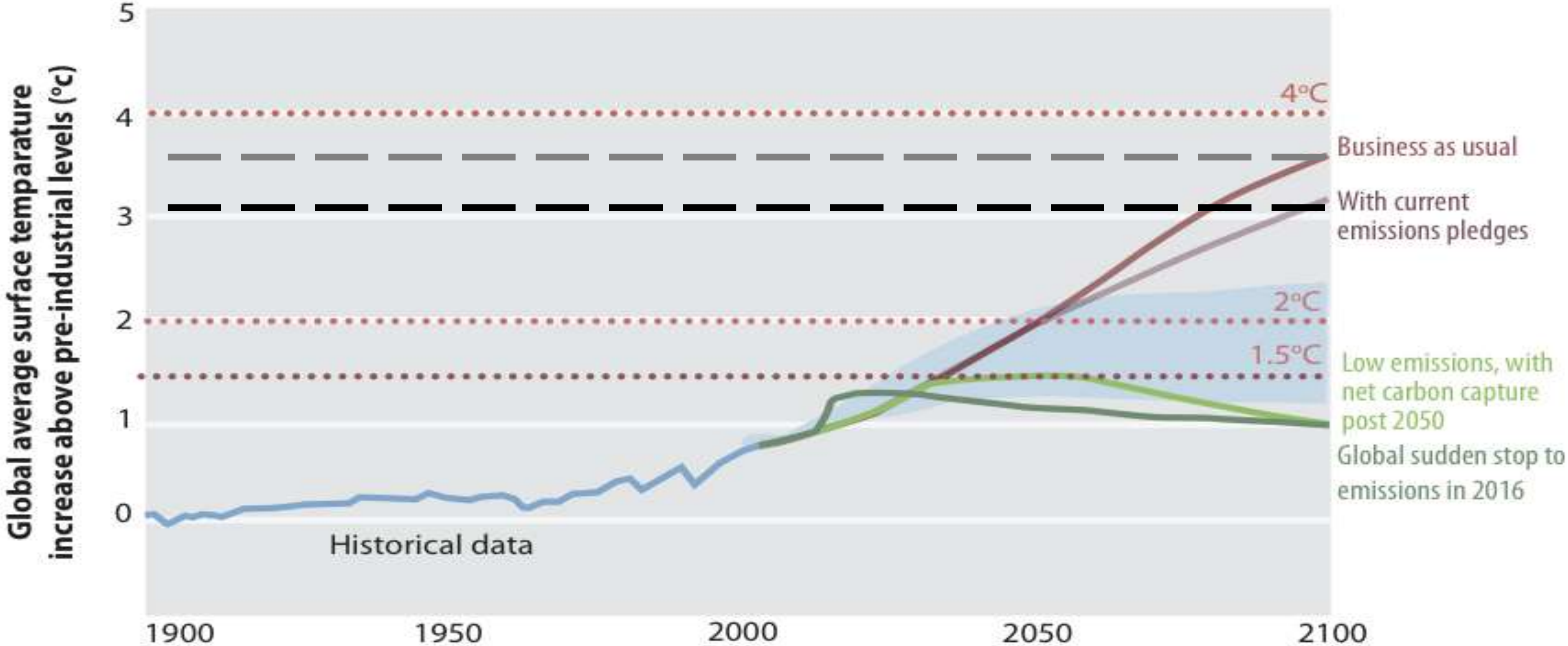

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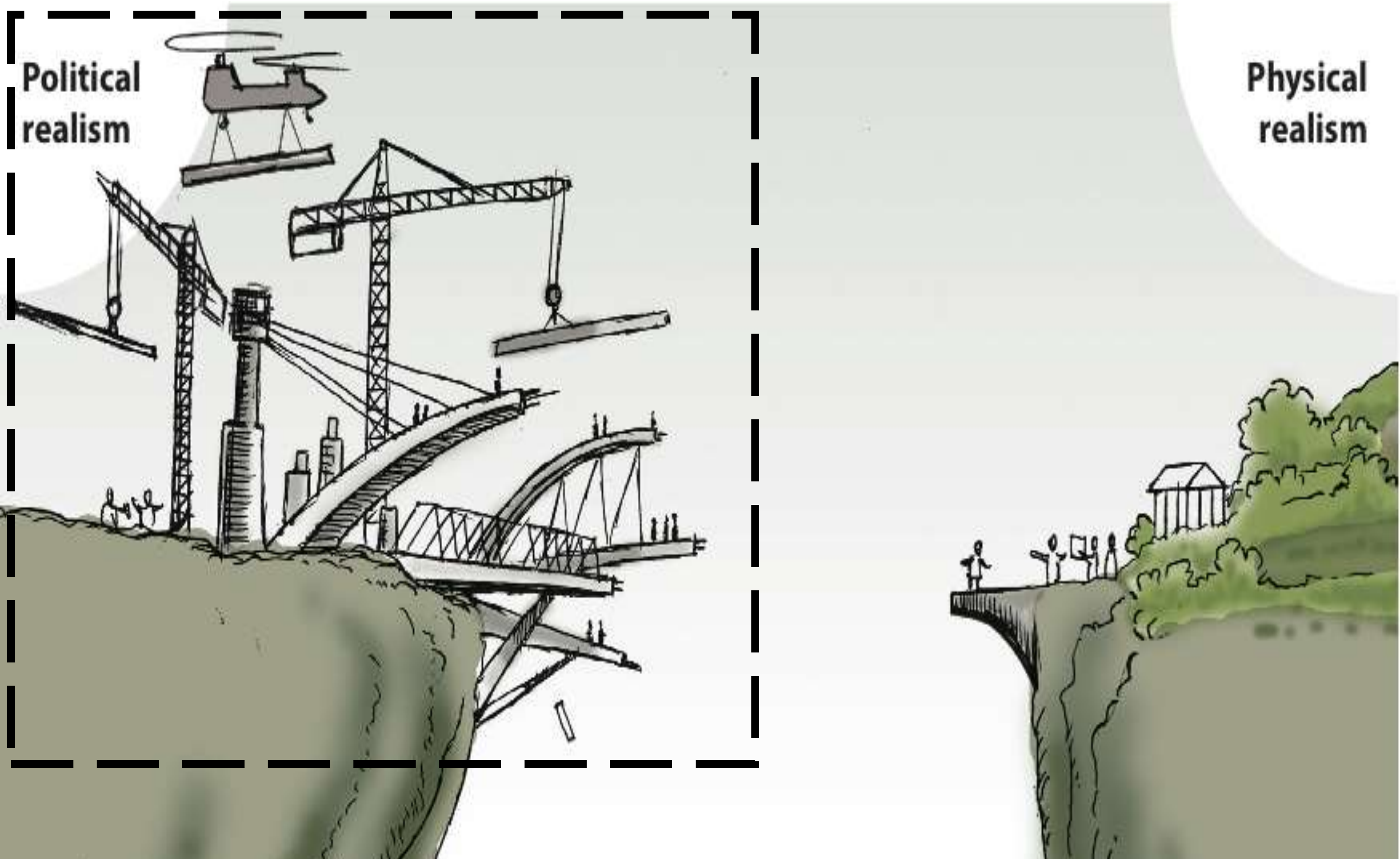
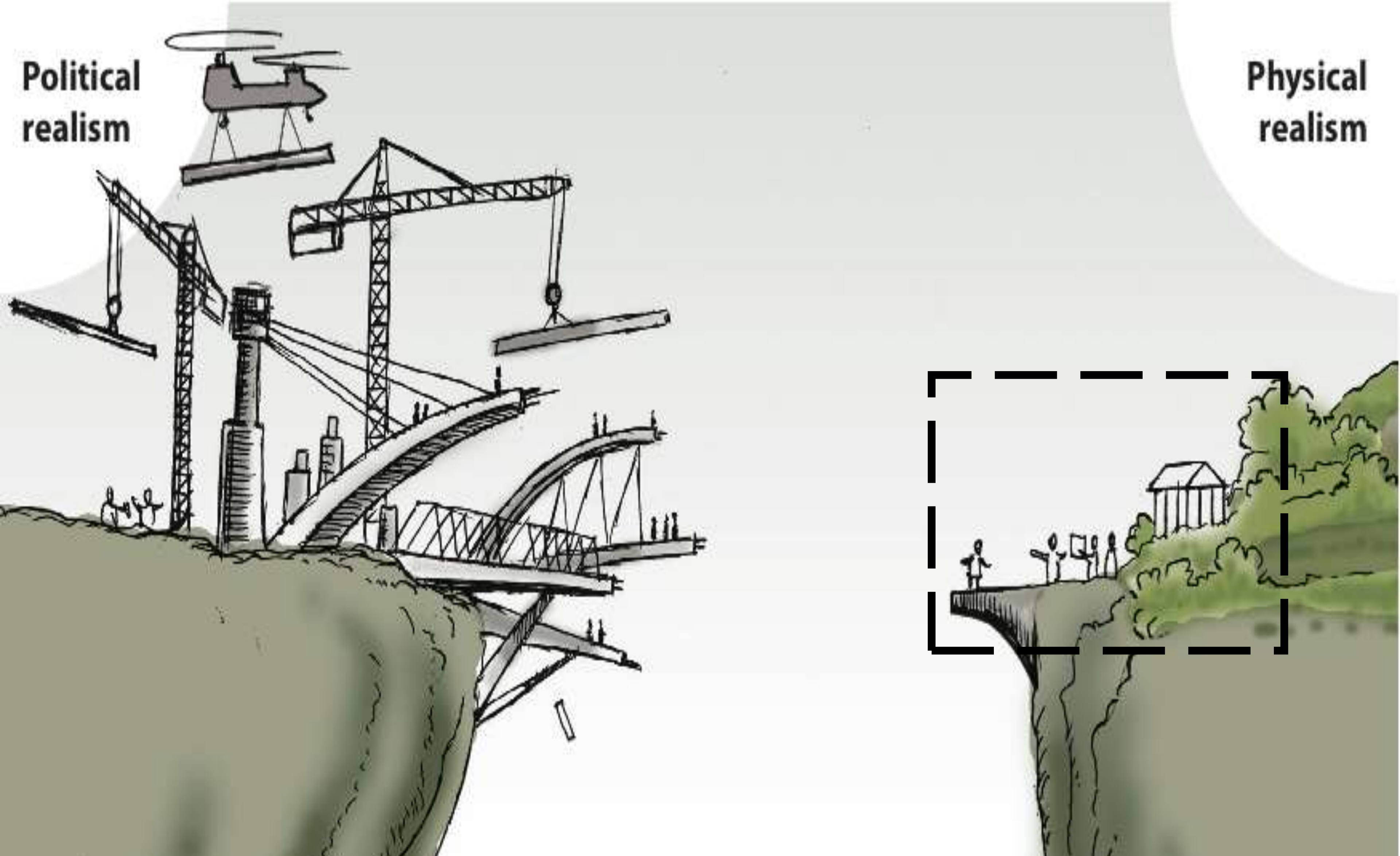

Political realism
Physical realism

Political realism



Physical realism

Some assumptions

- ‘Physically realistic’ approach (no BAU available)
  - We can’t change physics…

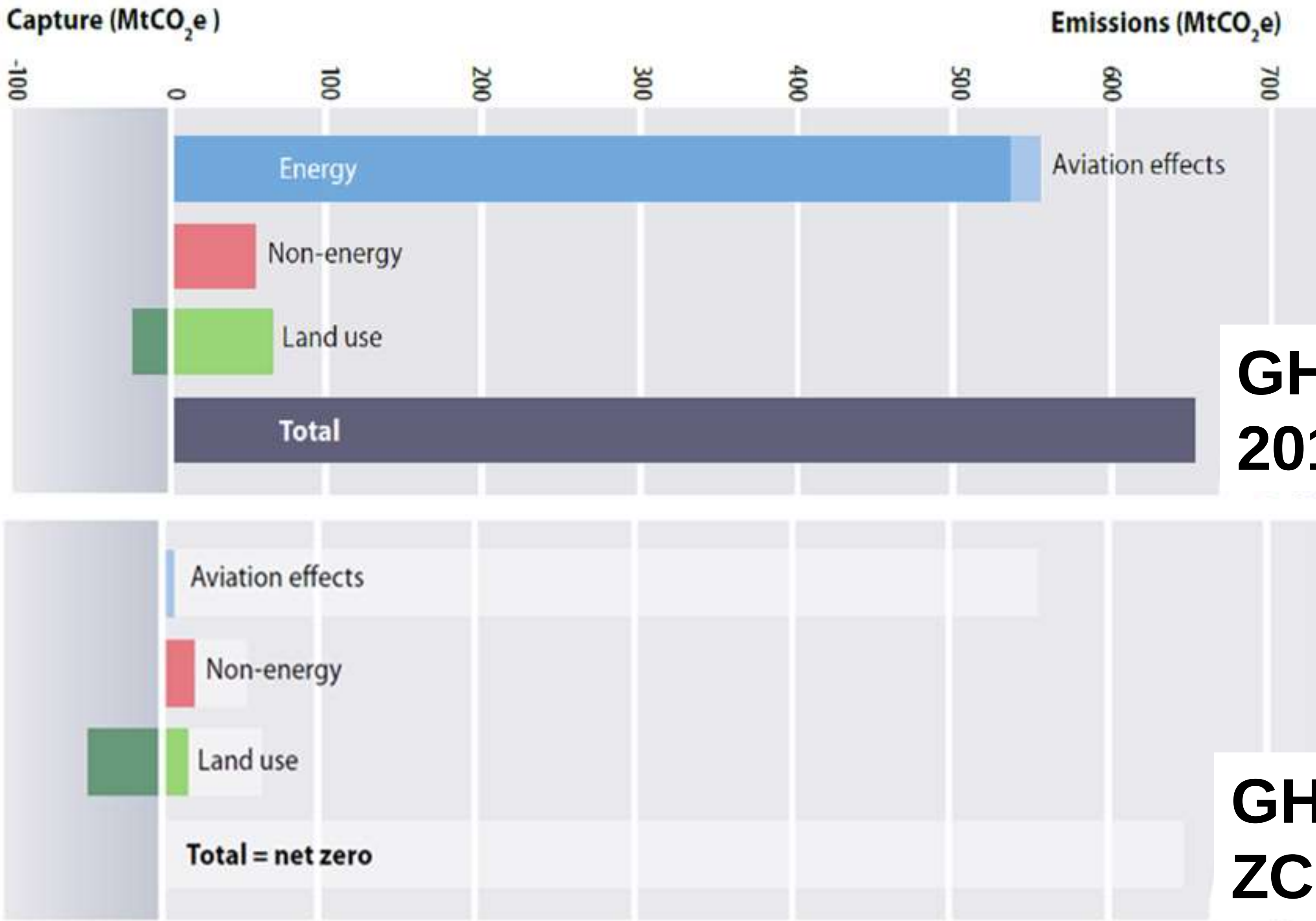
Some assumptions

- ‘Physically realistic’ approach (no BAU available)
  - We can’t change physics…
- Net zero emissions, basically ASAP
  - All greenhouse gases
  - Across all sectors – agriculture, land-use, industry…

Some assumptions

- ‘Physically realistic’ approach (no BAU available)
  - We can’t change physics…
- Net zero emissions, basically ASAP
  - All greenhouse gases
  - Across all sectors – agriculture, land-use, industry…

→ Big changes **will** be necessary.



GHGs: 2010

GHGs: ZCB

Some scenario aims

- Keep the lights on and keep everyone warm (make sure supply meets demand at all times).
- Make sure we all eat enough, and eat well.
- Keep a decent standard of living, with the benefits of a modern society.
- Support biodiversity – use less land than we do currently (at home and abroad).

Energy in ZCB

Some rules

- 100% renewable energy
  - No nuclear
  - No CCS
- UK resources only
- Technology available now
  - No relying on ‘silver bullets’

UK Energy 2010

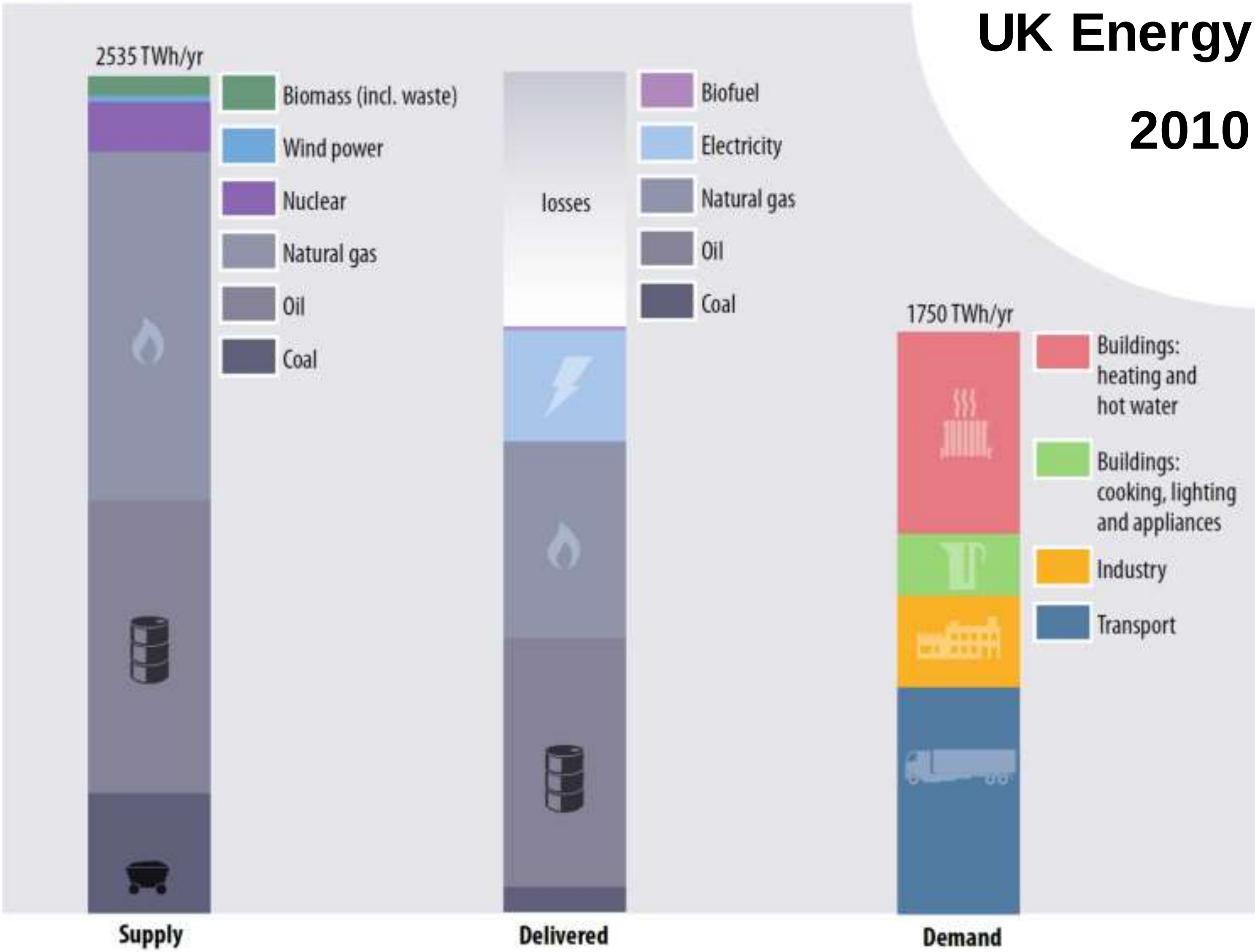


Figure 3.2: UK primary energy supply, delivered fuel mix and energy demand in 2010 (DECC, 2012a; DECC, 2012b).

UK Energy

ZCB

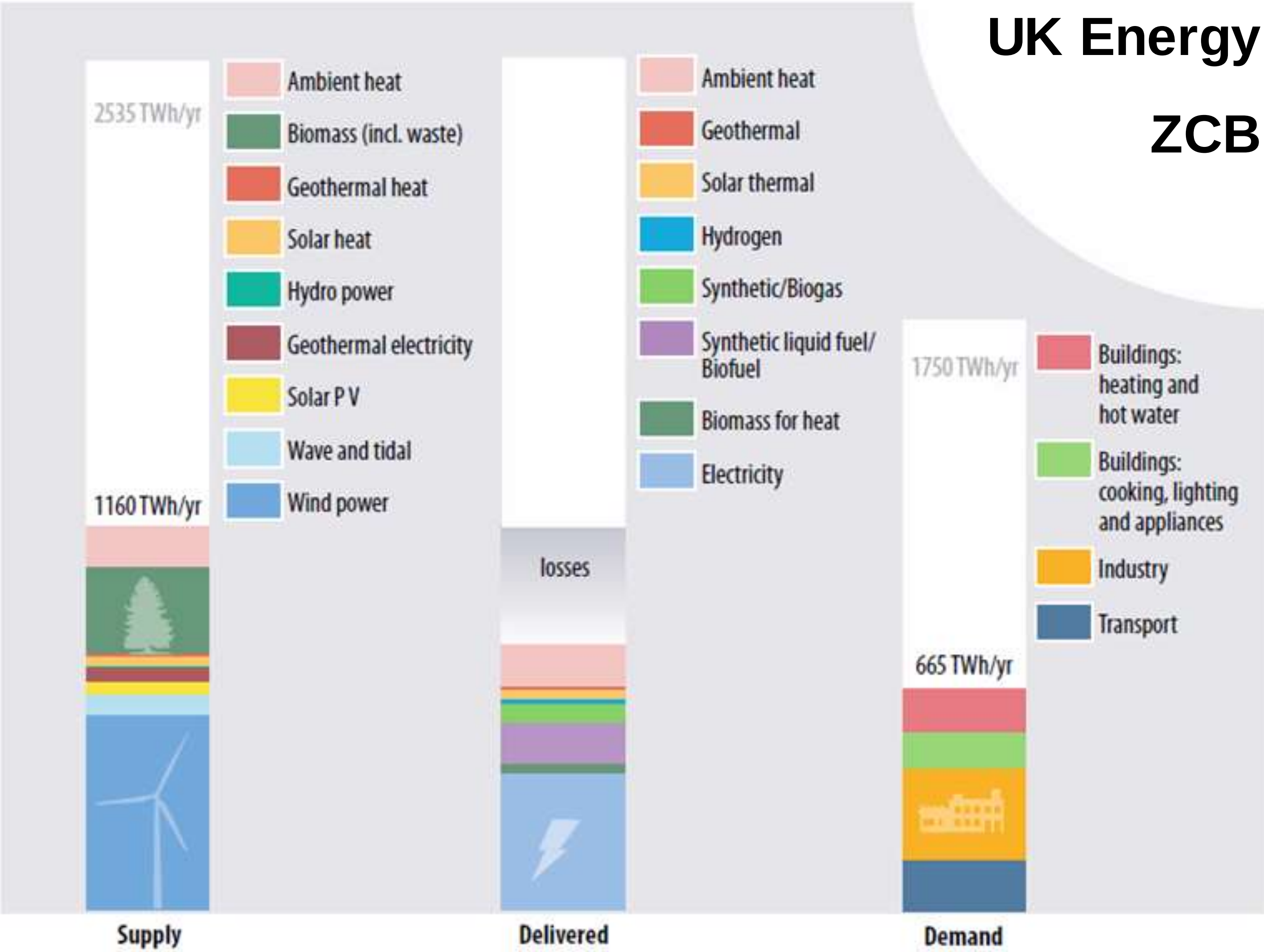


Figure 3.36: Primary energy supply, delivered fuel mix, and final energy demand for the UK in our scenario, relative to 2010.

UK Energy

ZCB

- Much reduced annual energy demand
  - Improved efficiency *and* behaviour change
- Electrification of systems
- 100% renewable (decarbonised) supply

UK Energy

ZCB

- Much reduced annual energy demand
  - Improved efficiency *and* behaviour change
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Not a new idea…

An Alternative Energy Strategy for the United Kingdom

(1977)

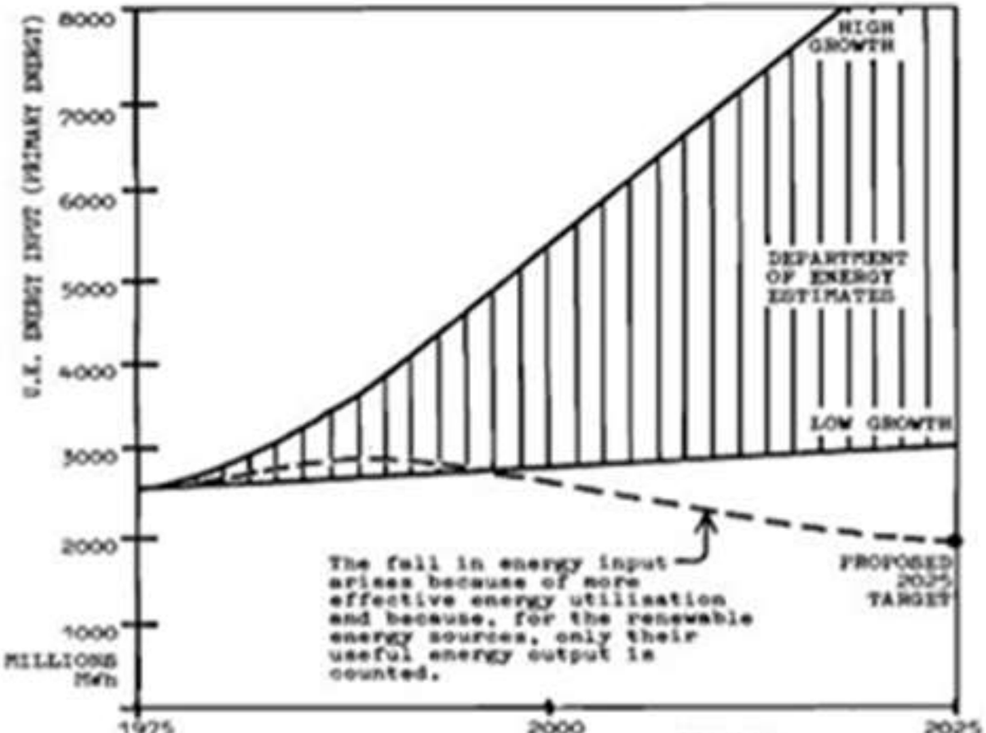
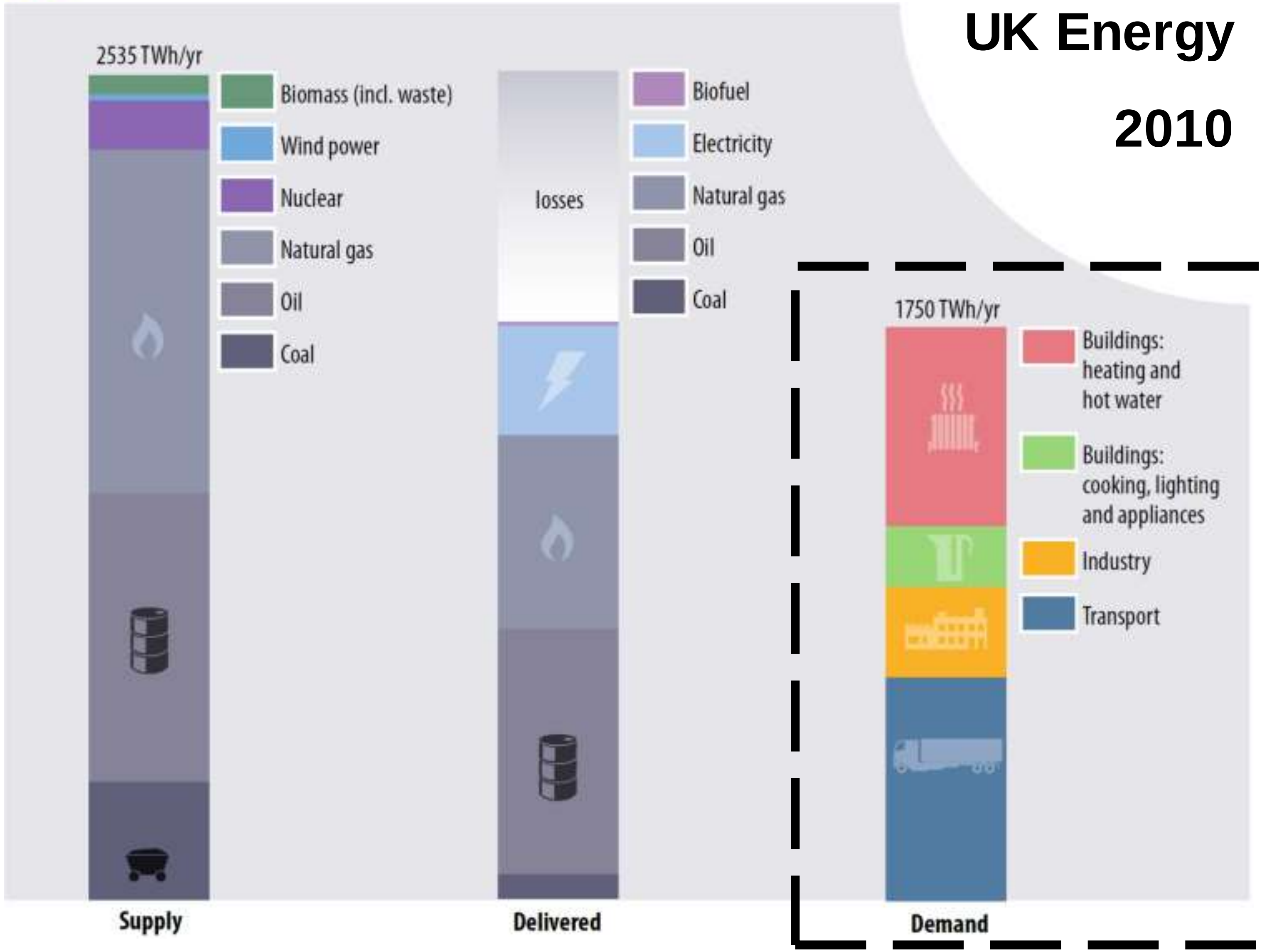


FIGURE 1

more efficient in their use of fuel but they involve the storage, handling and transportation of substantial quantities of plutonium, which is highly toxic and of military significance. Both types of reactor produce waste products which remain dangerous for very long periods of time. The Royal Commission on Environmental Pollution in its Sixth Report has drawn attention to the hazards of a large-scale nuclear power programme based on breeder reactors, mentioning the risks associated with accidents within reactors, the political risks involved in the so-called "plutonium economy" and the problems of the safe disposal of radioactive waste. On this last point the report recommends that there should be no commitment to such a programme until it has been demonstrated beyond reasonable doubt that a method exists to ensure the safe containment of long-lived, highly radio-active waste for the indefinite future.

UK Energy 2010



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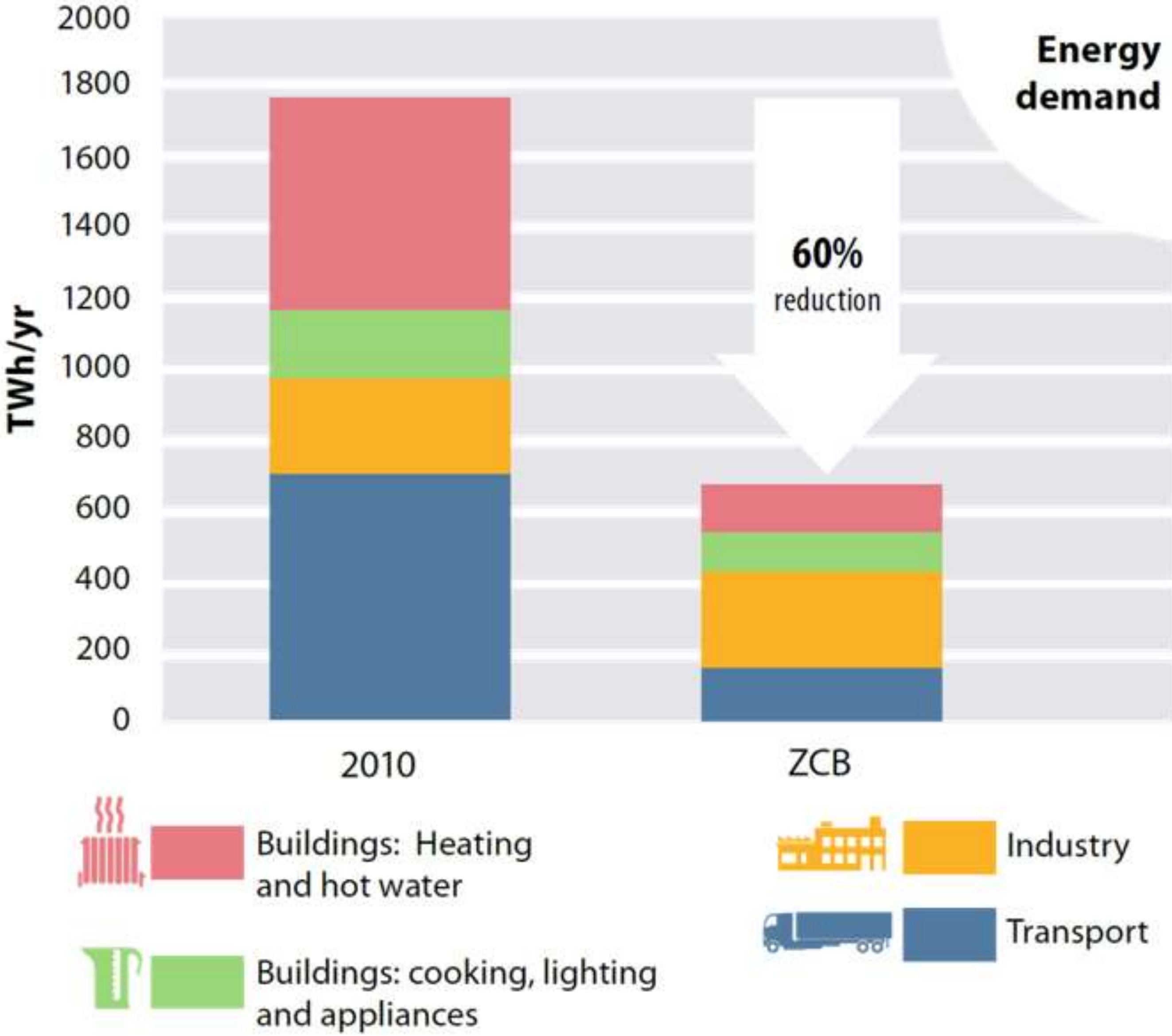

Figure 3.4: Total annual energy demand by sector in the UK in 2010 (DECC, 2012) and in our scenario.

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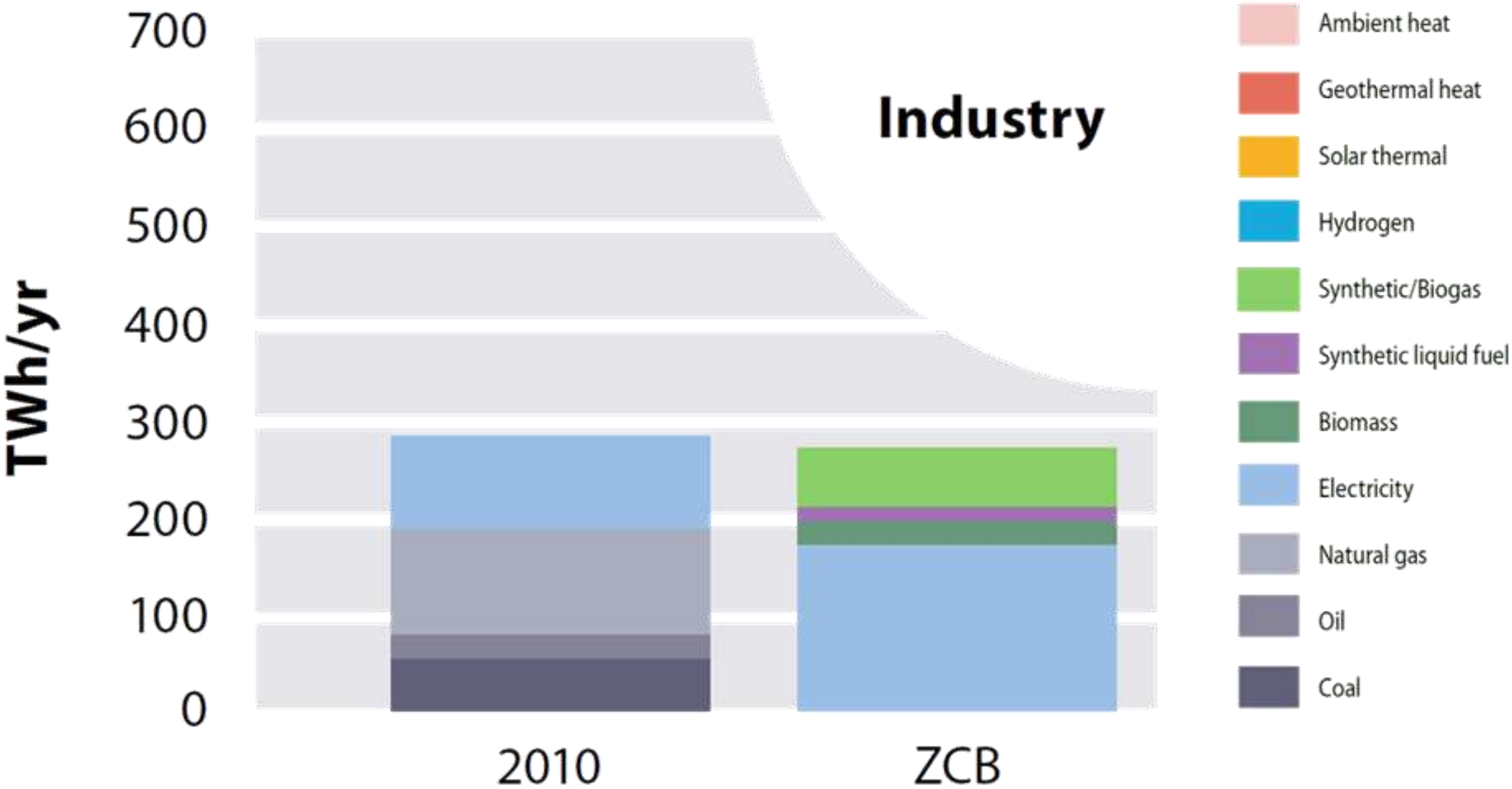


From: Figure 3.10: The change in energy demand for heating and hot water; cooking, lighting and appliances; and industry between 2010 (DECC, 2012) and our scenario: by amount and type of fuel.

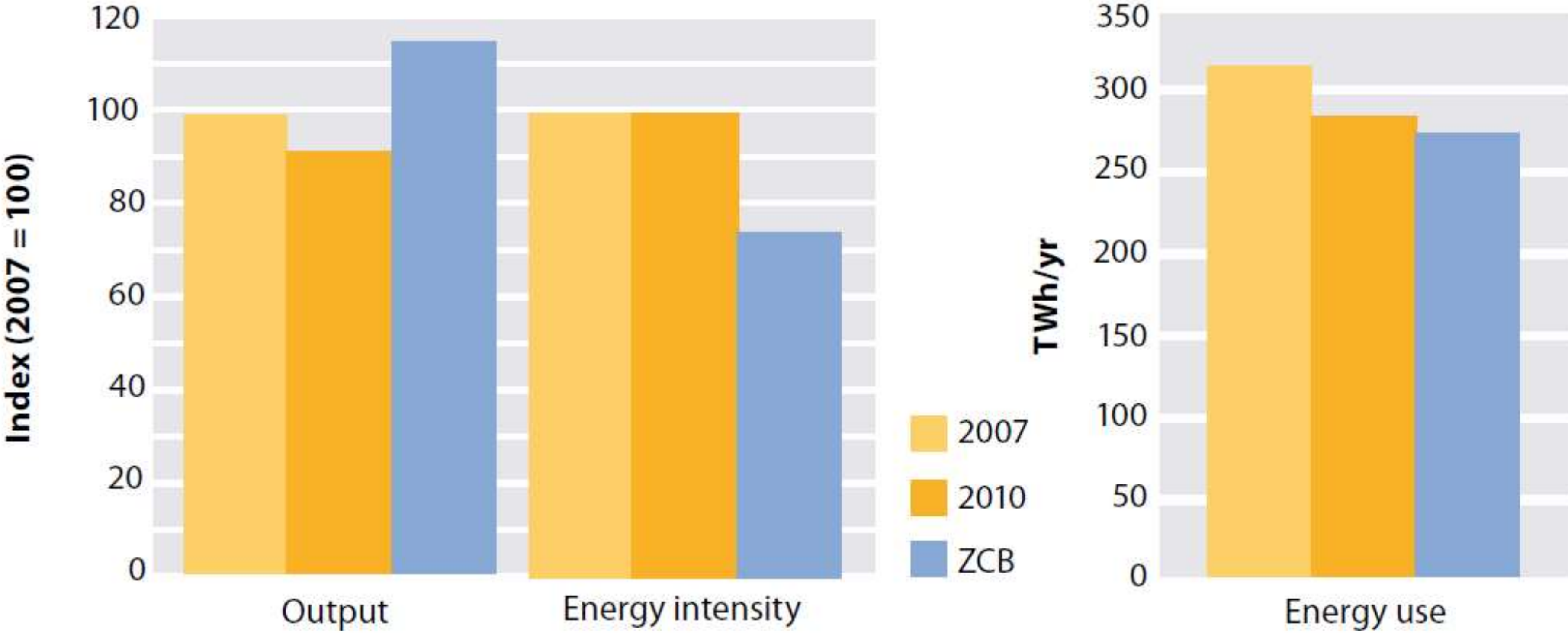
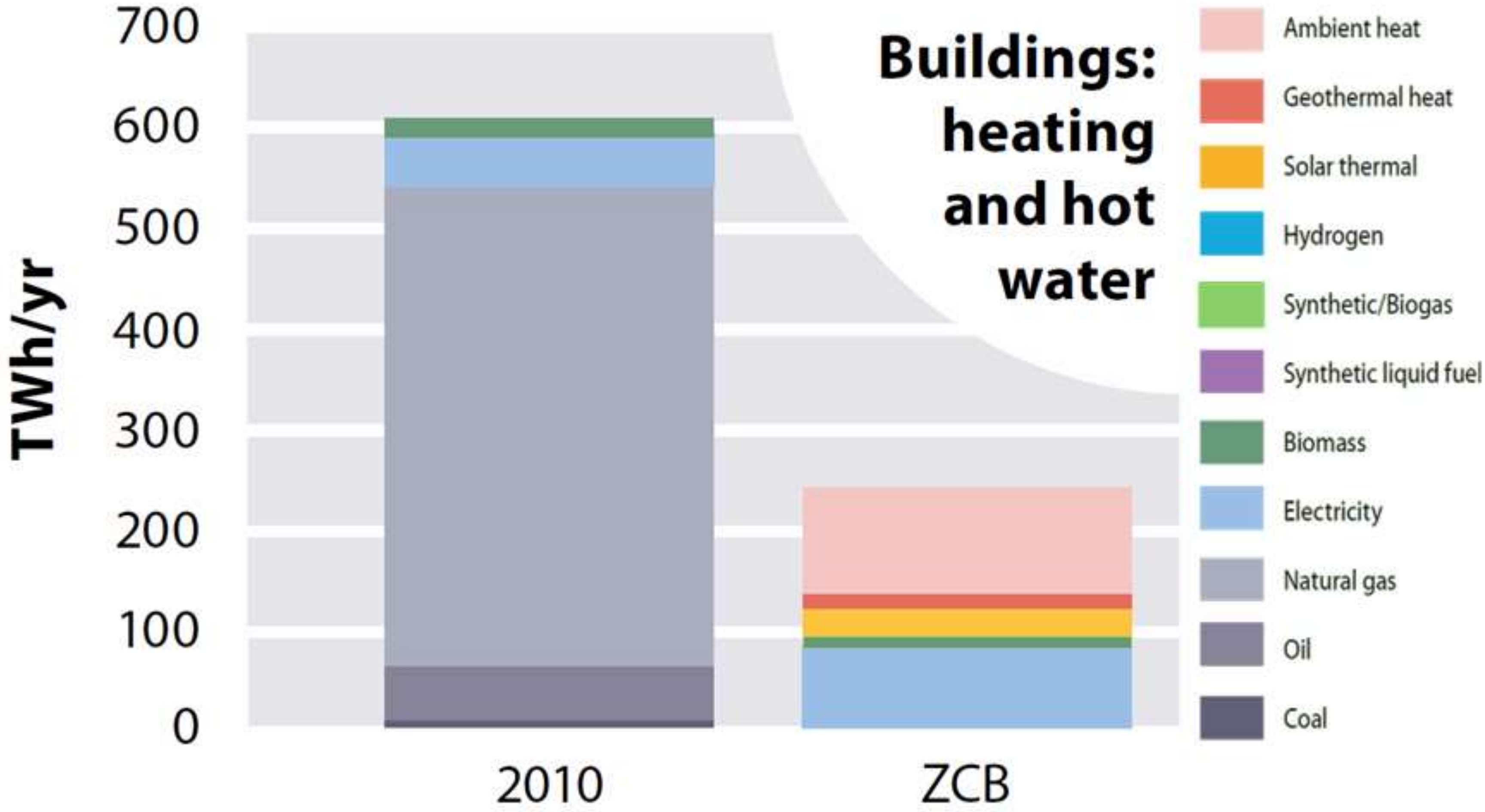


Figure 3.8: The amount of 'stuff' produced by UK industry (output), the energy used per unit of output (energy intensity), and the total UK industrial energy use for 2007 (representing pre-recession levels), 2010 (DECC, 2012) and in our scenario.



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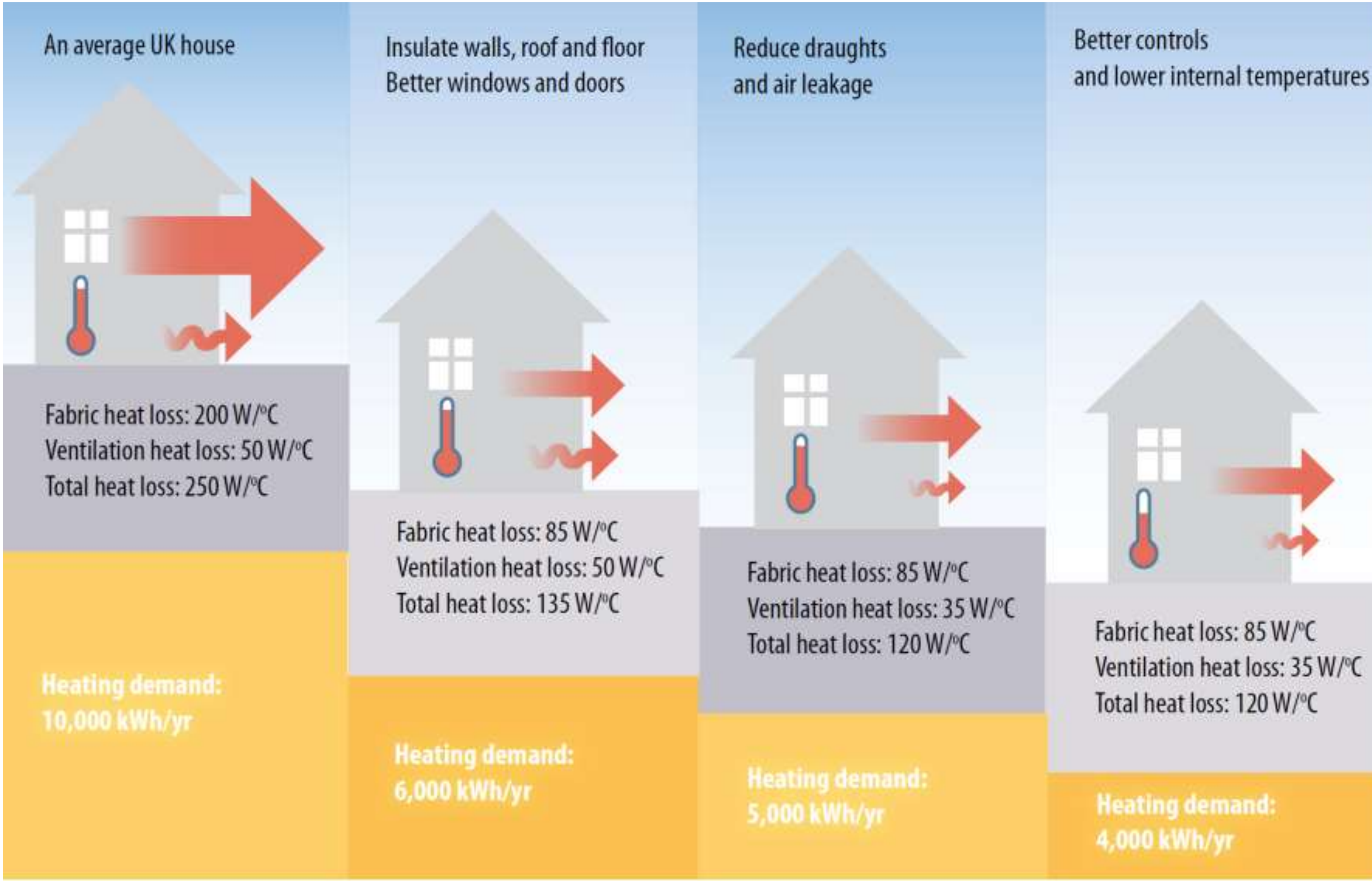


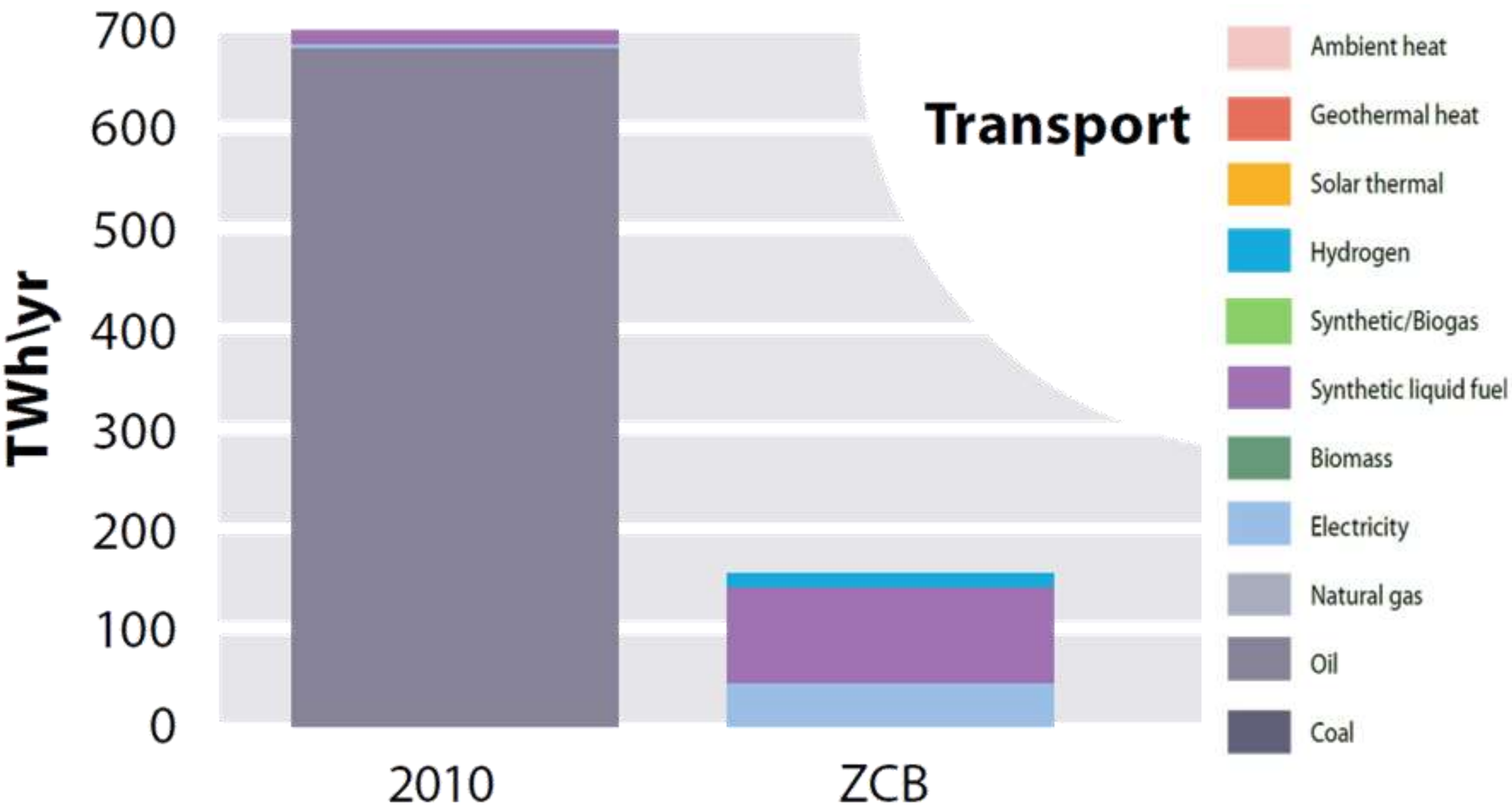


Figure 3.14: Change in total energy demand for transport and the types of fuel required in 2010 (DECC, 2012) and our scenario.

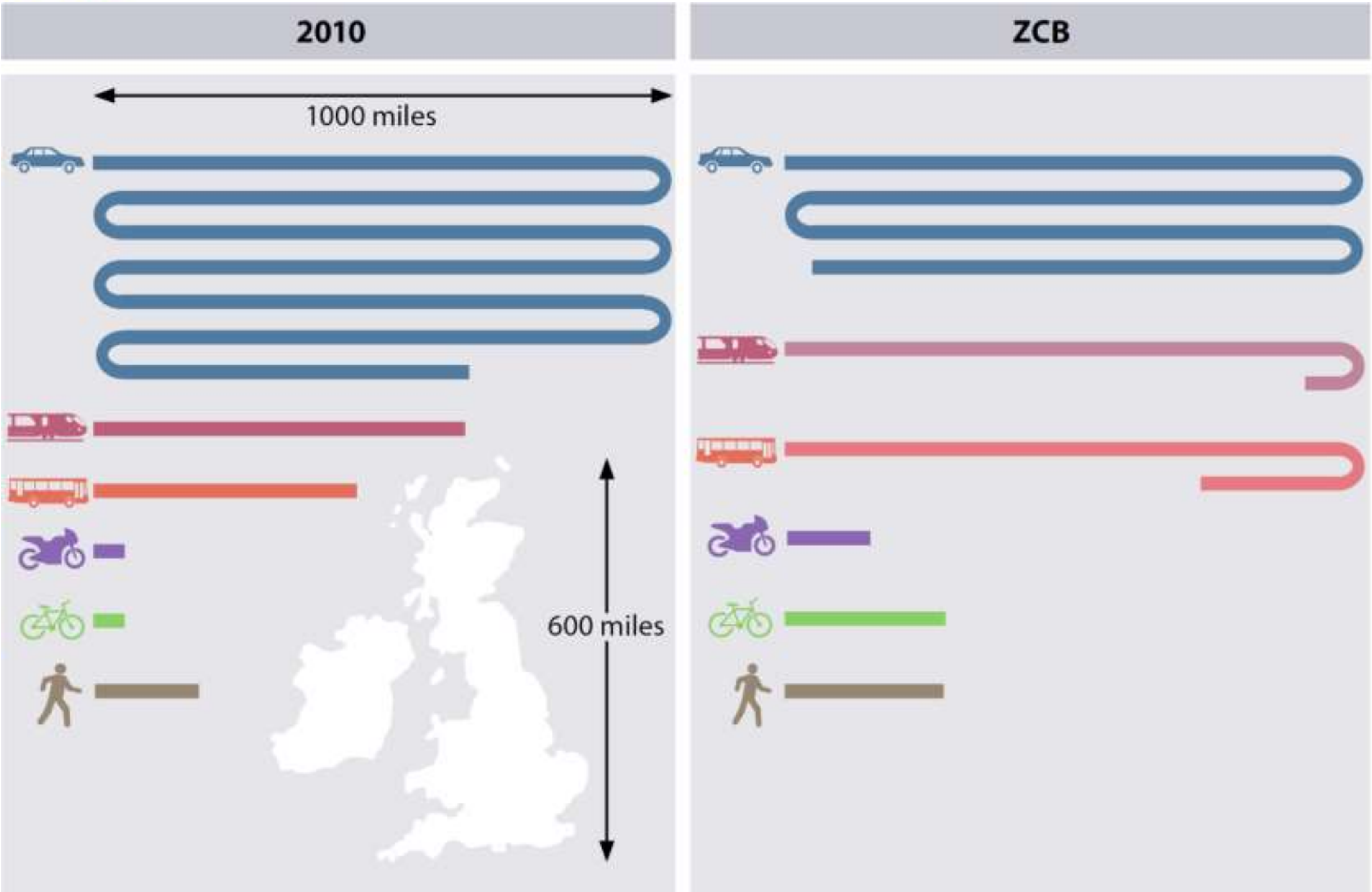


Figure 3.12: Average distance travelled per person per year by various modes of transport in 2010 (DfT, 2012) and our scenario.

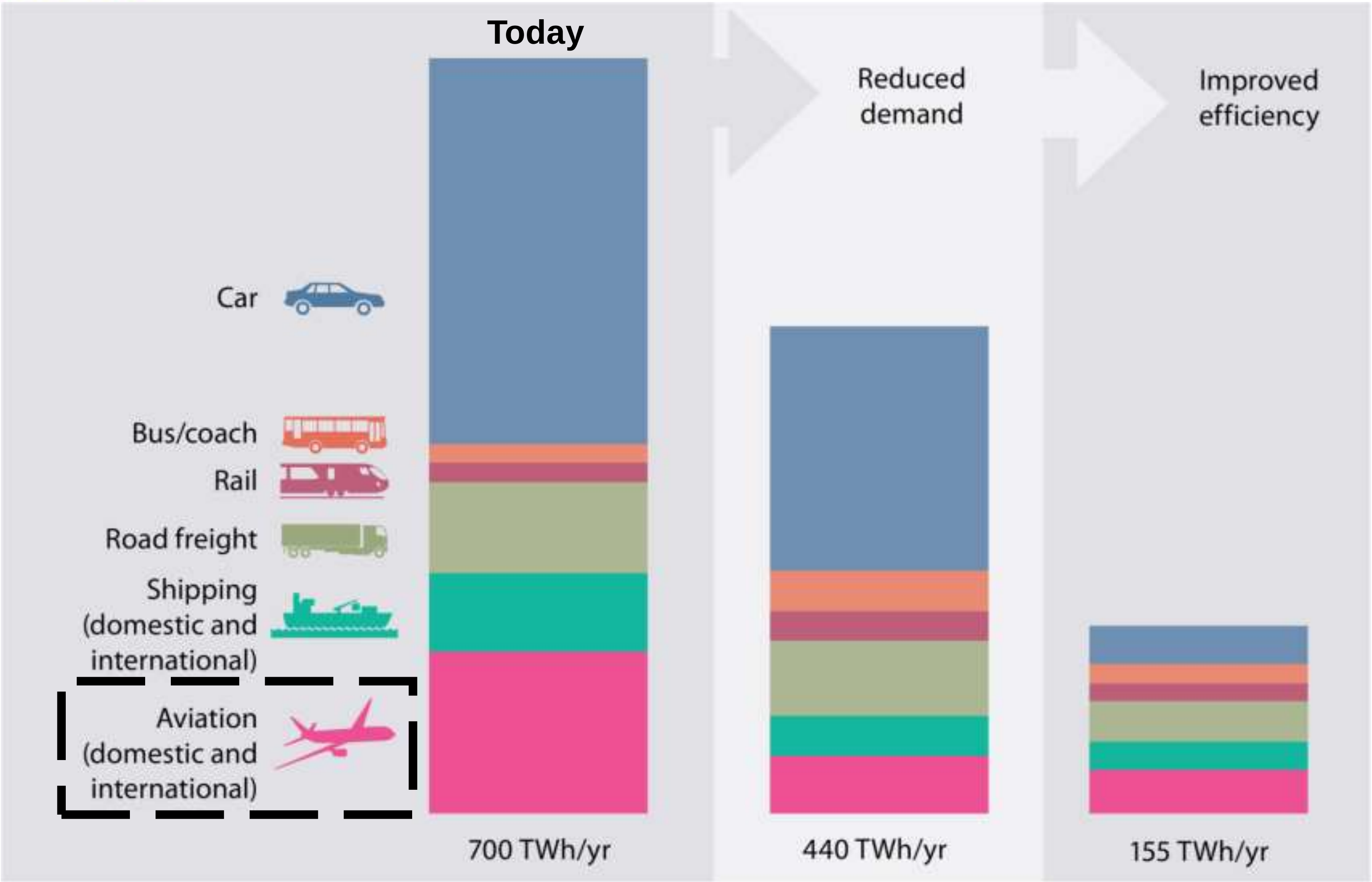
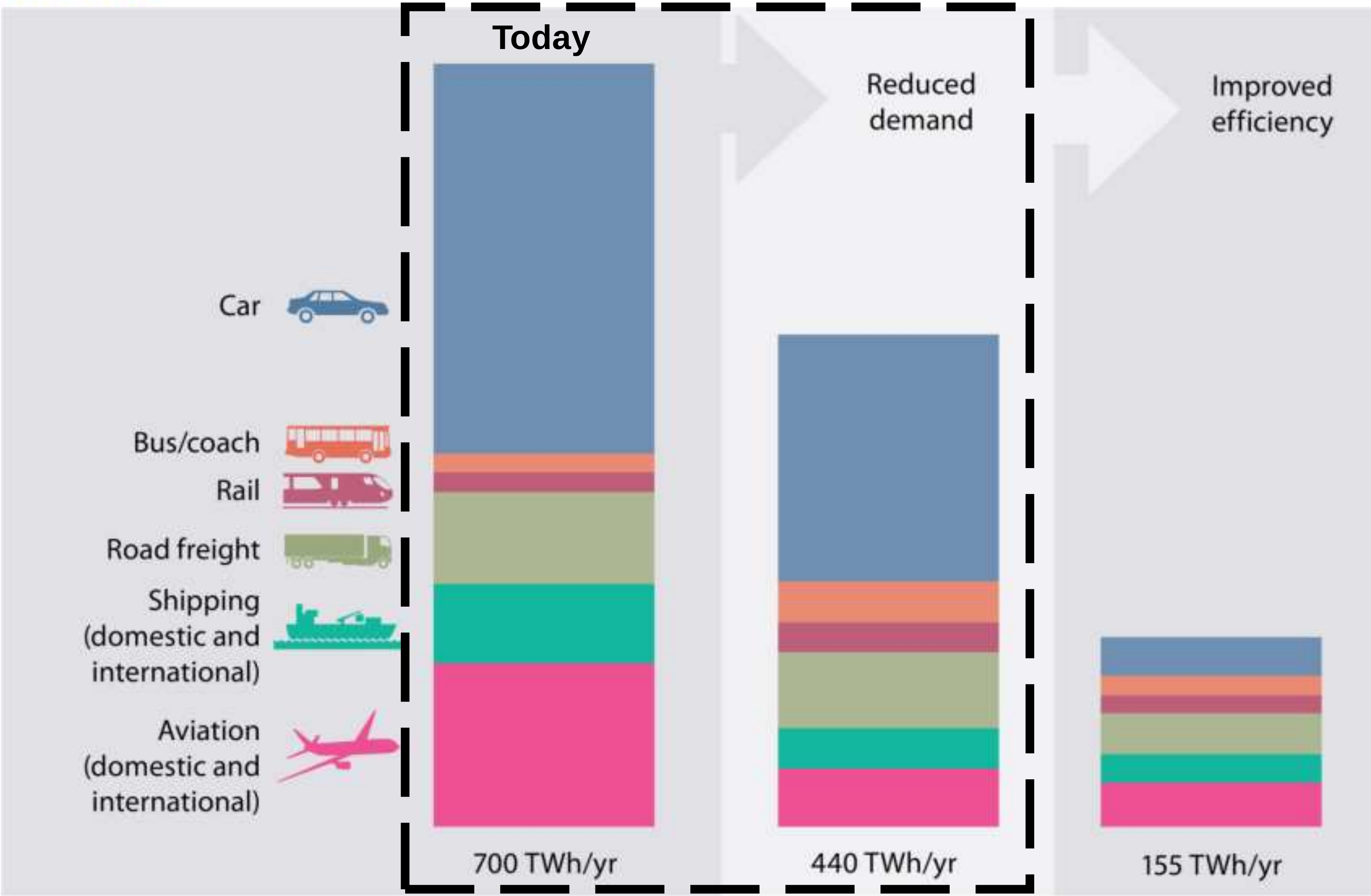


Figure 3.13: Reduction in energy demand for personal and commercial (freight) transport in our scenario (with initial figures from DECC, 2012).



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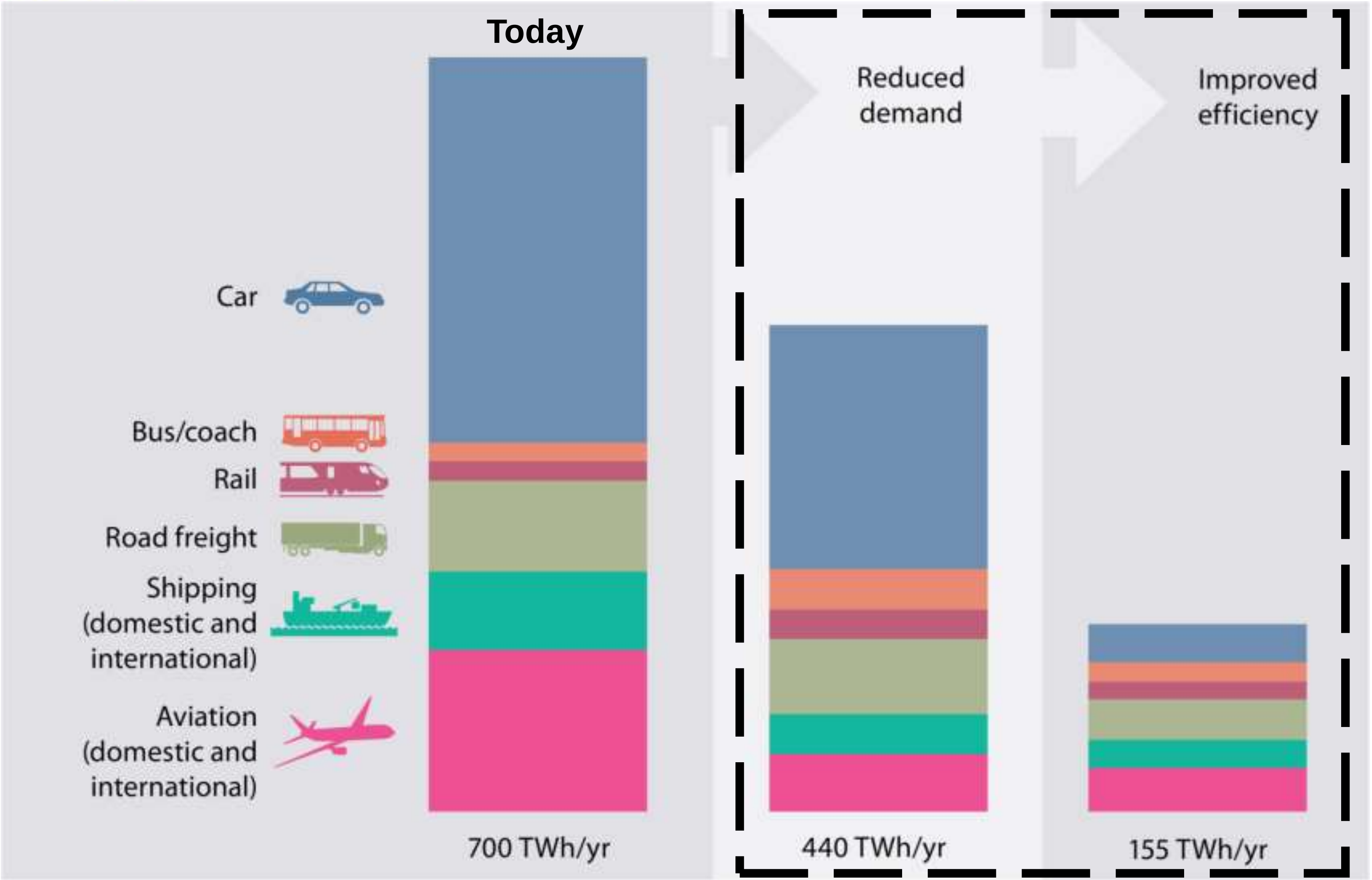

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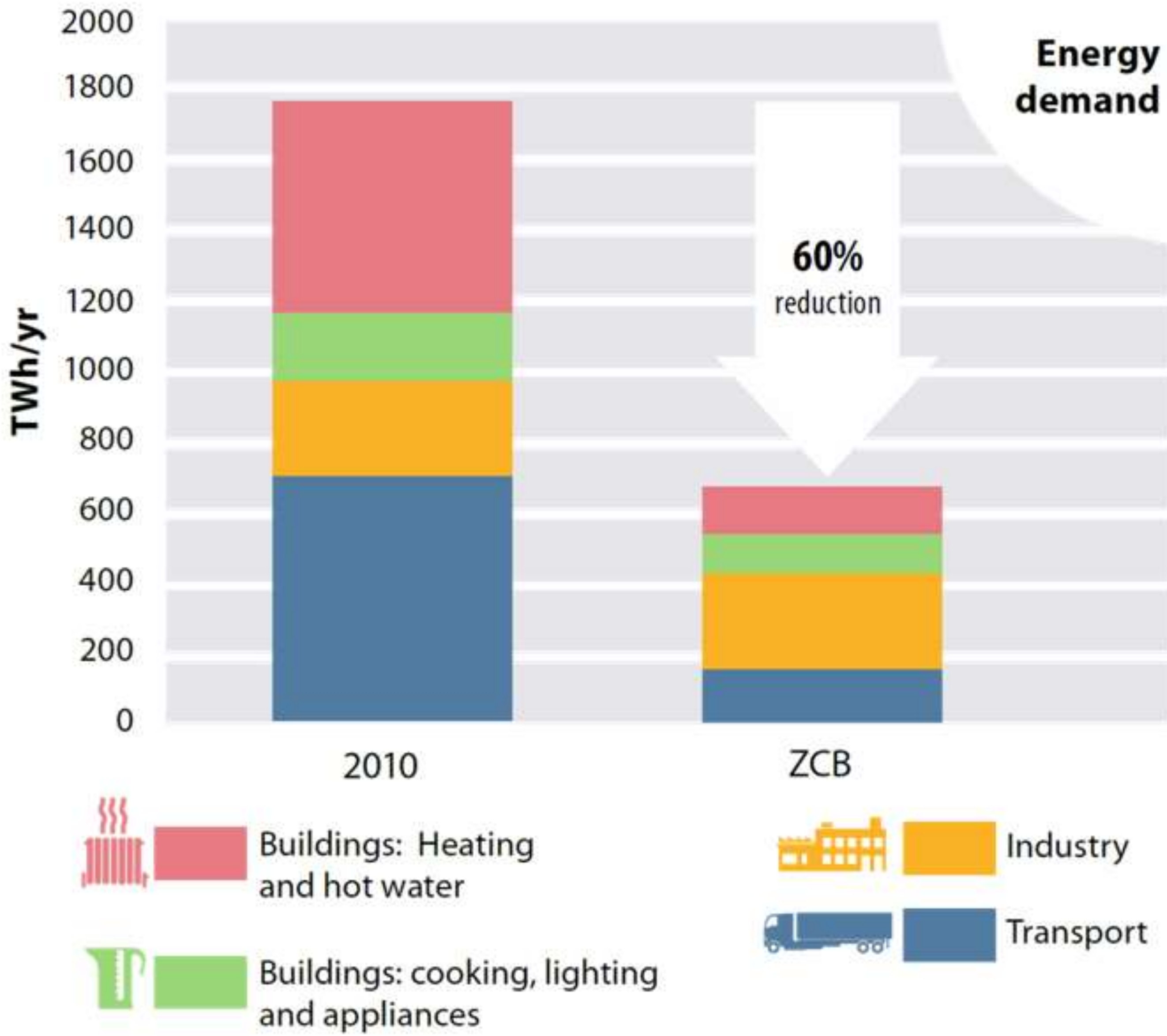

Figure 3.4: Total annual energy demand by sector in the UK in 2010 (DECC, 2012) and in our scenario.

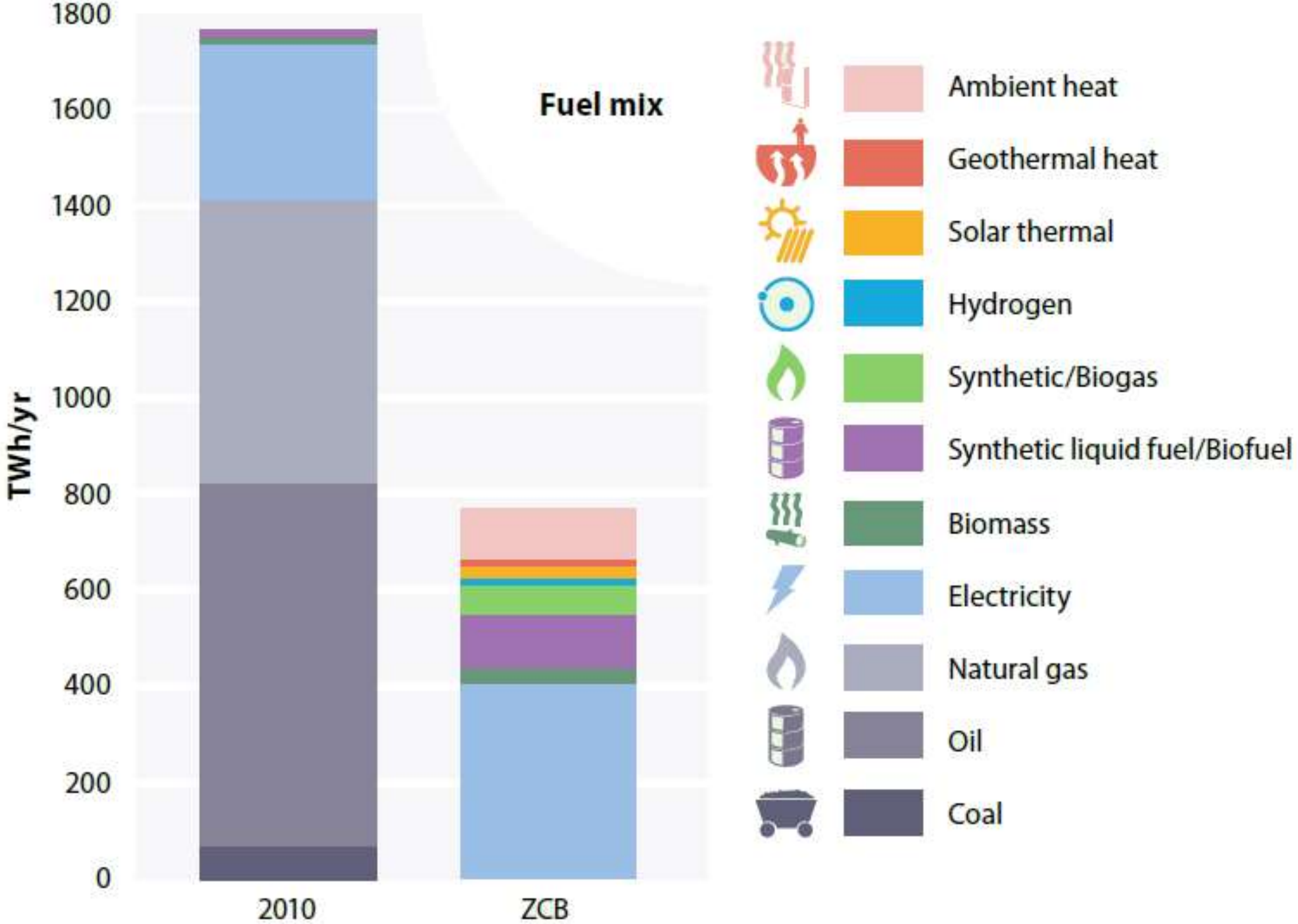

Figure 3.5: Annual energy use by fuel type in the UK in 2010 (DECC, 2012) and in our scenario.

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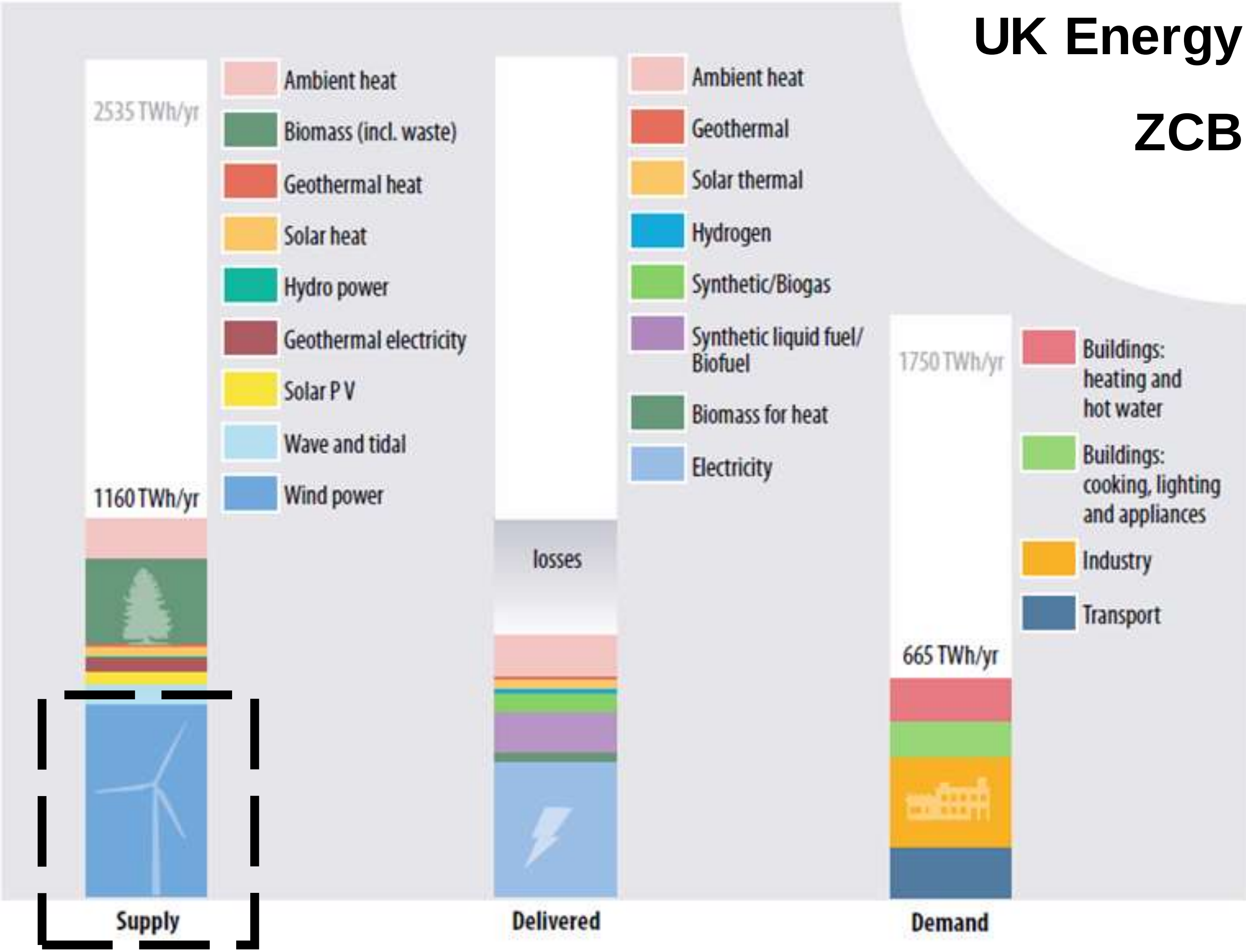
UK Energy

ZCB

Figure 3.36: Primary energy supply, delivered fuel mix, and final energy demand for the UK in our scenario, relative to 2010.

UK Energy

ZCB



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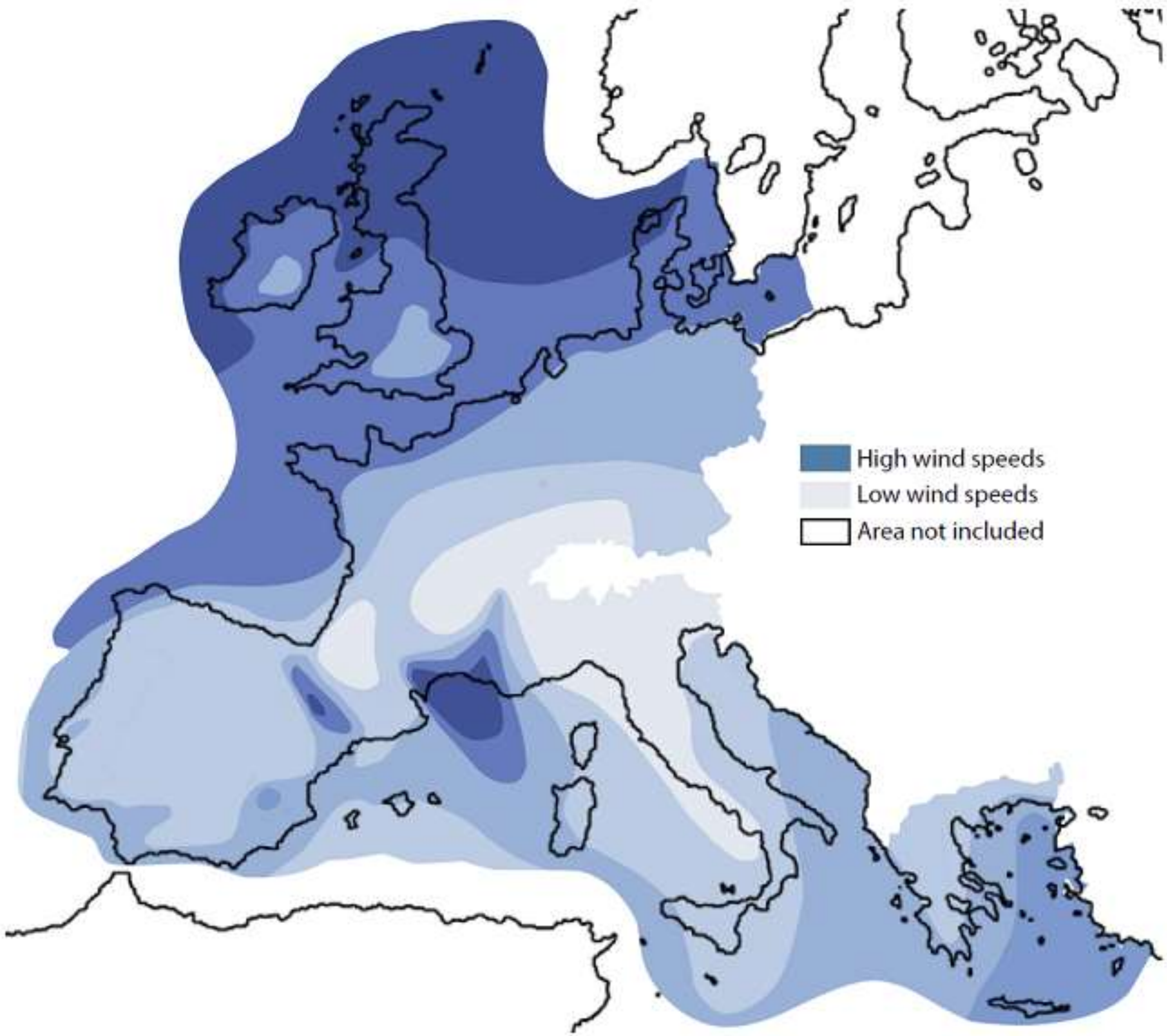

Figure 3.17: European wind speeds at 50 meters above ground level, ranging from the highest (dark blue), to the lowest (light blue). This represents sheltered and open areas, on hills and ridges, coastal areas, and in the open sea, though the highest wind speed and lowest wind speed will be different in each topographical area. Adapted from Troen and Petersen (1989).

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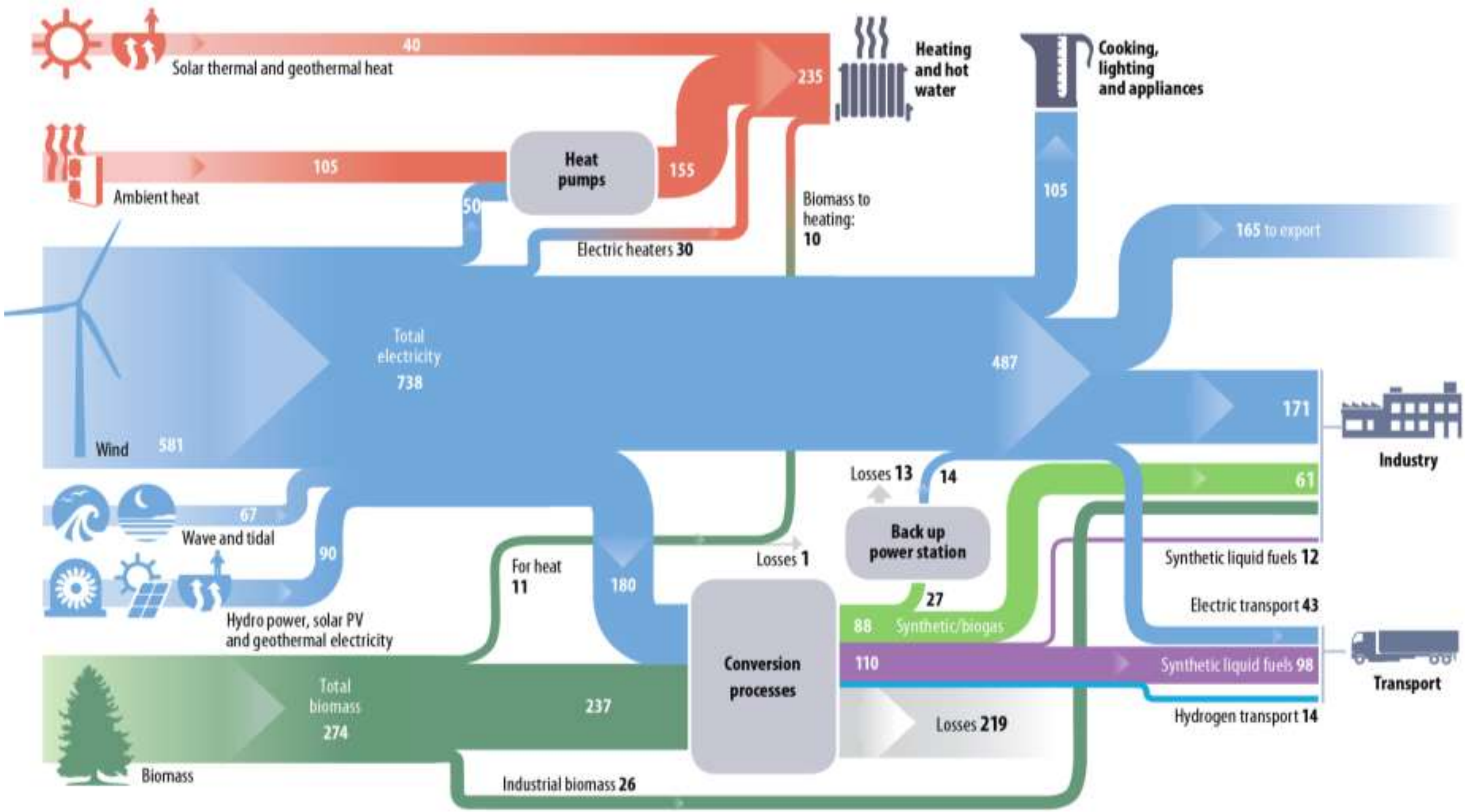
Figure 3.18: Energy flows in our scenario – from supply to demand. Numbers used here are rounded up or down to the nearest TWh and so inputs and outputs may not add up exactly.

Supply

Demand



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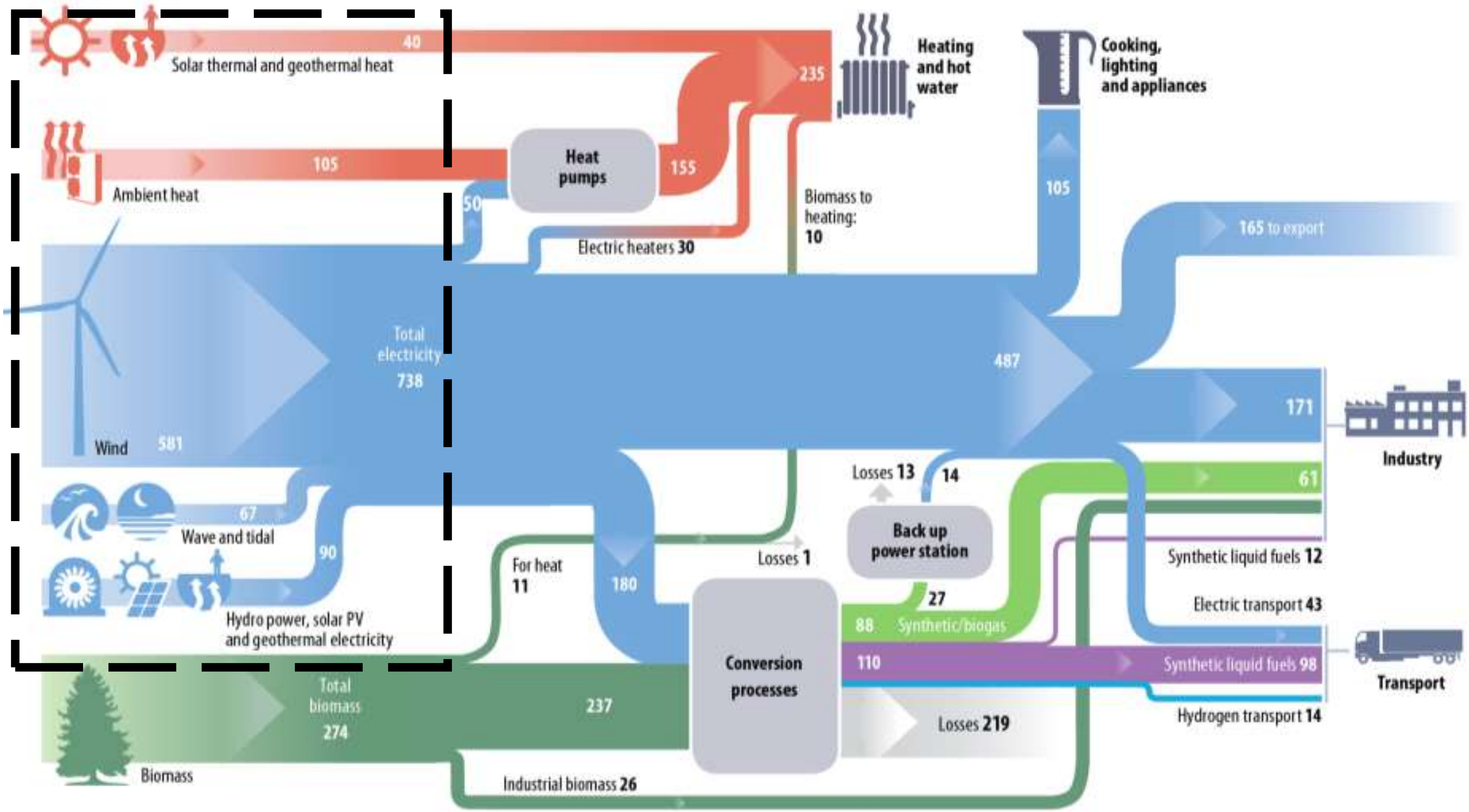
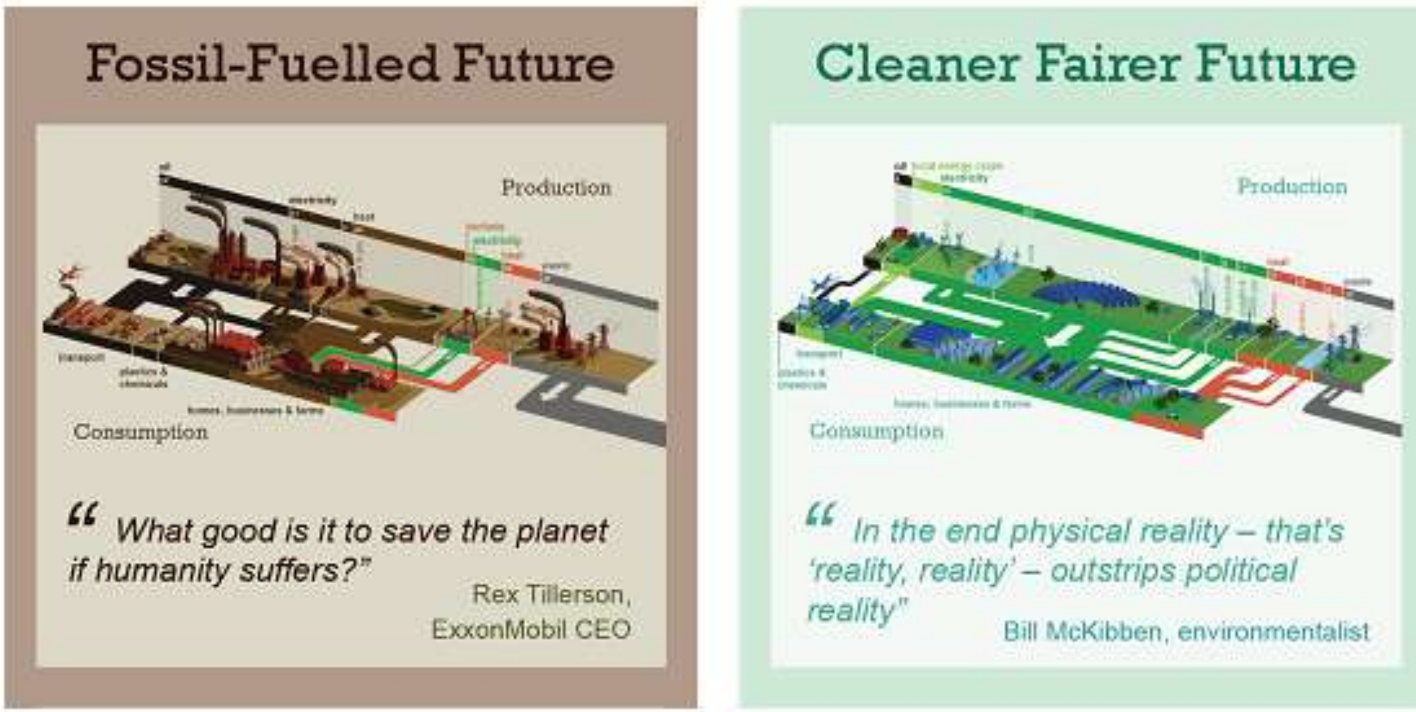


Comparison to energy production of estimated max capacity of renewable resource in the UK

	Estimated max. energy production (TWh/yr)	Reference	ZCB energy production (TWh/yr)	% of max. energy production
Tidal stream	116	Offshore Valuation Group (2010)	42	**28**
Tidal range	36			
Wave	40		25	**63**
Offshore fixed wind	400		530	**28**
Offshore floating wind	1500			
Onshore wind	60	Pöyry (2011)	51	**85**
Hydro	8	Arup (2011)	8	**100**
Solar PV	140	DECC (2010) 2050 pathways, level 4	58	**41**
Solar thermal	116		25	**22**
Geothermal electric	35		24	**69**
Geothermal heat	?		15	
Ambient heat	N/A		105	

So we definitely have enough resource…

(In fact, globally, we have enough resource for everyone…)



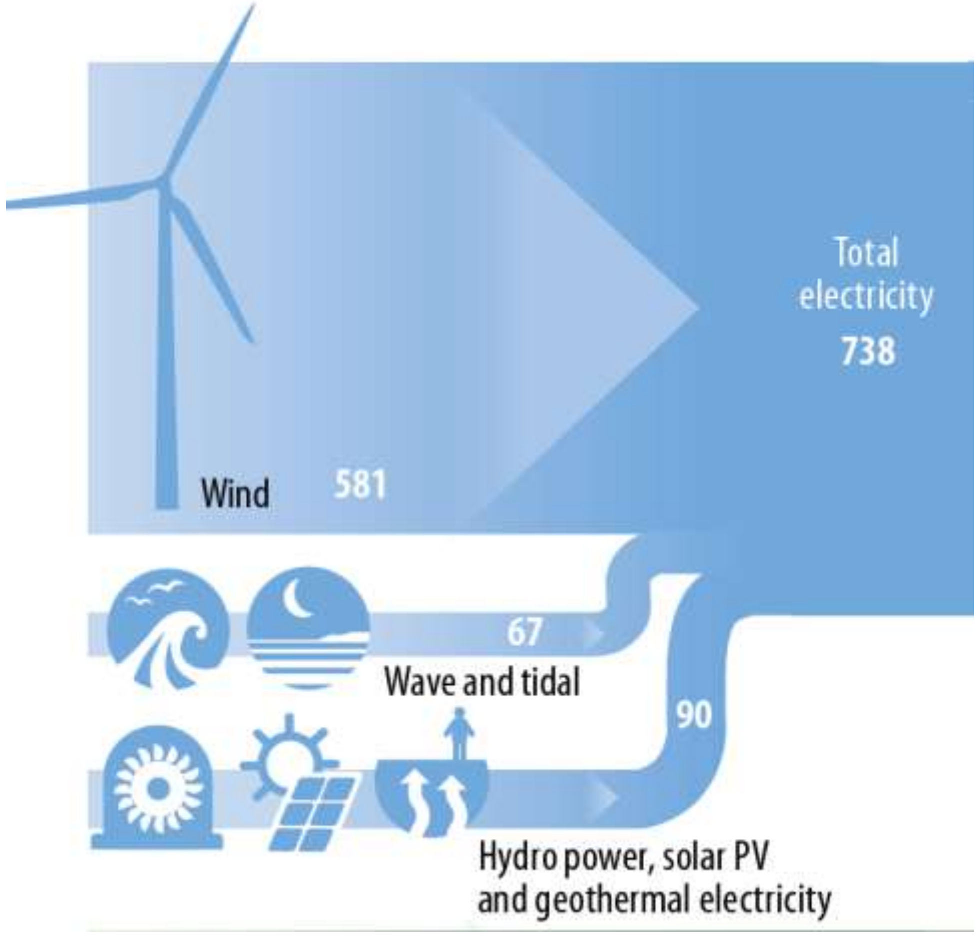
UK TAR SANDS NETWORK

http://www.twoenergyfutures.org

But…

Is this a reliable energy system?

(or: Can we 'keep the lights on?')



Balancing Variability in ZCB

How we deal with intermittency in ZCB

With thanks to

- Tobi Kellner and Philip James
- Loughborourgh University (Future Energy Scenario Assessment (FESA) model)
- Fraunhofer Institute for Wind Energy and Energy System Technology (IWES) (*Energieziel 2050*, German Department of the Environment)

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- Members of the public

ZCB hourly energy model

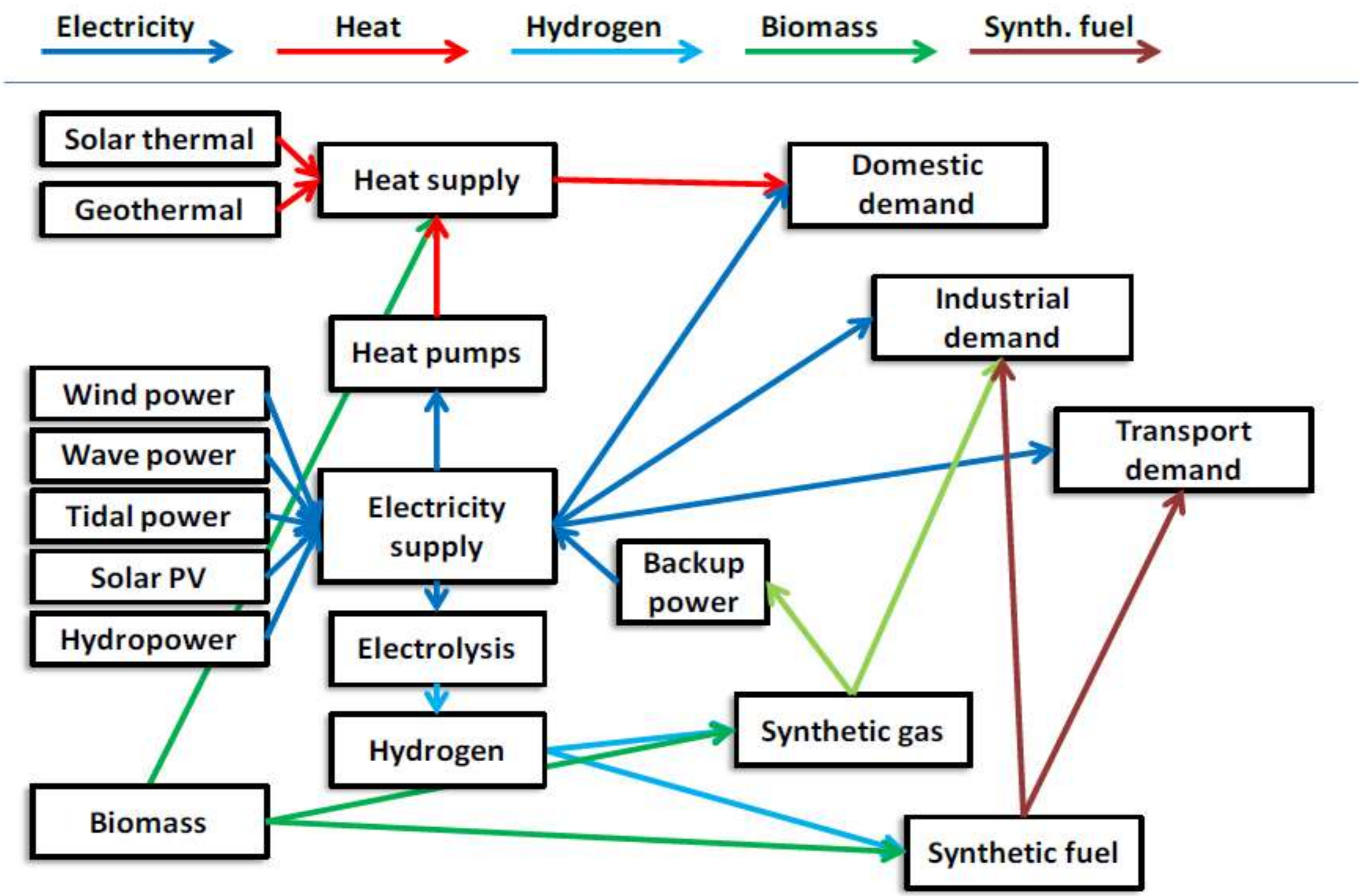
Parameter	ZCB hourly energy model
Spatial system boundaries	UK (not Britain!)
Interaction beyond boundaries	None (island system)
Spatial resolution	Treat UK grid as a single point ("copper plate UK")
Temporal resolution	1 hour

Ten years of data (2002 – 2011) = 87,648 hours:

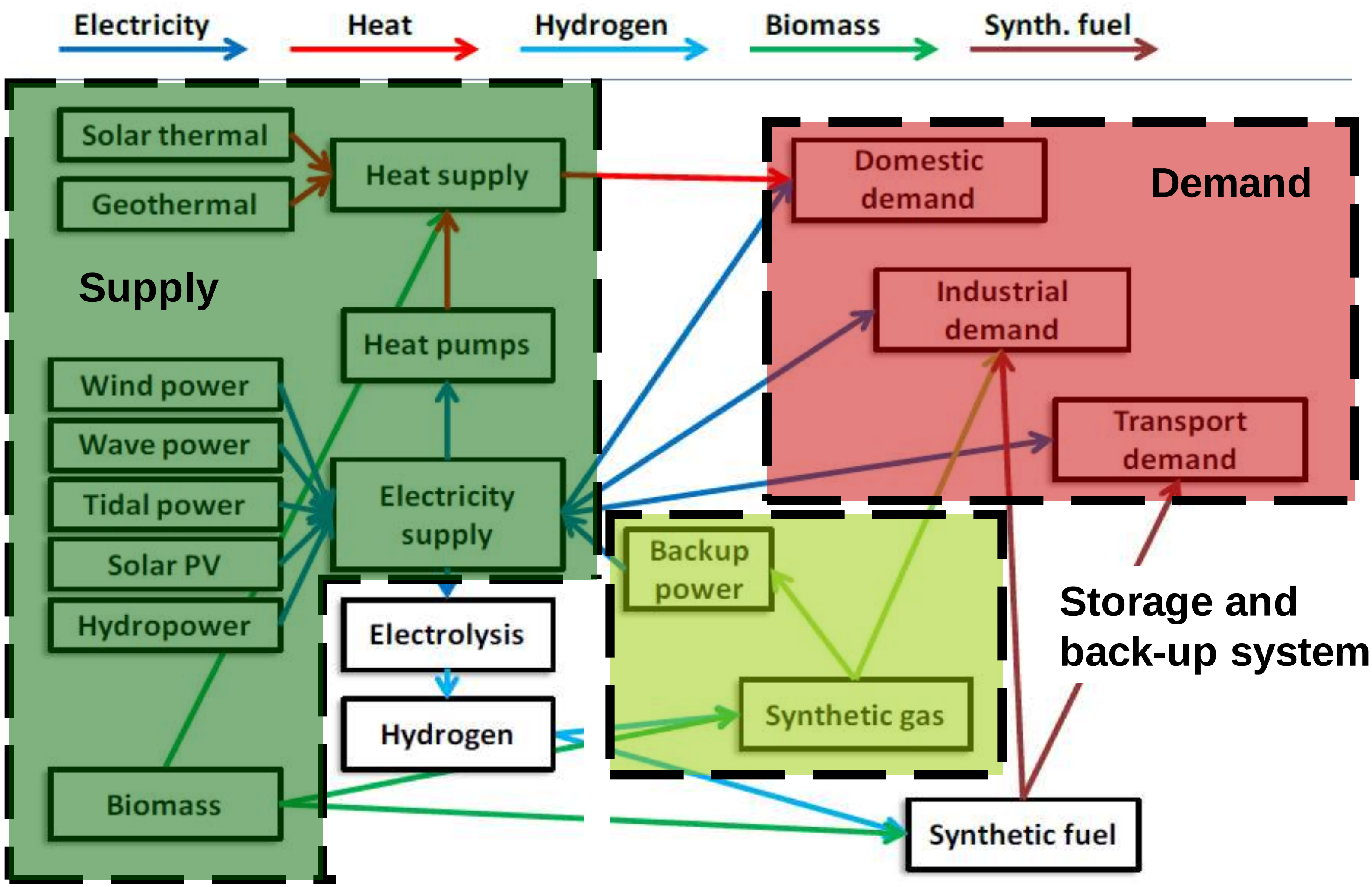
- Hourly offshore and onshore wind speeds, solar radiation, wave heights, (NASA, Met Office, BADS)
- Hourly electricity consumption (UK National Grid)
- Daily weighted average temperatures (UK National Grid)

Installed capacity and demand from ZCB scenario

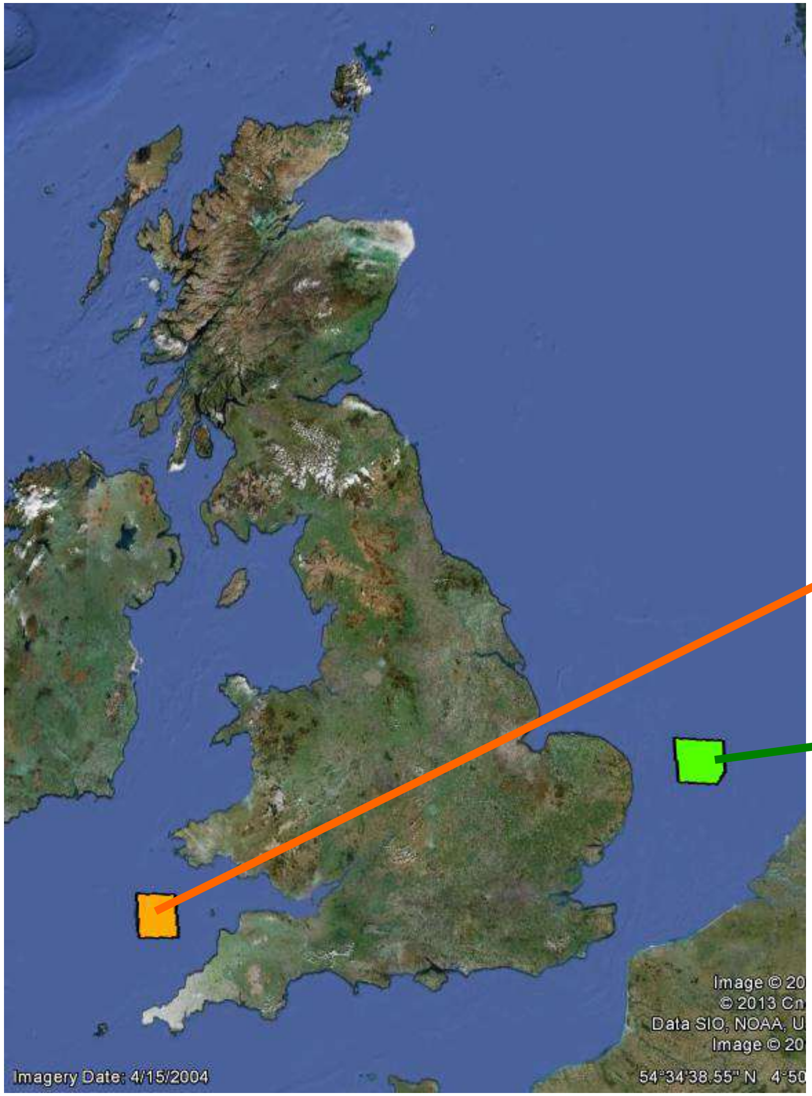
ZCB hourly energy model

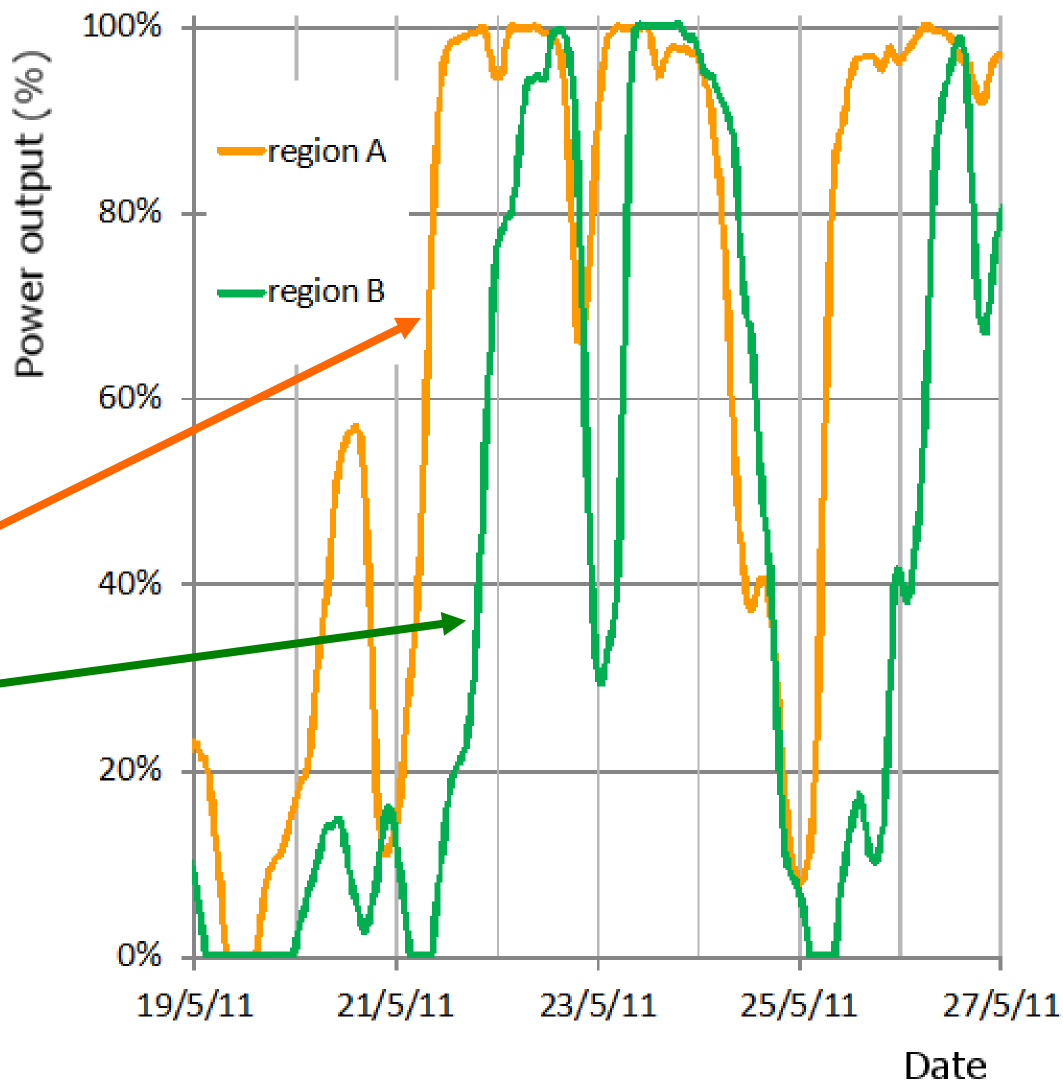


ZCB hourly energy model



Example: Offshore wind





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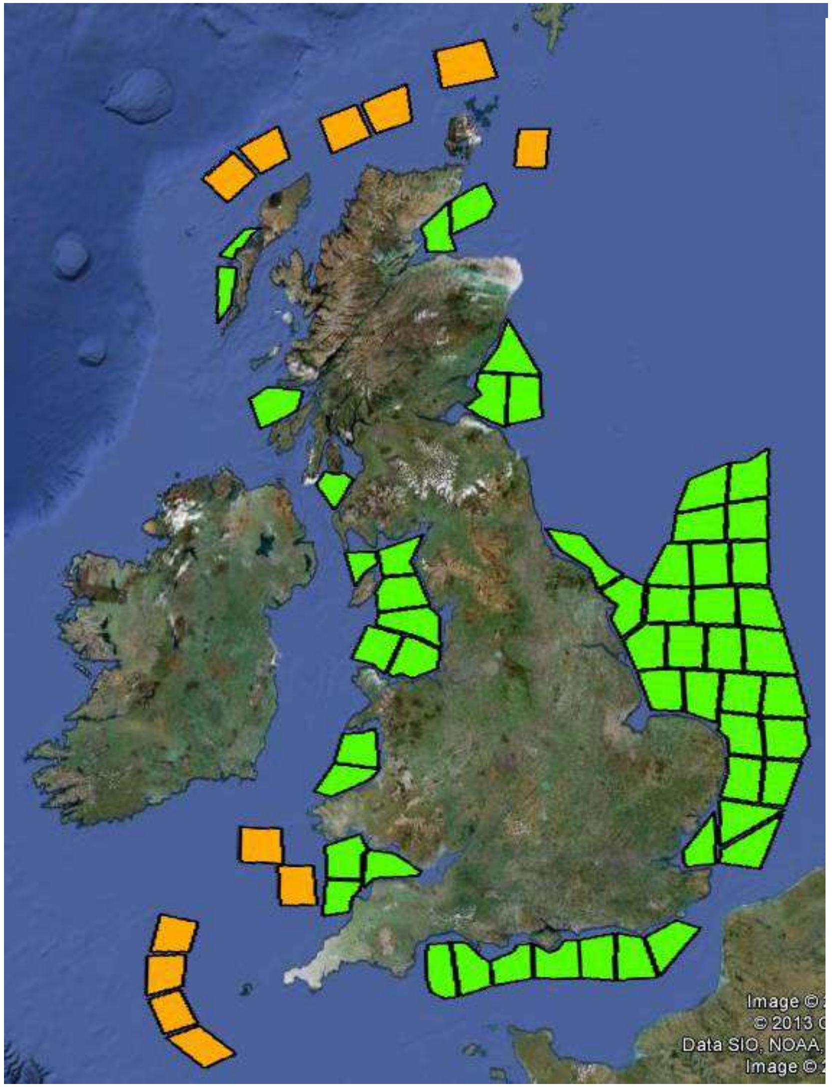

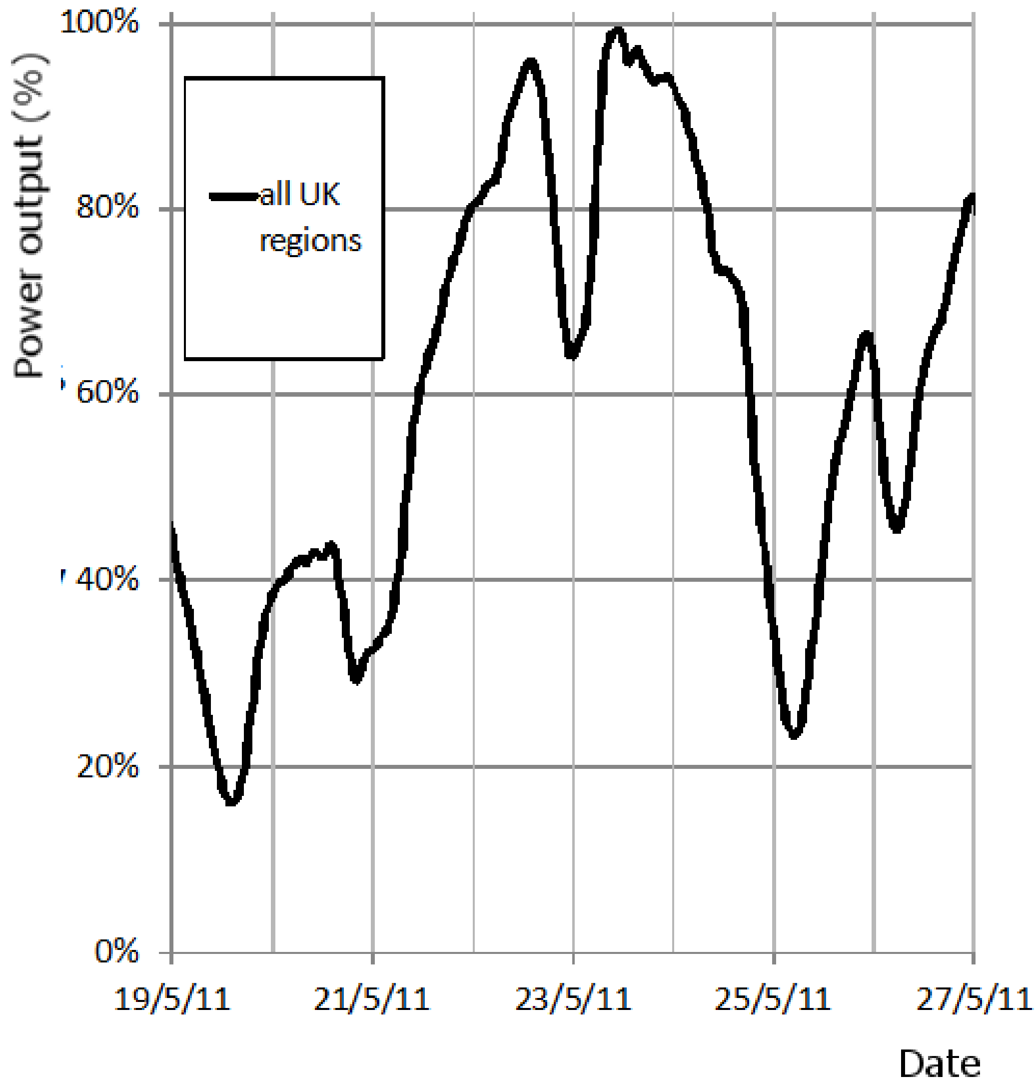

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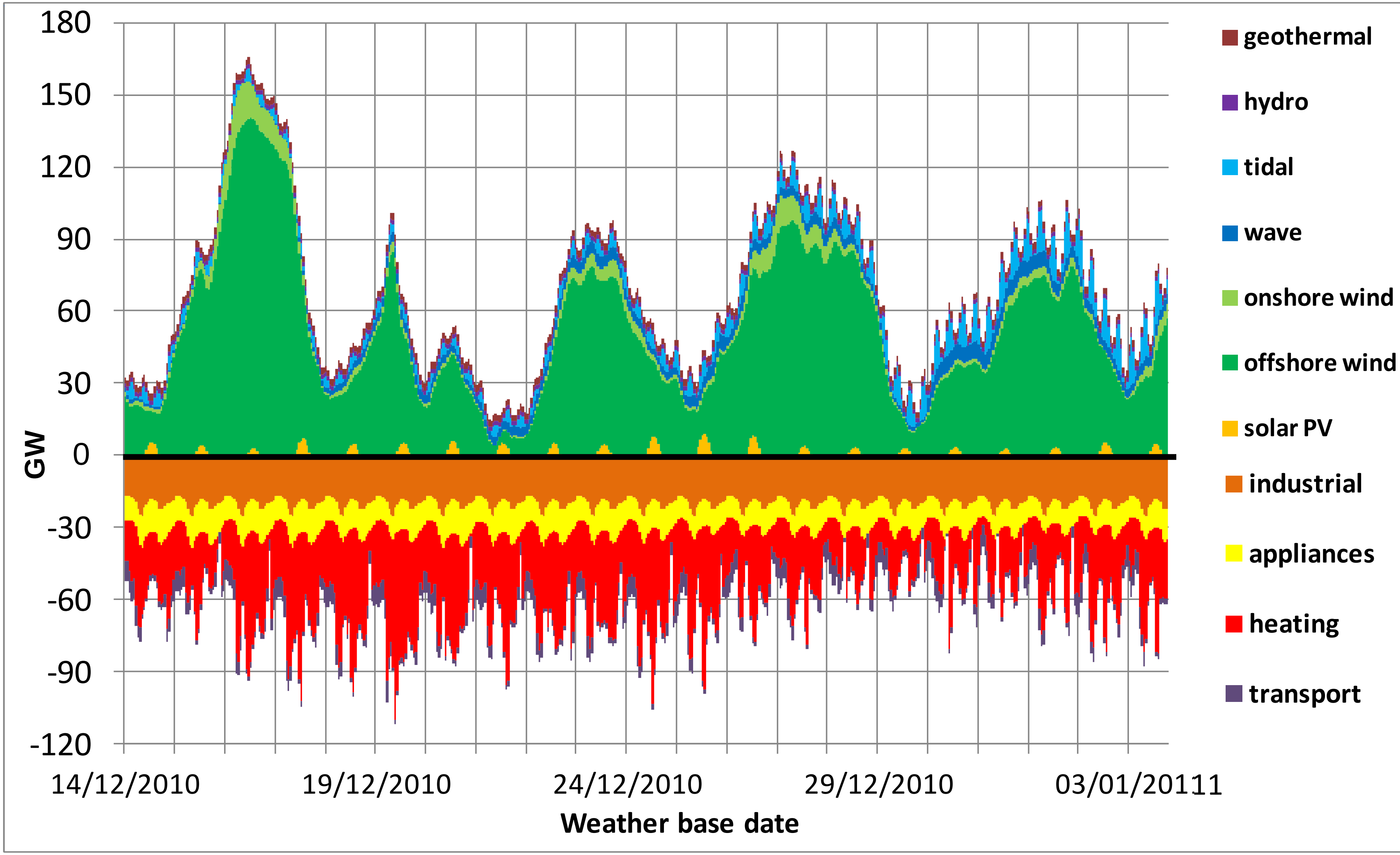

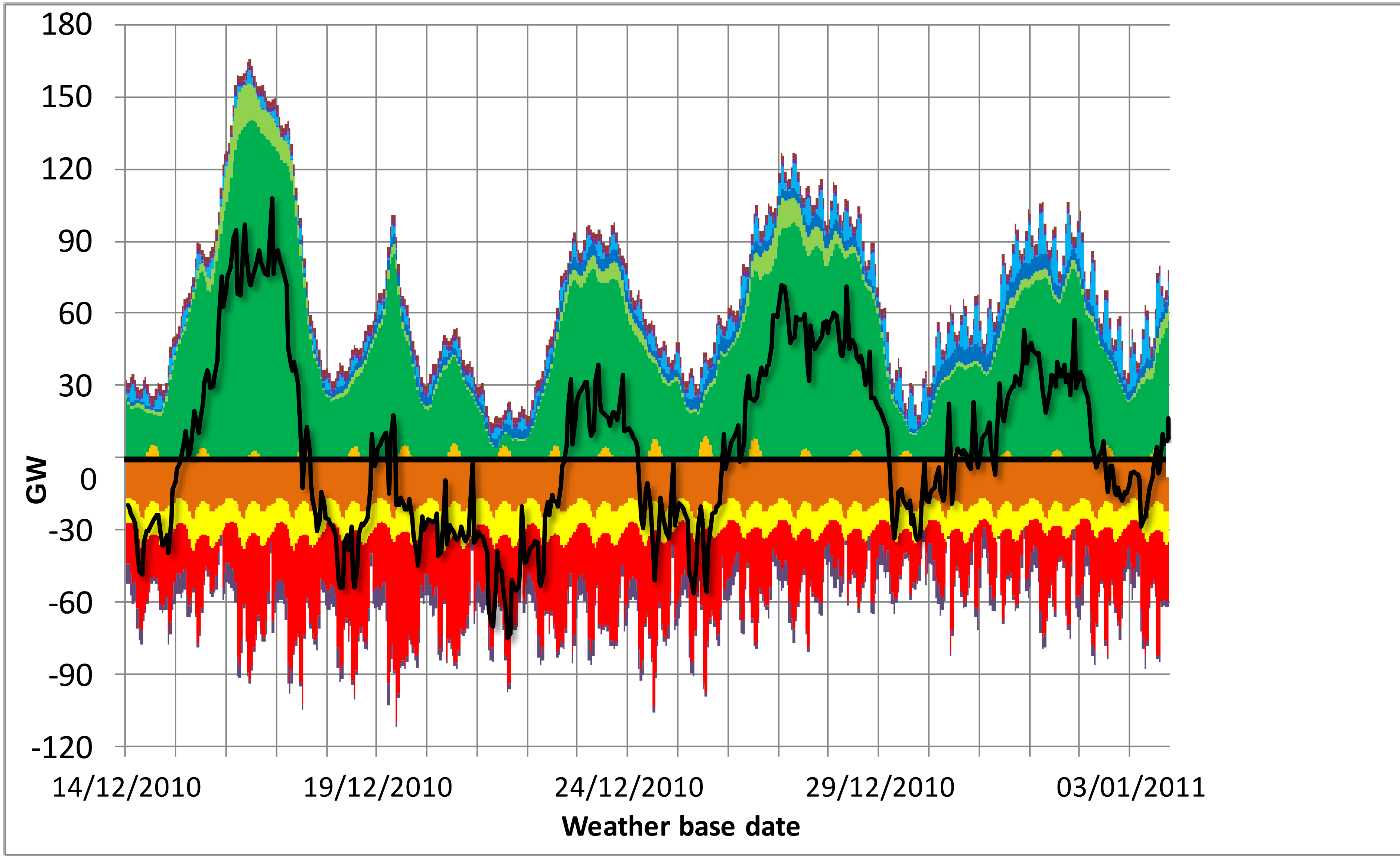
180
150
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-60
-90
-120
GW
14/12/2010
19/12/2010
24/12/2010
29/12/2010
03/01/2011
Weather base date

Best hour: 22 May 2011 (Sunday)

Britain heading for hottest, driest spring since records began

Britain is enjoying its hottest, driest spring since records began with temperatures of up to 75F (24C) predicted this week and a sunny Bank Holiday weekend ahead.

If the fine weather holds and Britain gets a further 116.4 hours, it will beat a record that has stood since 1948 Photo: Rui Vieira/PA

By Andy Bloxham
2:13PM BST 22 May 2011

Follow 863 followers

Figures from the Met Office show the average temperature across the UK since the start of March is just over 48.6F (9.2C) – the warmest since records began in 1910.

Weather
News » UK News »
Andy Bloxham »

In Weather

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UK since the start of March is just over 48.6F (9.2
records began in 1910.

By Dailyrecord.co.uk | 23 May 2011 06:40

Summer? What Summer? Scotland battered by 100mph winds

Travellers urged to keep updated as storm sweeps across the country.

Tweet 0 Like Share 0

Worst hour: 21 December 2010, 8 am (Tuesday)

5 January 2011 Last updated at 17:20

Last December UK's coldest for 100 years

By Richard Black
Environment correspondent, BBC News

Last month was the coldest December documented for the UK since nationwide records began 100 years ago, the Met Office has confirmed.

For central England, it was the second coldest December since 1659.

However, the first analysis released of global temperatures shows 2010 was one of the warmest years on record.

The UK's harsh weather was caused by anomalously high air pressure that blocked mild westerly winds and brought cold air south from the Arctic.

Crisp, wintry weather turned usually fluid attractions into static features

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5 January 2011 Last updated at 17:20

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The Telegraph

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Weather | Weather Forecast | Audi quattro Weather Watch

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Is the EU stealing UK wind!? (and its still cold)

The thermometer plunged to a new winter low overnight as temperatures reached -22.3C (-8.1F) in the Scottish highlands - almost as cold as the South Pole.

Print this article

Share 23

Facebook 22

Twitter 1

(very difficult to find news stories about a 'not very windy' day…)

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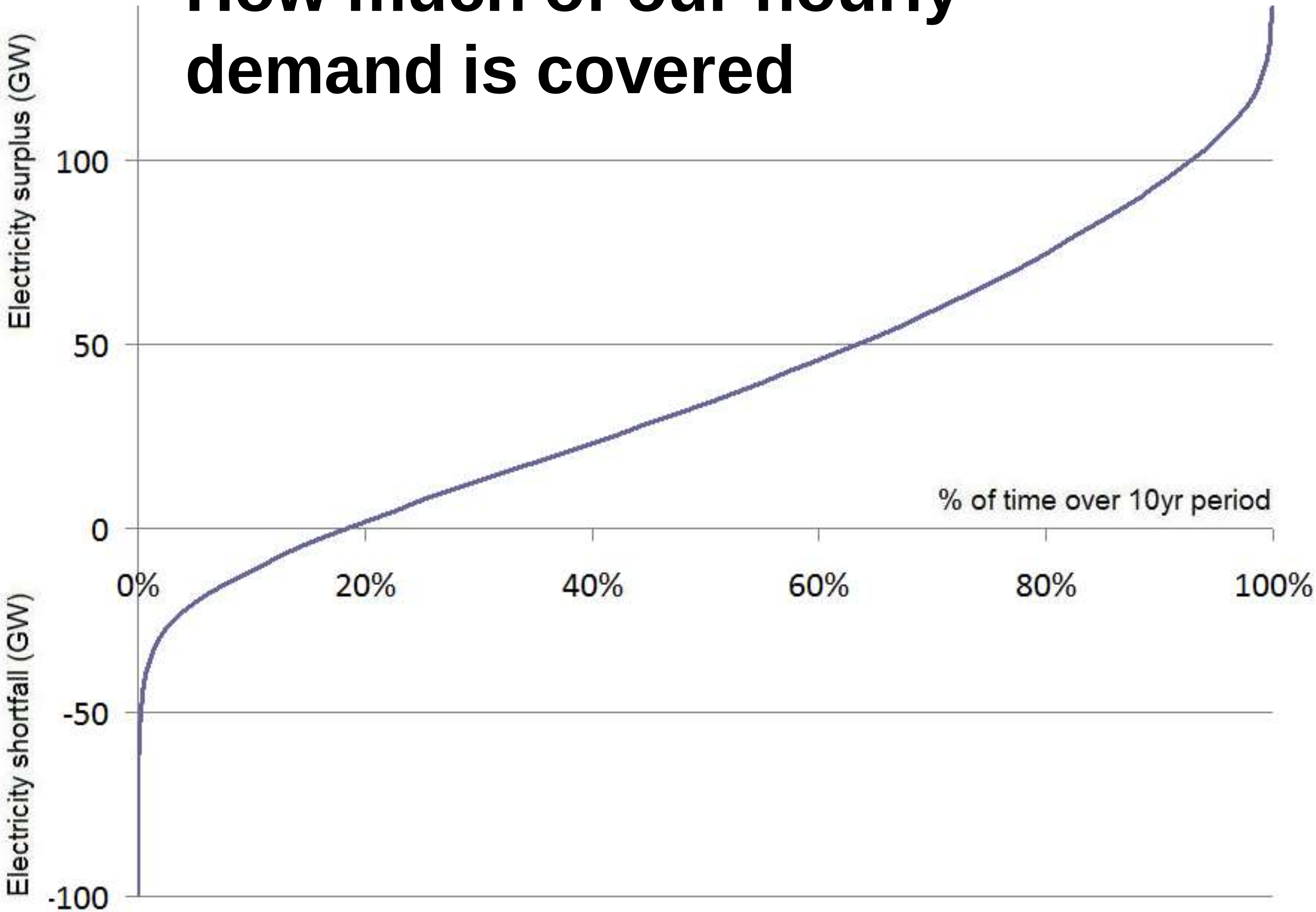
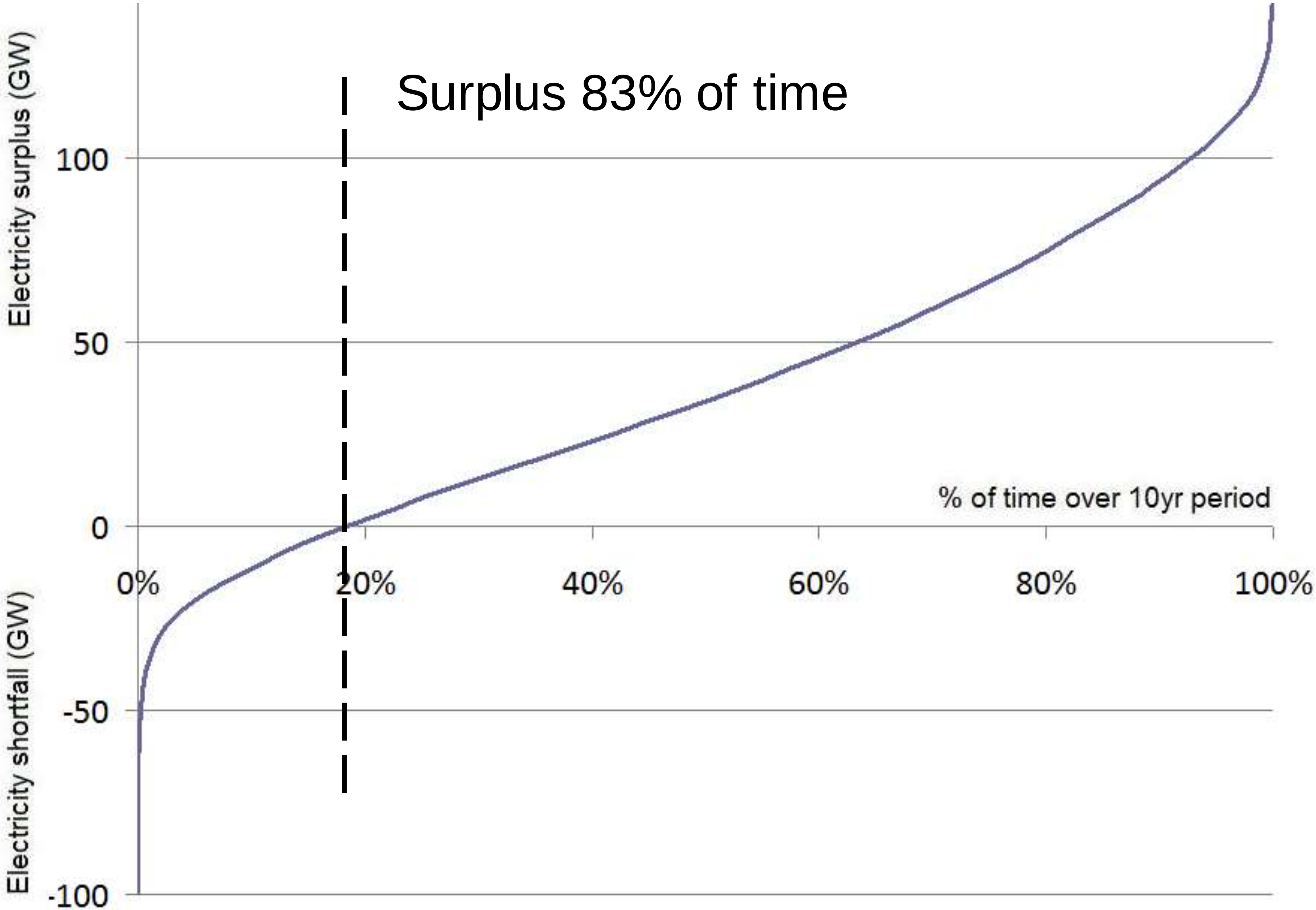
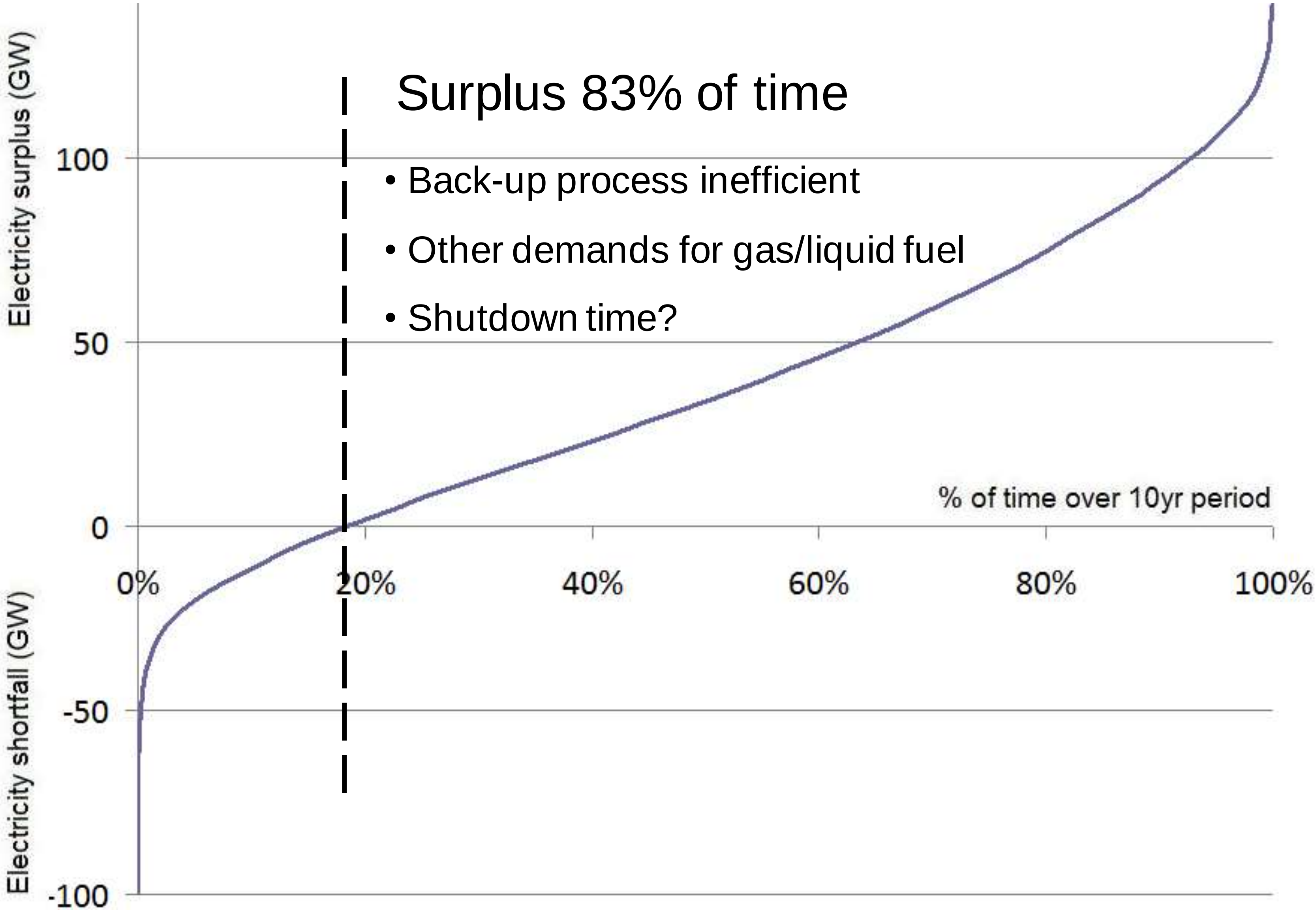
How much of our hourly demand is covered



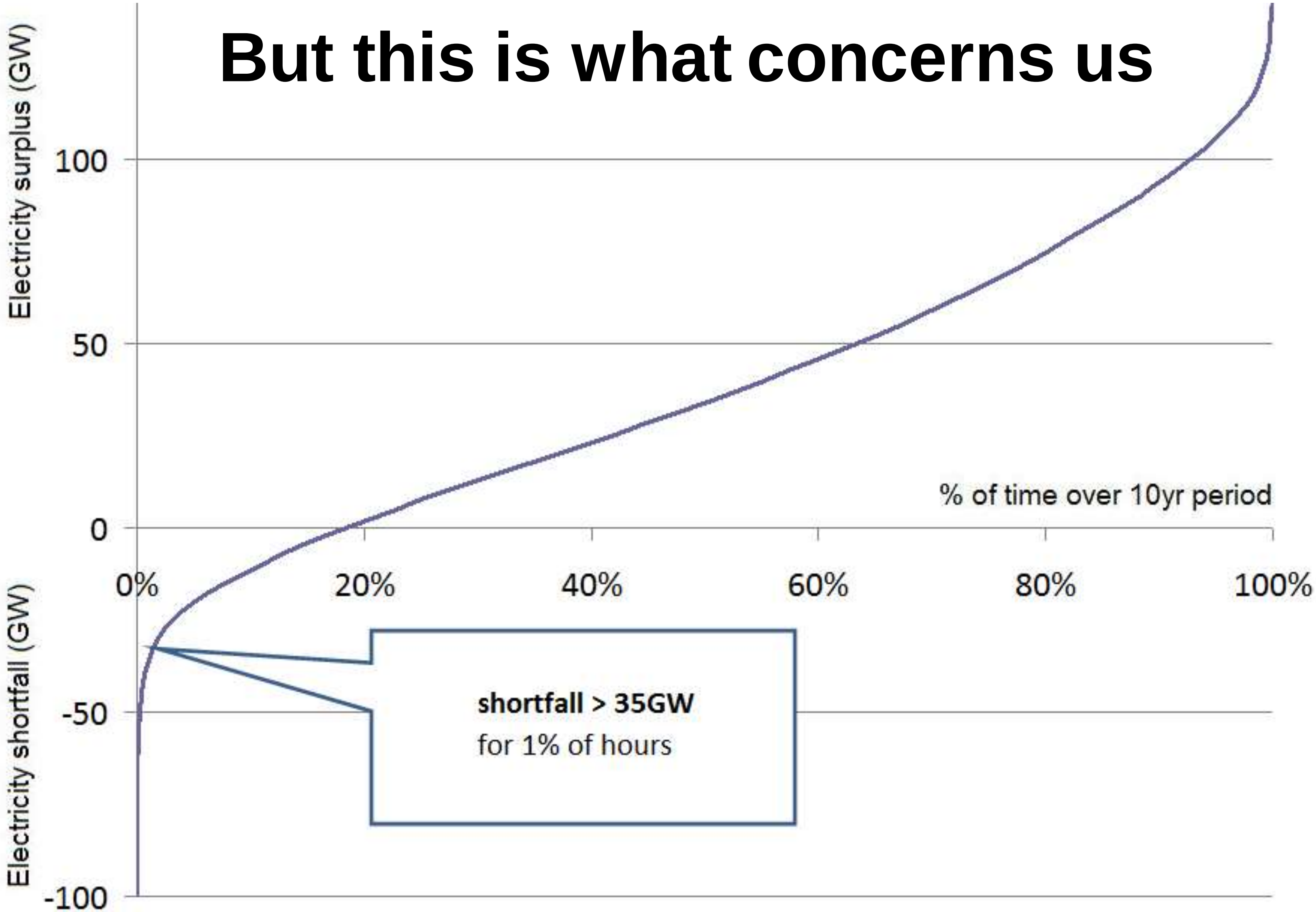

Surplus 83% of time
Electricity surplus (GW)
Electricity shortfall (GW)
100
50
0
-50
-100
% of time over 10yr period
0%
20%
40%
60%
80%
100%

Surplus 83% of time

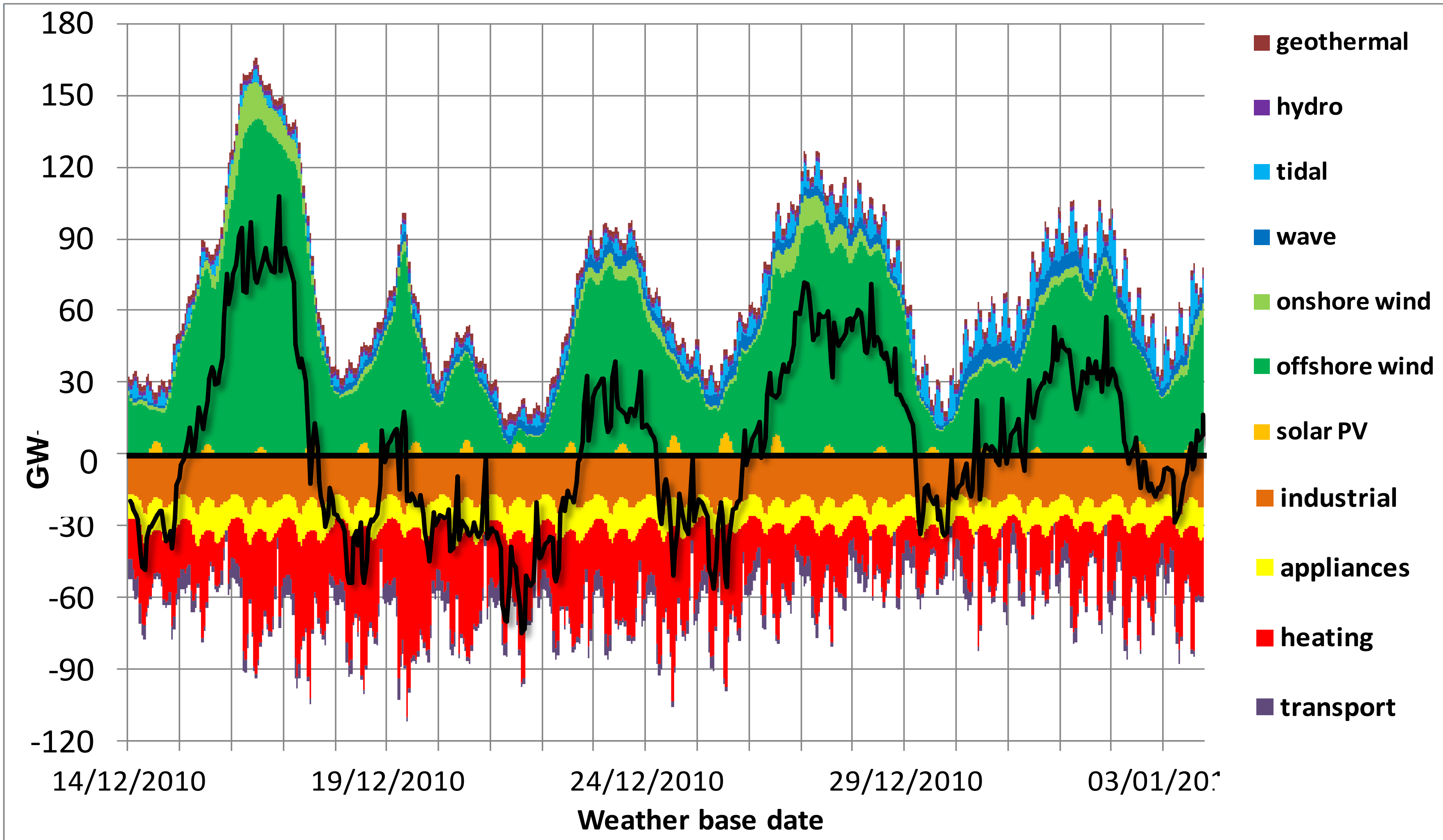
- Back-up process inefficient
- Other demands for gas/liquid fuel
- Shutdown time?



But this is what concerns us



Short-term fluctuations

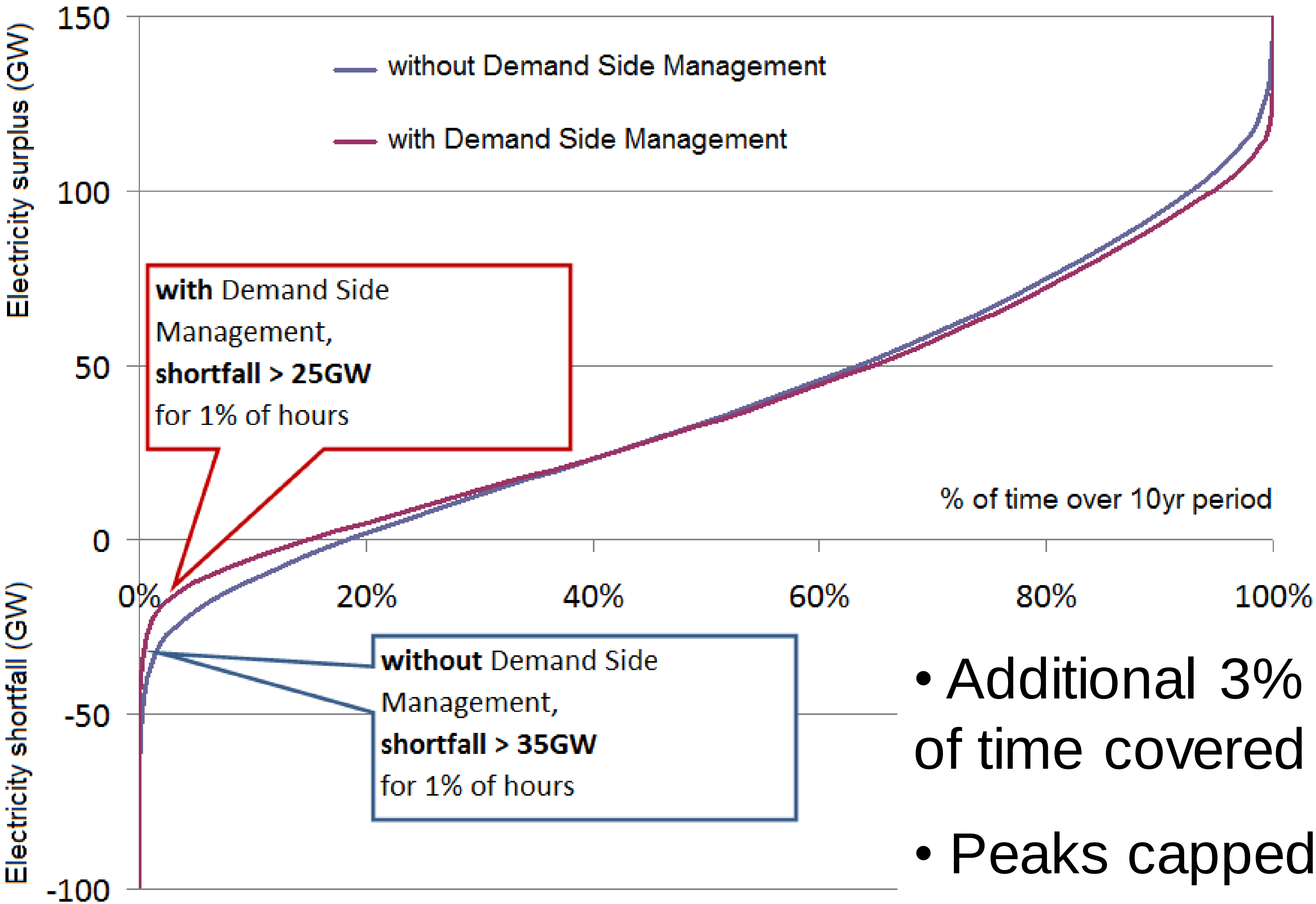


Short-term fluctuations

- Large hour-to-hour variations

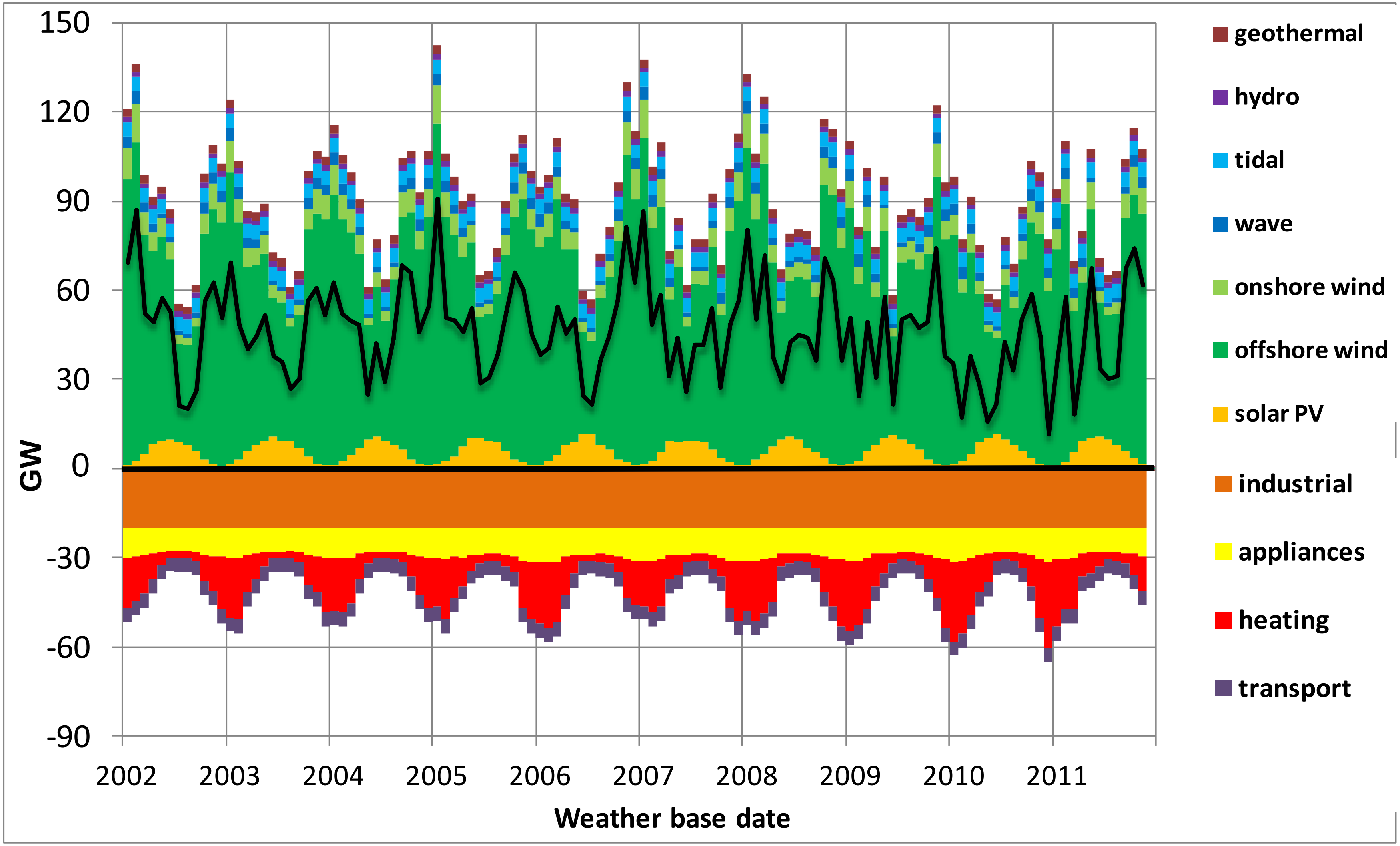
Short-term fluctuations

- Large hour-to-hour variation
- **Demand Side Management (DSM)** can help e.g. “smart charging“ of electric cars (~25GWh)
- **Pumped hydro storage** and **heat storage** can provide short-term storage (~25GWh; ~100GWh)



- Additional 3% of time covered
- Peaks capped

Longer-term fluctuations



Longer-term fluctuations

- Significant longer-term variation between months and years
- We need:
  - Ideally many TWh of **storage** required
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→ Must be carbon neutral

Synthetic gas

- **Hydrogen** can easily be created from renewable electricity (electrolysis)
- But **methane** is easier to store and we have vast existing infrastructure
- The **Sabatier reaction** = methanation (upgrading) of hydrogen $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

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→ Less biomass required **and** use of surplus electricity.

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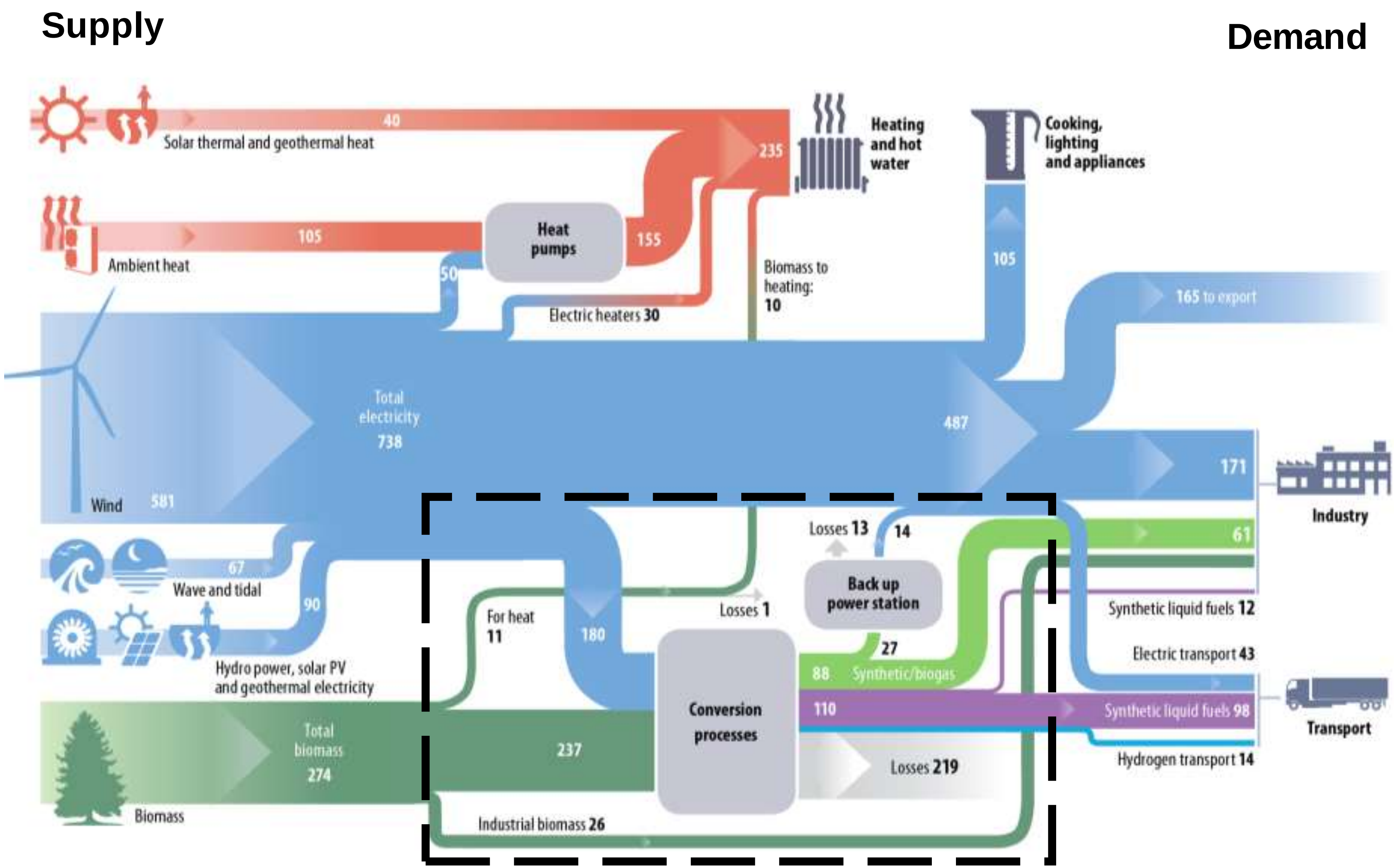
Figure 3.18: Energy flows in our scenario – from supply to demand. Numbers used here are rounded up or down to the nearest TWh and so inputs and outputs may not add up exactly.



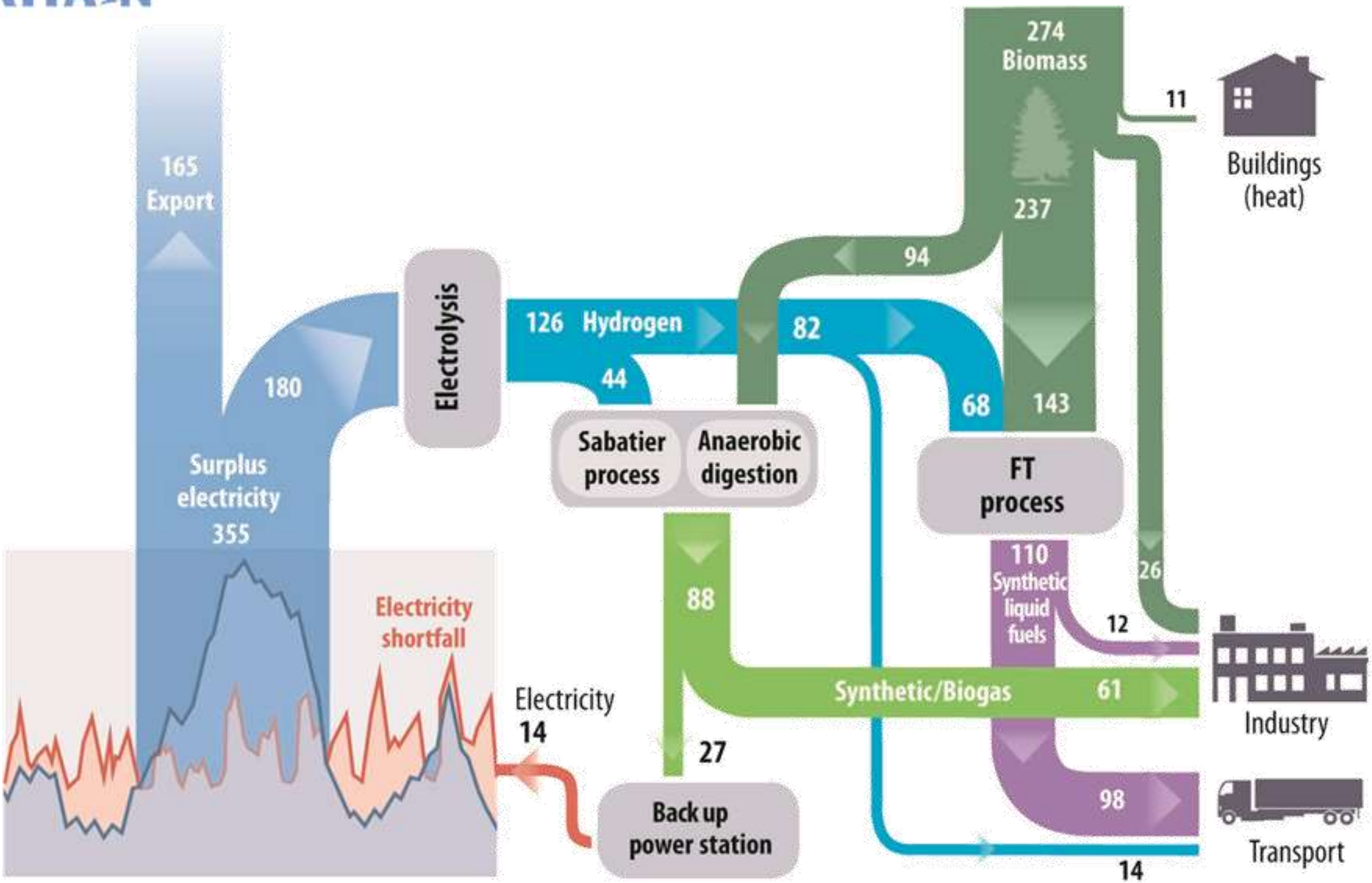
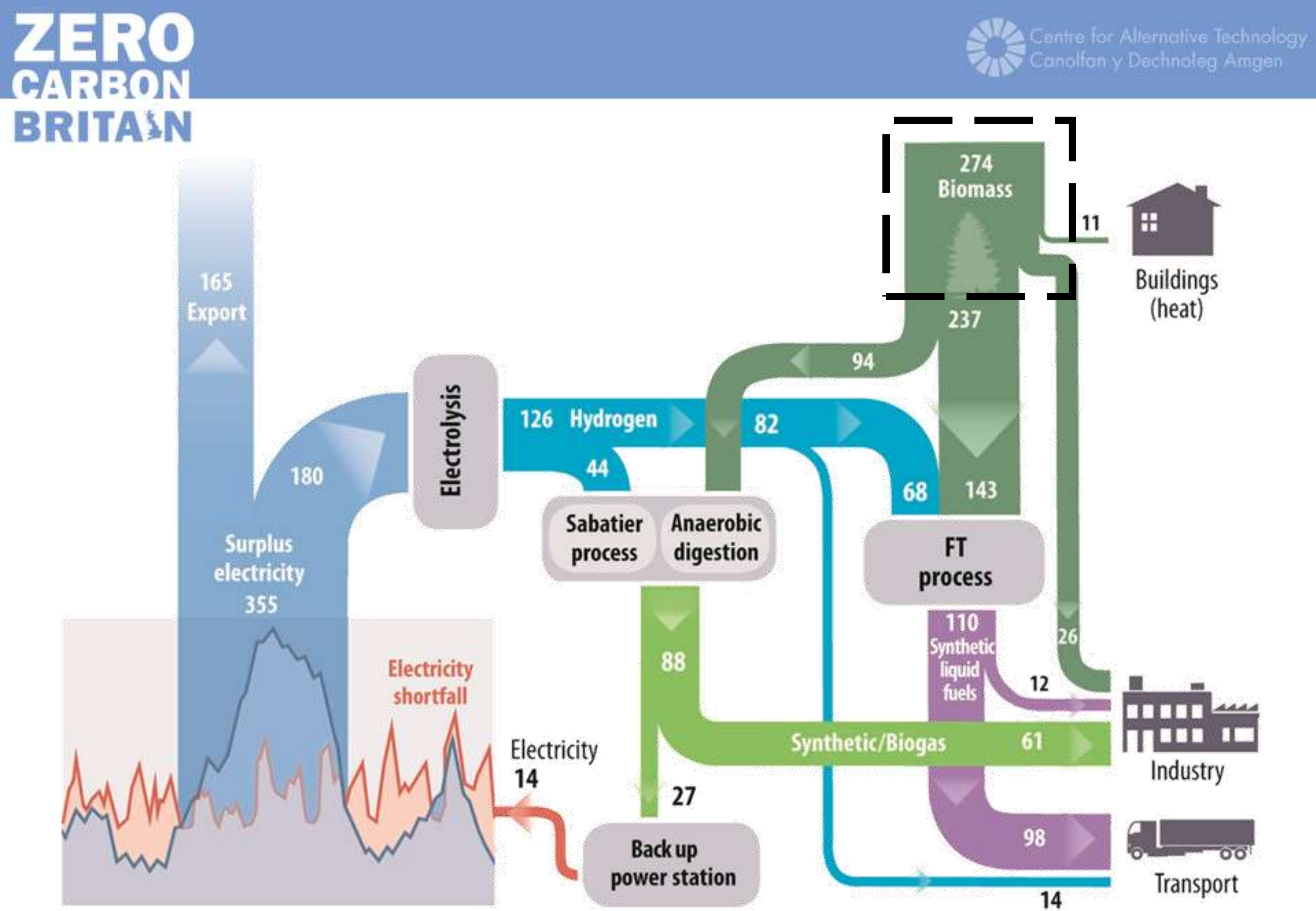


Figure 3.20: From surplus electricity and biomass to synthetic fuels for industry, transport and energy system back up. Losses are not shown in this figure.



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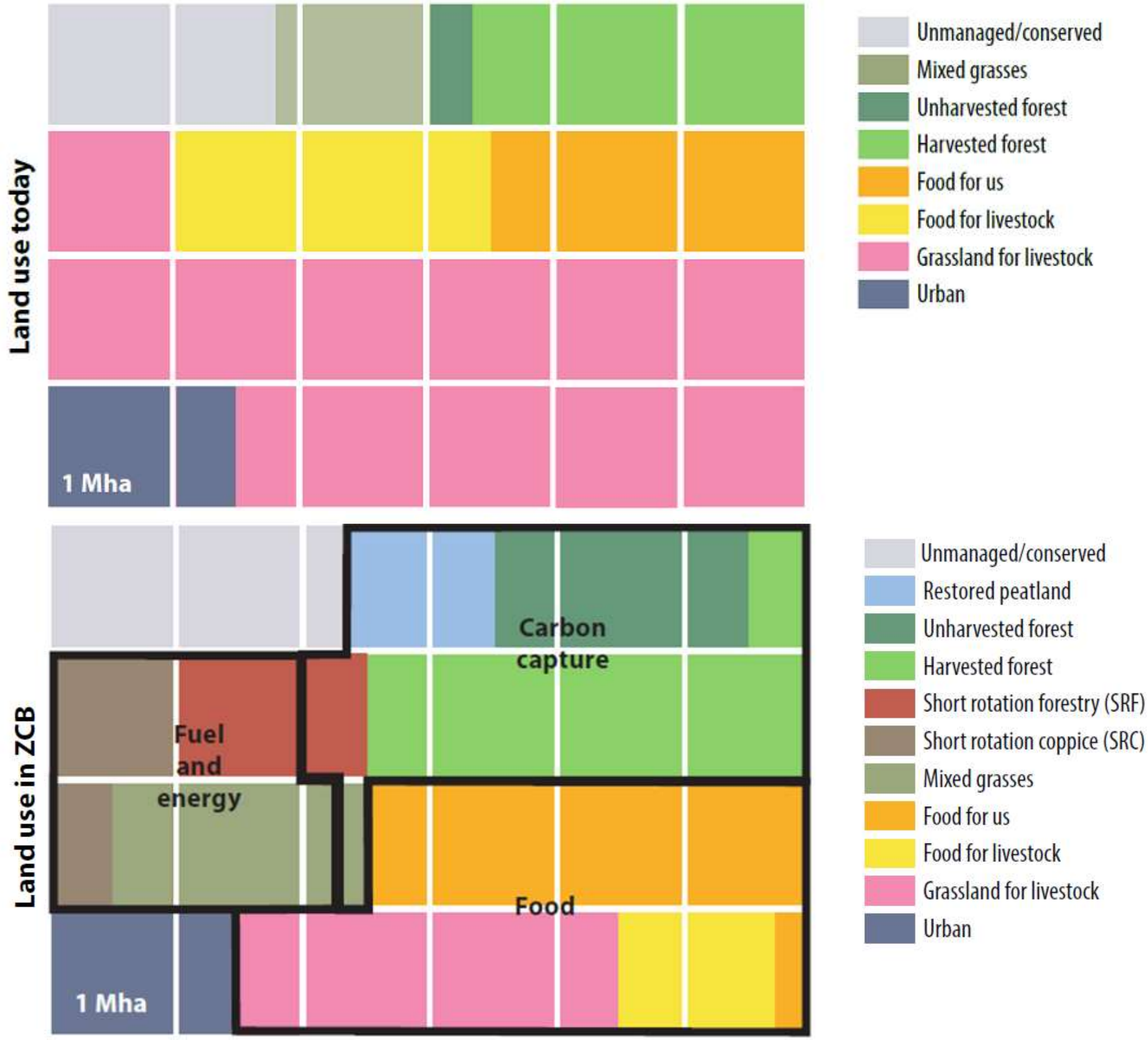
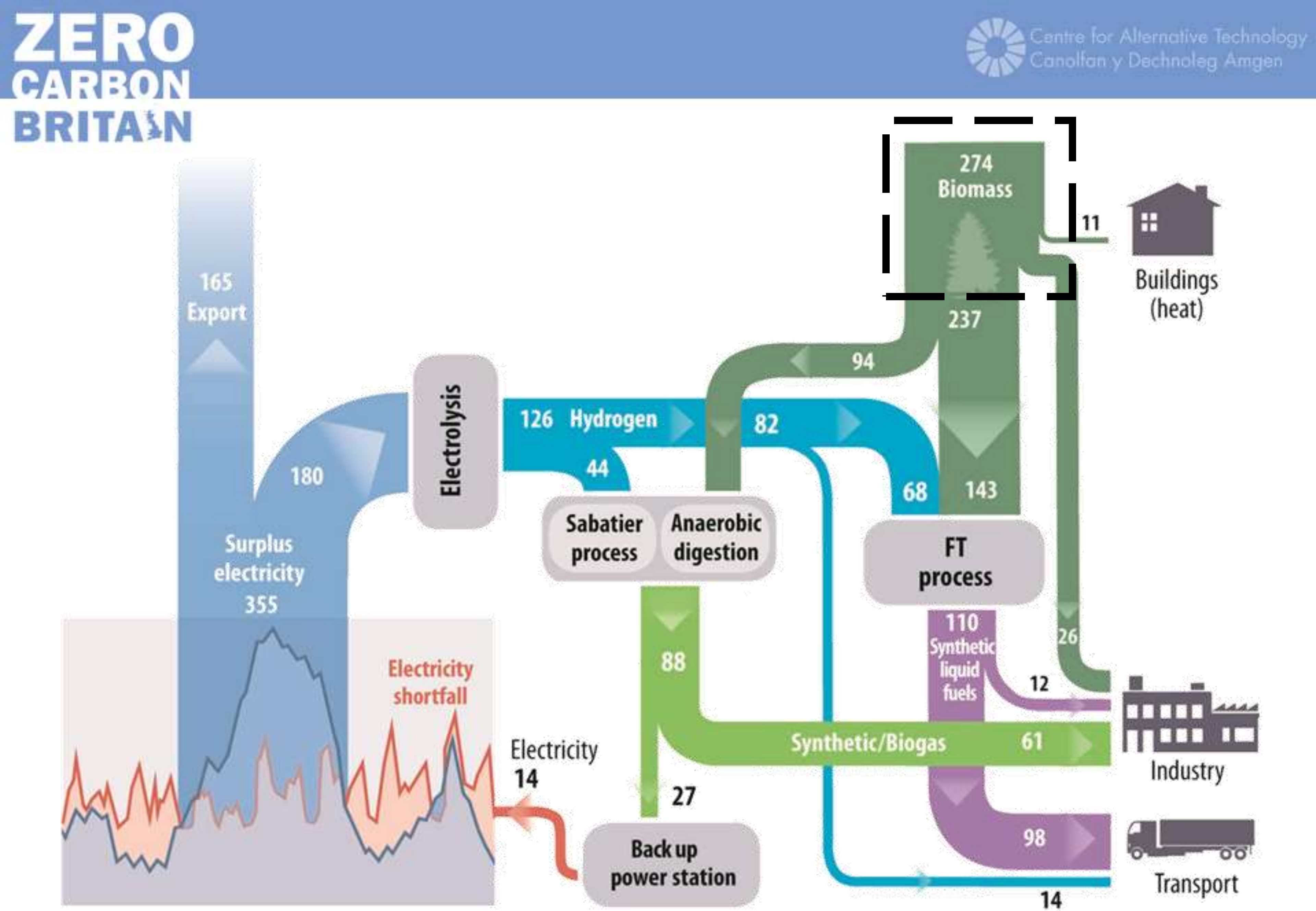
(This is another story…)





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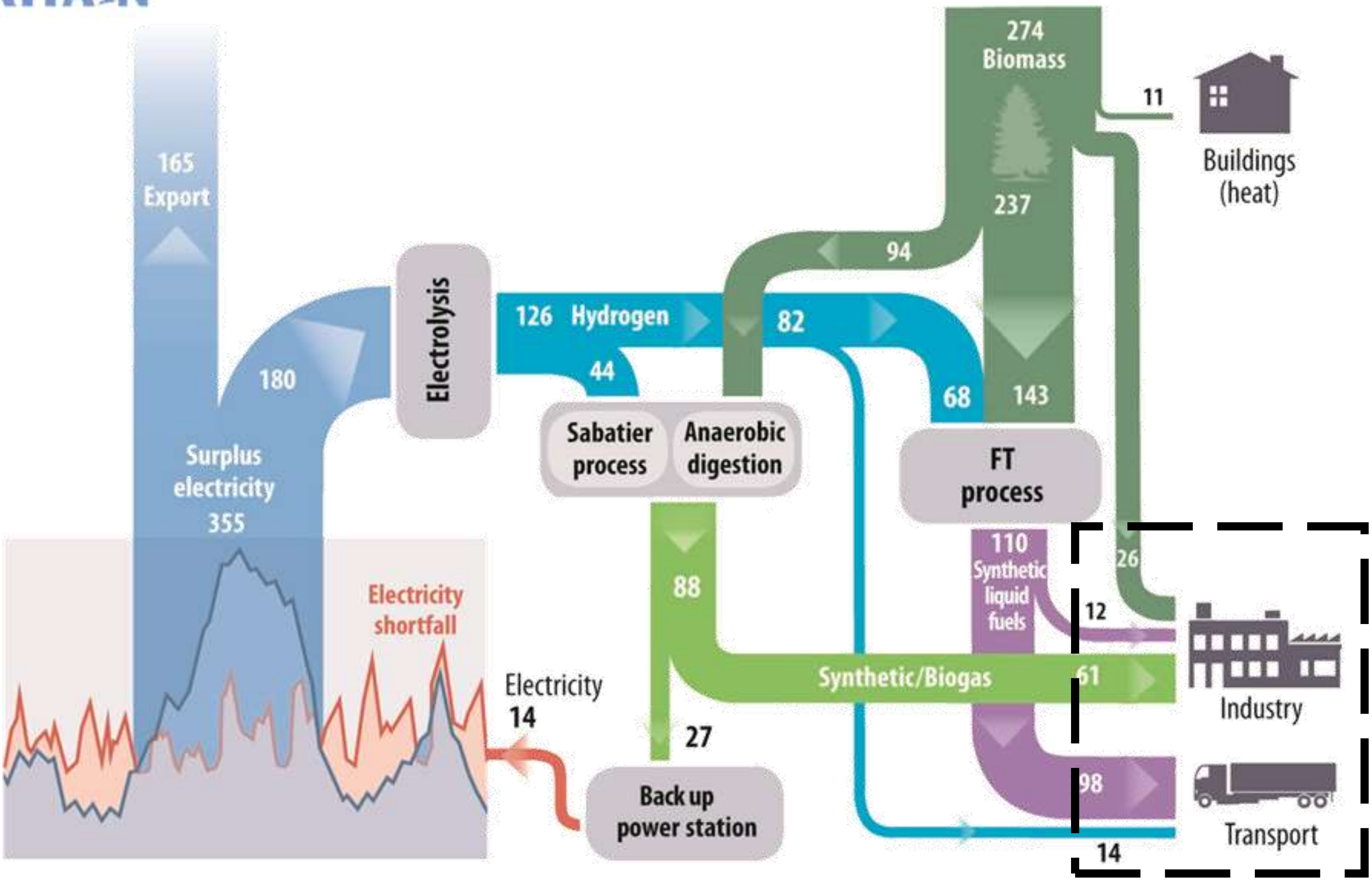

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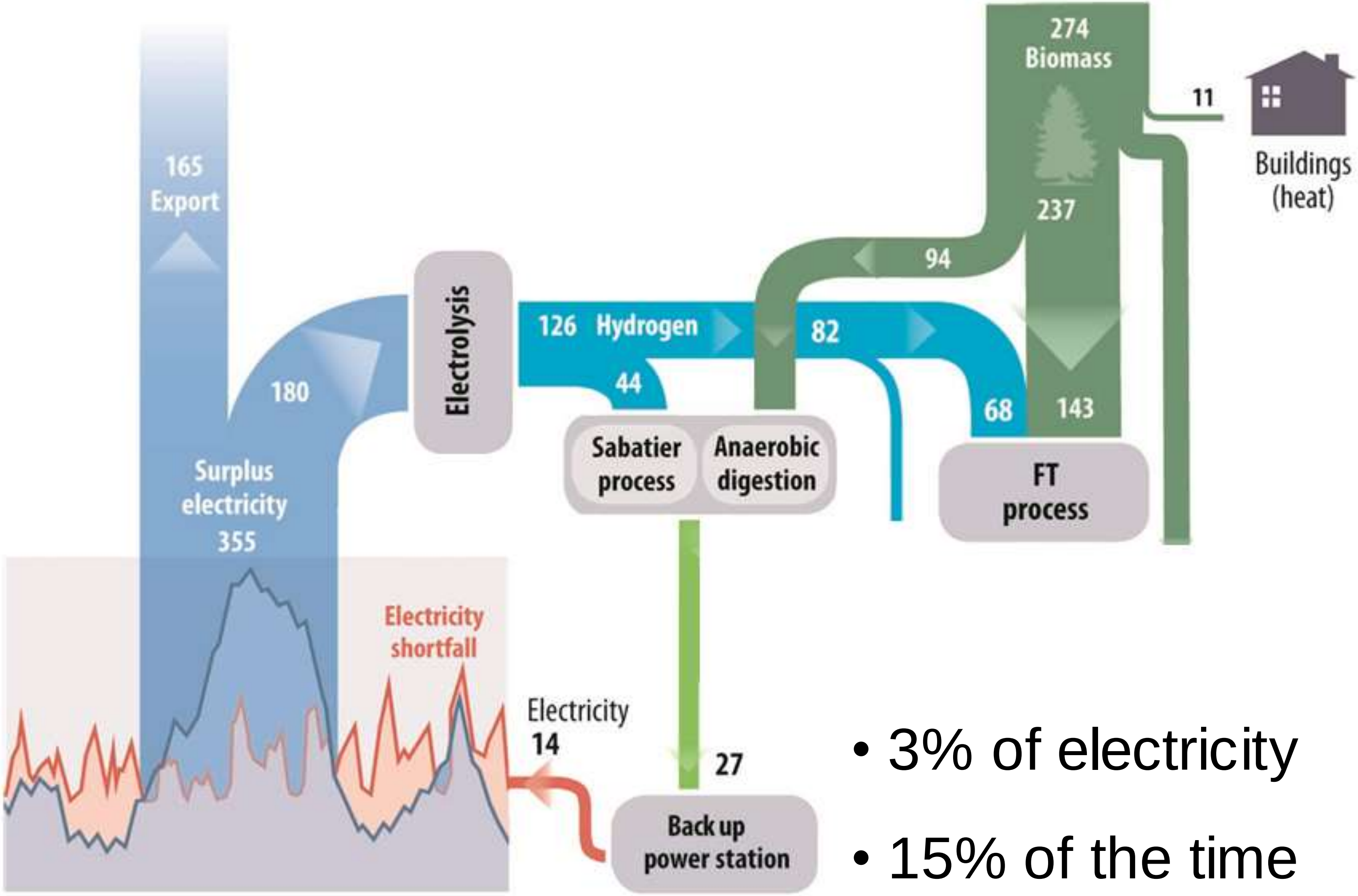
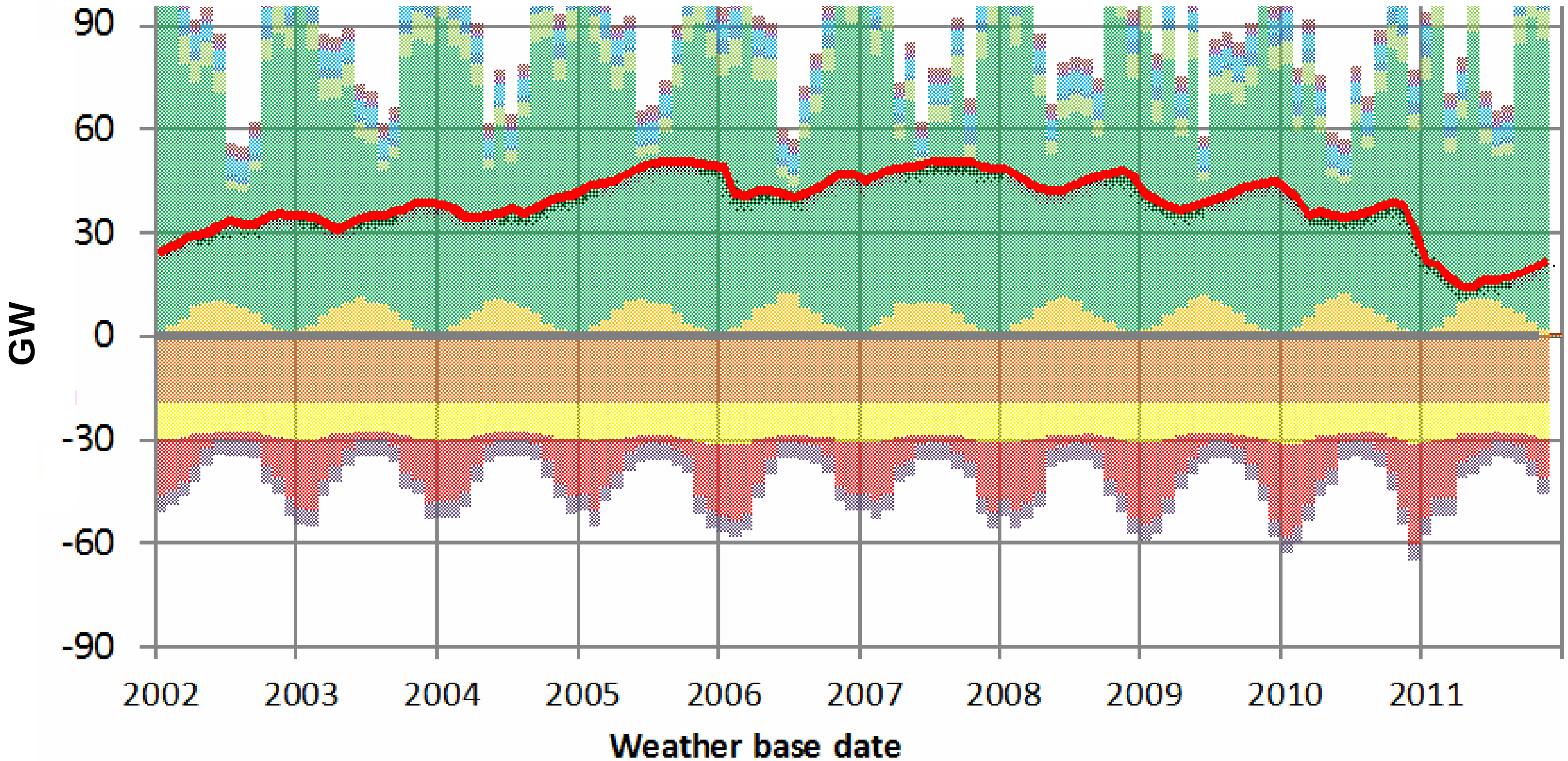


Figure 3.20: From surplus electricity and biomass to synthetic fuels for industry, transport and energy system back up. Losses are not shown in this figure.

- 3% of electricity
- 15% of the time

Synthetic gas store

- 60,000GWh storage = ~ 2 x UK today
- ~45GW back-up turbine capacity = ~ UK today



Lessons in 'managing variability'

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- Spreading renewable resources about
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What helps a bit:

- Demand side management (“smart charging“)
- Short-term storage (pumped hydro and heat)

What we really need:

- Large flexible, quickly despatchable storage
- (not ‘baseload‘ energy)

Still more to learn…

- Optimisation
- Sensitivity analysis – simulate future weather?
- Analysis of extreme shortages

However, ZCB does show that

- We can provide a **reliable, zero carbon energy system**.
  - Using our own resources.
  - With 100% renewable energy.
  - Without nuclear power or fossil fuels.

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We do have to make some **big changes**!

(“Dear Santa…”)


BUILT ENVIRONMENT
LAND USE & AGRICULTURE
ENERGY
TRANSPORT (TWh?)
SOCIETY/
HEALTH
less meat eaten
demand side management
SECURE ENERGY SYSTEM FOR ALL
less steel in BE, more in wind turbines
heat demand (70%)
10Mt biomass for buildings (etc)
16Mt biogas (grid)
70Mt biomass
10Mt biomass CHP
(doubled?)
hydrogen
17Mt CO2e LU
CARBON BUDGETS
embodied emissions

The aims of the ZCB project

To demonstrate that integrated and technically feasible solutions **do exist**.

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To demonstrate that integrated and technically feasible solutions **do exist**.

To **support and inspire** the action needed to achieve a positive zero carbon future.

→ To help us see what this kind of future looks like, and what it would mean to our lives

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5 BRITOMART
TA 10020

John Lewis
HUNTED
GAP
BUS STOP

We have the technology to power ourselves with 100% renewable energy, to feed ourselves sustainably and to leave a safe and habitable climate for our children and future generations.

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