UK renewables – limitless energy or a precious resource?

Today's decisions delivering tomorrow's sustainable future

IET Renewable power generation
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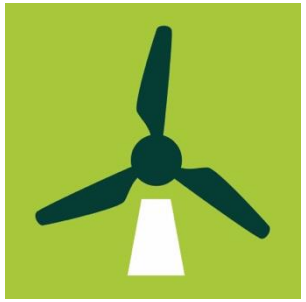
1. Introduction
2. What resources do we have?
3. What are our future renewables needs?
4. Comparing resources to requirements
5. The capacity challenge
6. Conclusions and recommendations
7. Non-technical factors
8. Survey results

Introduction – why the question?



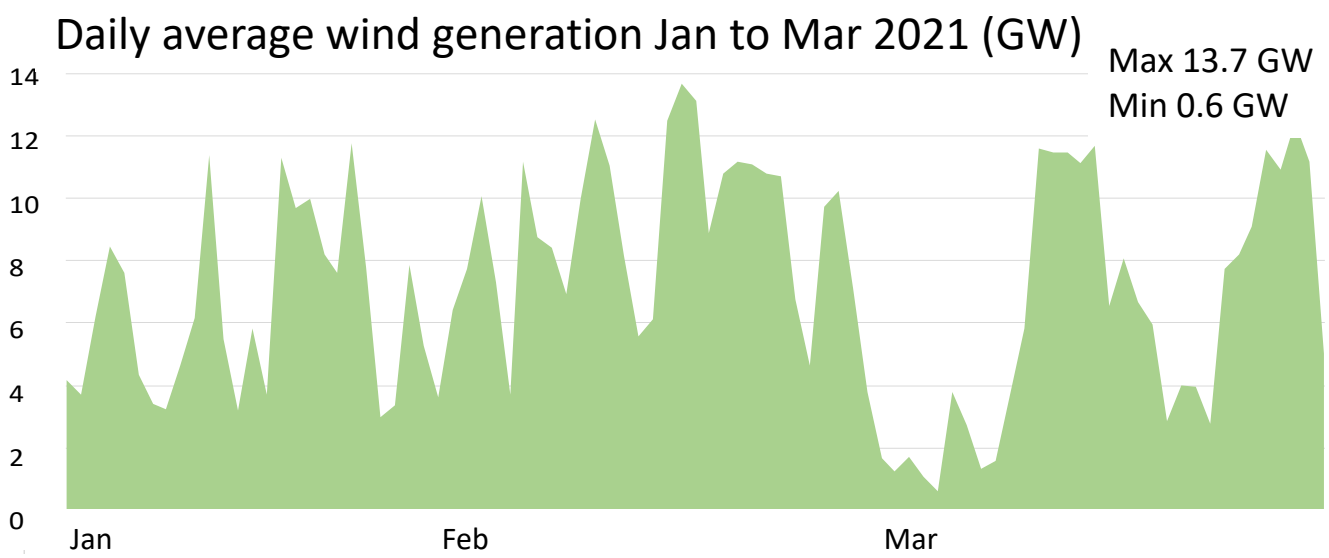
UK renewables – limitless energy or a precious resource?

- Renewables seem to be the answer in every situation
  - But the scale seems to get less attention
- A lot of excellent information available
  - Used a variety of sources – and a few models
- A multi-dimensional challenge –
  - Primarily a consideration of technical feasibility
- Hopefully a pragmatic and impartial view of resource availability and needs…
  - This subject evokes a passion like no other!

Renewable resources - wind

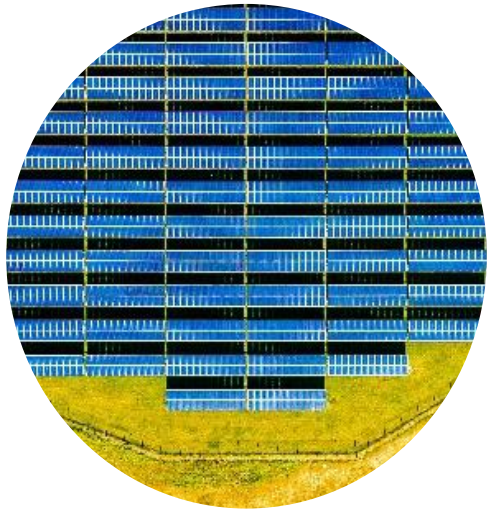
- UK is a leader in development
- Offshore windpower is particularly valuable
  - Hornsea 2 (55 miles off Yorkshire coast) will become the largest windfarm in the world
  - 165 turbines, 1.3 GW
- New floating platforms to access deep water resources
- But…wind output is intermittent – technical and economic questions

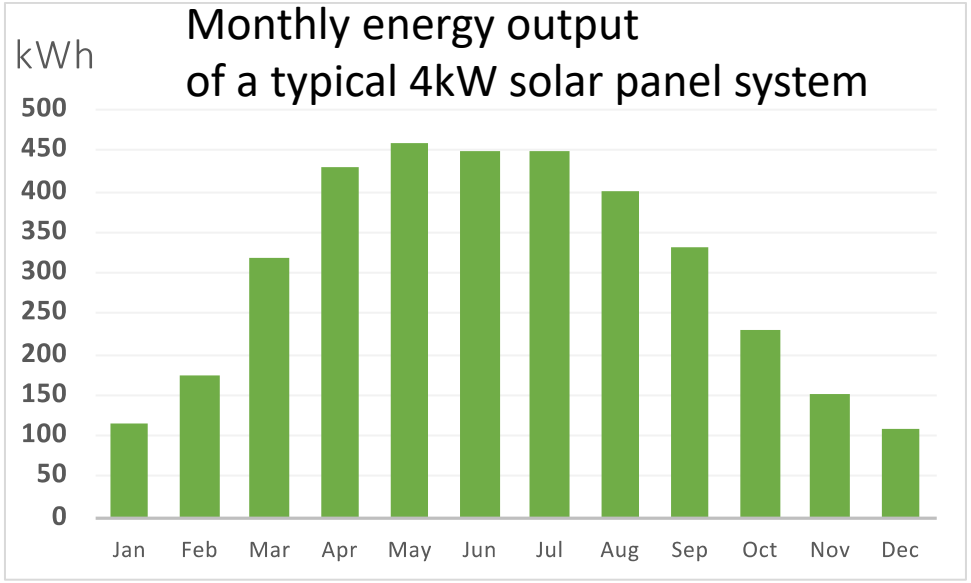
(2050 estimate - 400 TWh available for UK)



Renewable resources - solar

- Limitations at UK latitude
- Output is reasonably predictable
  - But… best in the summer months!
- Valuable at large and small scale
- Individuals can invest –
  - Good for society engagement



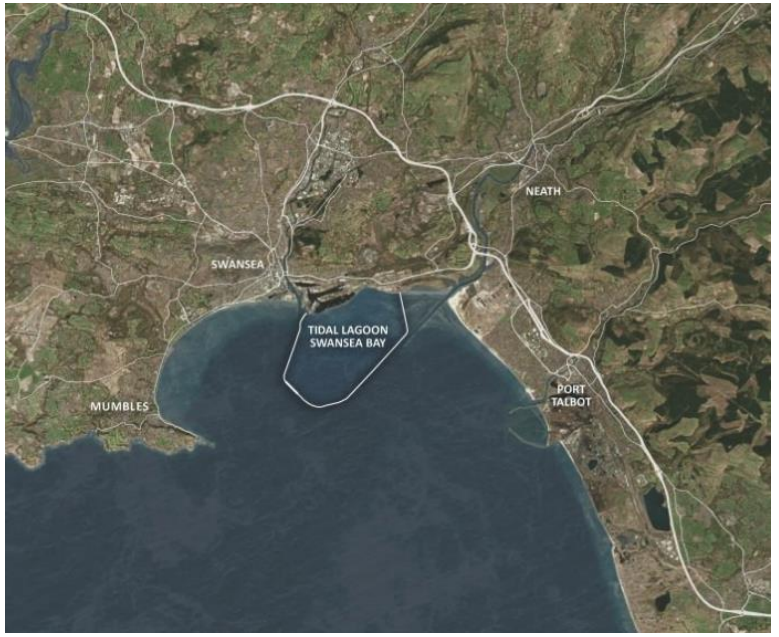


(2050 estimate - 75 TWh available for UK)

Renewable resources - tidal

- Wave, tidal stream, tidal range
- Potentially a substantial resource
  - UK is a leader in research
  - Huge range of estimates
- It's predictable 😀
- But… it's a harsh environment, and there are environmental concerns
- For now, other sources are cheaper
  - One day its predictability will be valued

(2050 estimate - 20 TWh available for UK)



tidallagoonpower.com

In 2018 government chose not to back the £1.3 billion Swansea Bay tidal energy project – a world first.

(0.5 TWh pa. Said to be 3x cost of Hinkley Point C per kWh)

Renewable resources - biomass

- Fuel derived from biomass - plant or algae material or animal waste
- Potentially brilliant - absorbs carbon from the atmosphere
- Very flexible resource - can be used for heat, power generation, aviation fuel production etc.
- Could be combined with Carbon Capture and Storage (CCS) to lock away emissions (BECCS)

- But…real concerns over habitat damage, water use, displacement of food crops and the carbon cost of production and transport

(2050 estimate - ?? TWh available for UK)

- *Drax power station in North Yorkshire provides the most renewable power of any single location in the UK.*
- *14 specialised trains deliver around 20,000 Tonnes of biofuel each day, producing an output of ~14 TWh per year.*
- *Compressed wood pellets sourced from sustainably managed working forests in the US, Canada, Europe and Brazil*

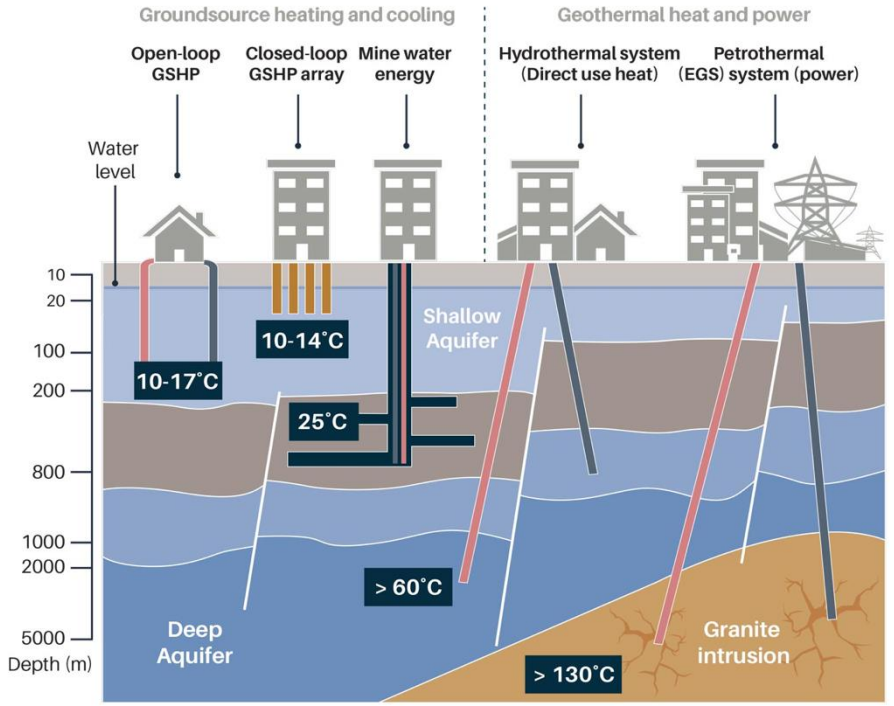
Renewable resources - geothermal

- Ground source and water sources are readily exploited - eg National Trust Packwood House / Killerton House
- Mine-water could be an attractive heat source for some
- Need space for ground collector network
- Deep, underground resources are generally only accessible in a few UK locations
- Useful heat is available across UK at depths of 7 k

  - wells are currently 3 km - if drilling technology improves then maybe…

- A case for increased R and D?

(2050 estimate - ?? TWh available for UK)



[CP22/040 Geothermal Energy Technologies Figure, BGS © UKRI. All Rights Reserved Sourced: https://www.bgs.ac.uk/geology-projects/geothermal-energy/]

Summary of renewable resources

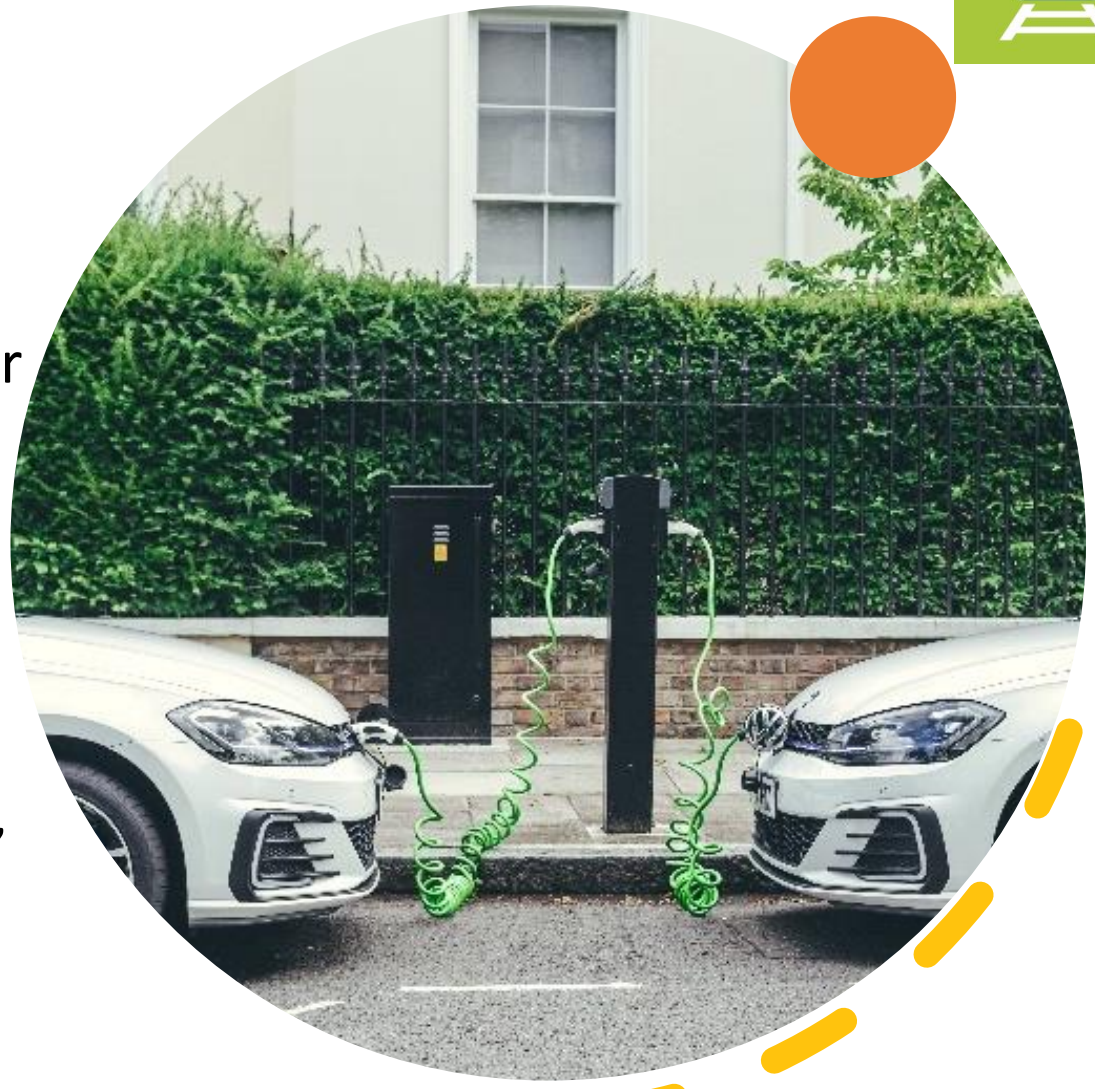
Available renewable electricity estimate (2050)	
Energy	TWh pa
Wind	400
Solar	75
Wave / tidal	20
Biofuels	?
Geothermal	?
Total	**495**

Options for transport

- Light transport shaped by functionality and emerging global market for electric vehicles
  - A Mars bar contains enough energy to power an EV for a mile
  - Hydrogen powered cars use 4 Mars Bars!

(Paul Barnfather)

- Potential for market shift to vehicle / ride hire
- Heavy goods, rail and aviation guided by weight, energy density and range requirements
  - Biofuels / electricity / hydrogen

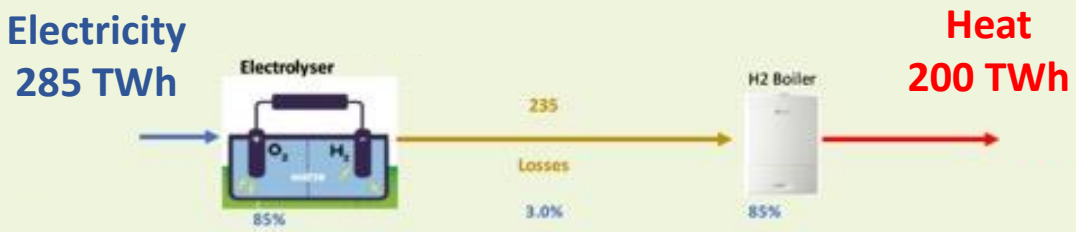


(2050 estimate - 121 TWh pa energy requirement)

Options for heat

Energy supply impacts of space heat options

Hydrogen Boiler

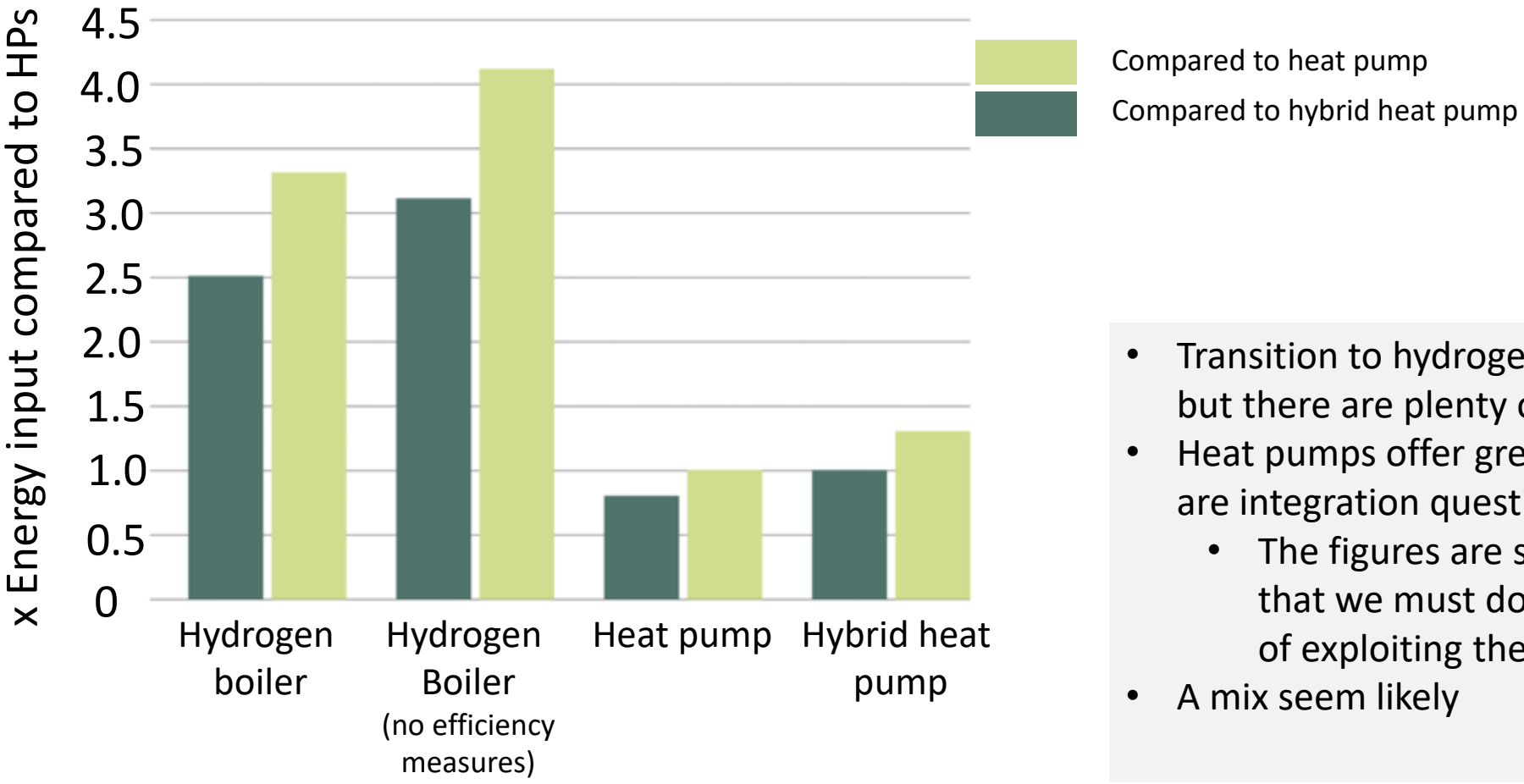


Hydrogen Boiler (no buildings efficiency measures)

Heat Pump

Hybrid Heat Pump

Options for heat cont'd



- Transition to hydrogen can sound simple, but there are plenty of challenges
- Heat pumps offer great potential, but there are integration questions
  - The figures are so compelling though, that we must do our best to find ways of exploiting the virtues
- A mix seem likely

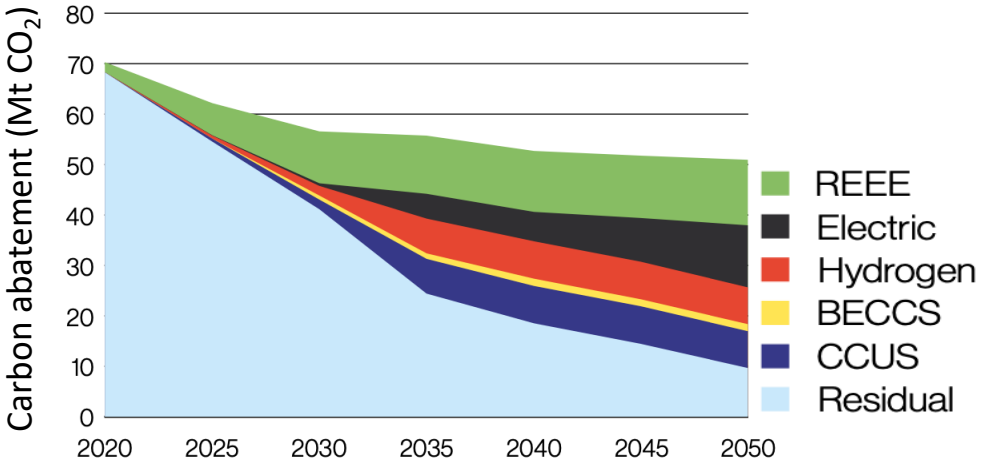
(2050 estimate - 86 to 352 TWh pa energy requirement)

Options for Industry

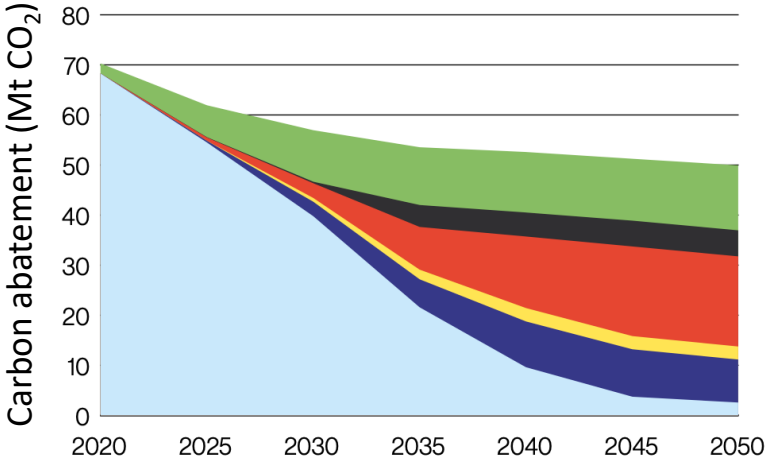
- Substantial energy requirements across a wide range of processes
  - Around 50% of emissions are in geographical clusters (eg Grangemouth, Humberside)
- Innovation in advanced technologies, fuel switching, CCS, digital technologies
- Trade policies and potential export opportunities
- Skills transition / potential
- Pathway determined by individual choice
  - Location / business model / choices made by surrounding sites

(2050 estimate - 73 TWh pa energy requirement)

Cluster networks – UK industry

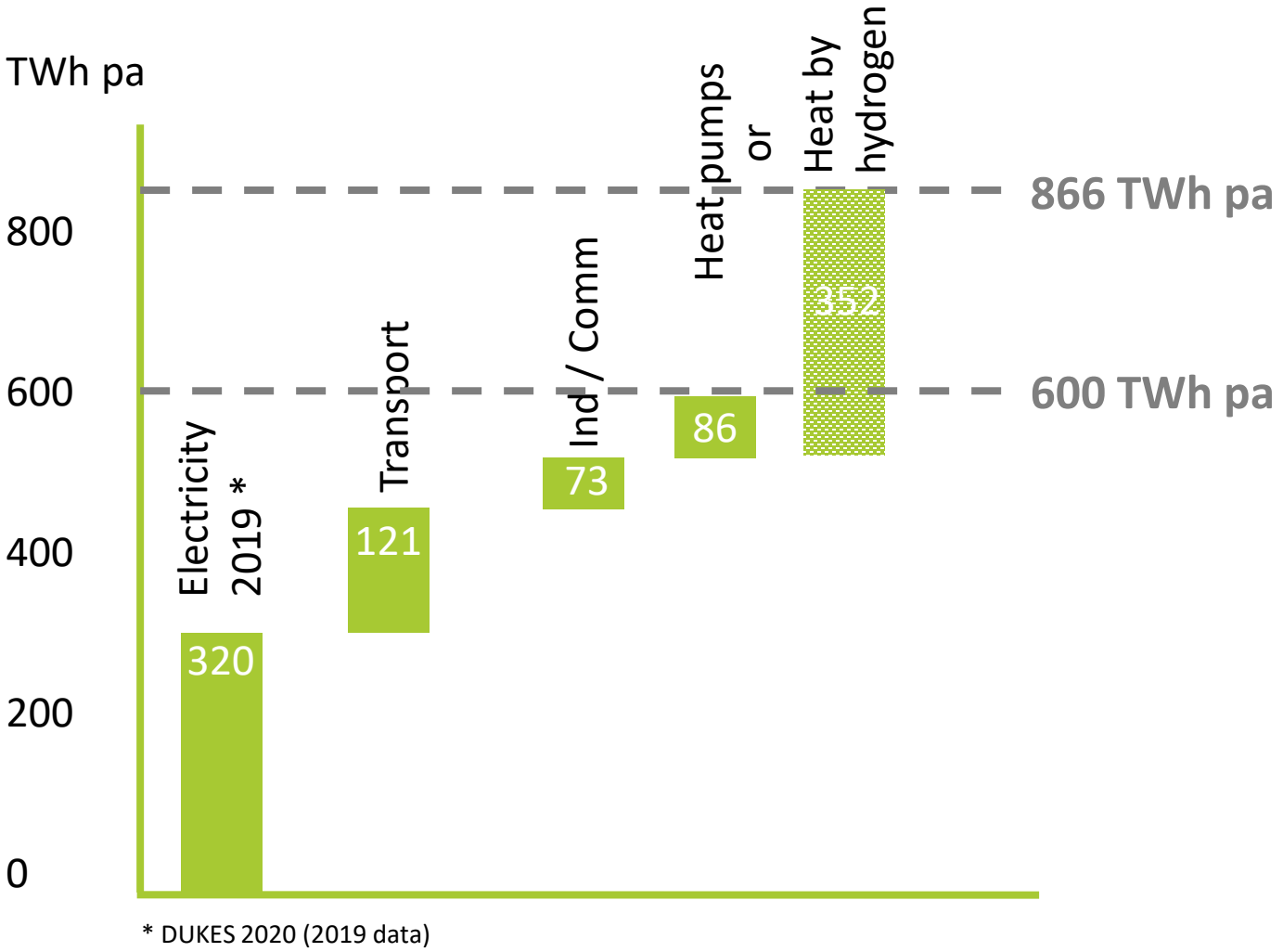


National networks – UK industry



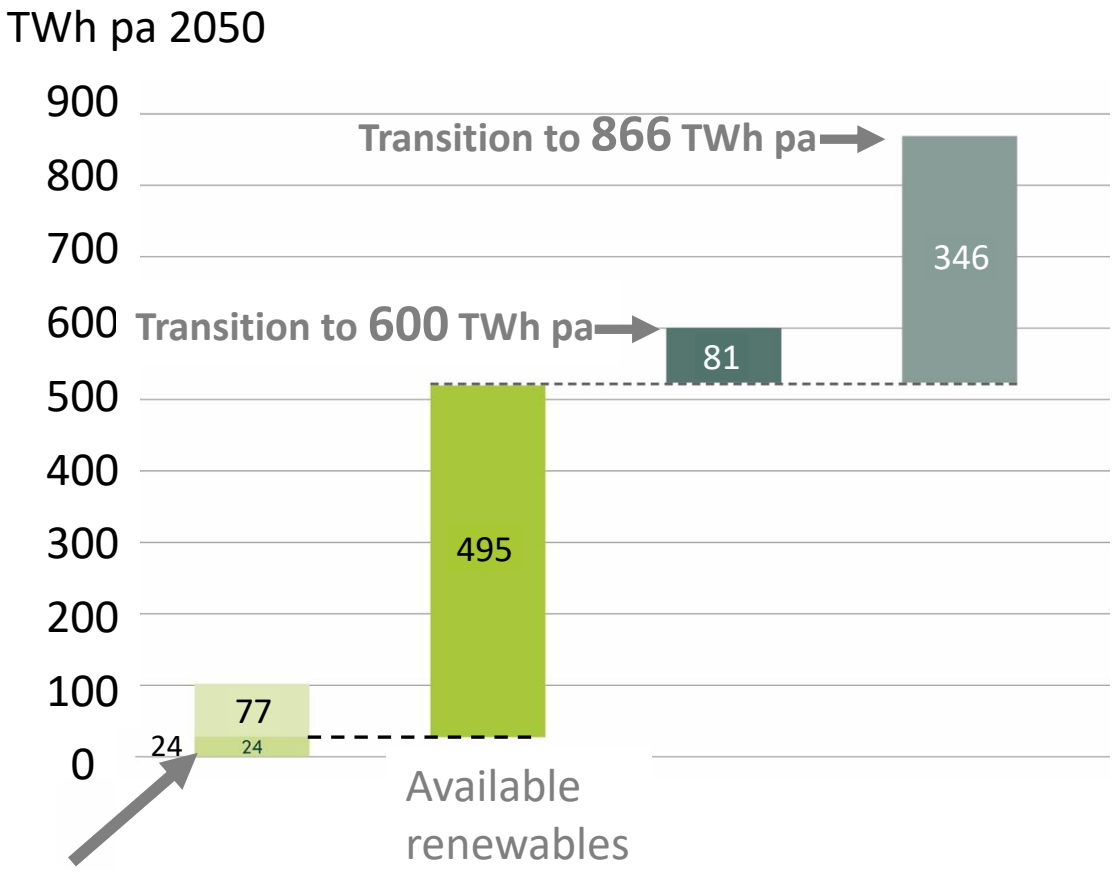
Industrial Decarbonisation Strategy, March 2021

Electricity requirements (2050)



* DUKES 2020 (2019 data)

Requirements vs availability (2050)



Existing renewables (77 TWh pa) – assume re-power by 2050
Sustainable power under development (24 TWh pa) - Hinkley Point C

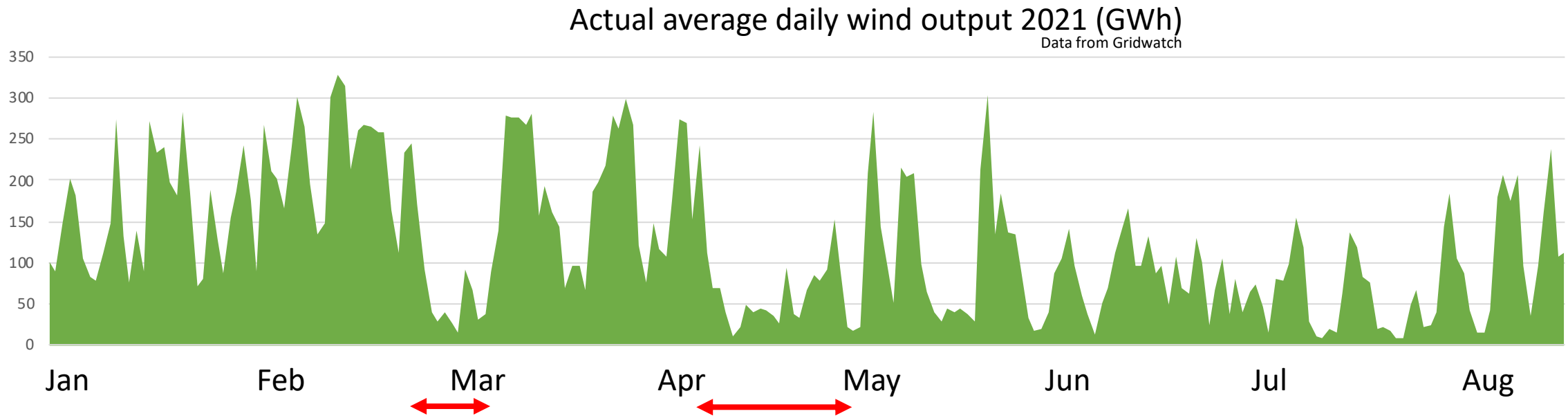
Policy paper
British energy security strategy
Updated 7 April 2022

24 GW nuclear by 2050 (~185 TWh pa)
50 GW wind by 2030 (~220 TWh pa)

Equates to -
around 7.5 x 'Hinkley C' nuclear stations
+ 38 x 'Hornsea 2' windfarms

Potentially achievable - an impressive challenge - even greater when repowering is considered

The 2050 system capacity challenge



11 days
~ 557 GWh total delivered
~ 16,500 GWh req'd (2050)

18 days
~ 932 GWh total delivered
~27,000 GWh req'd (2050)

- Renewables outputs are driven by variable (and changing) climate conditions
- Prolonged periods throughout the year with low renewables output
- Scale of requirement + consecutive lows provide a serious challenge for energy storage capacity

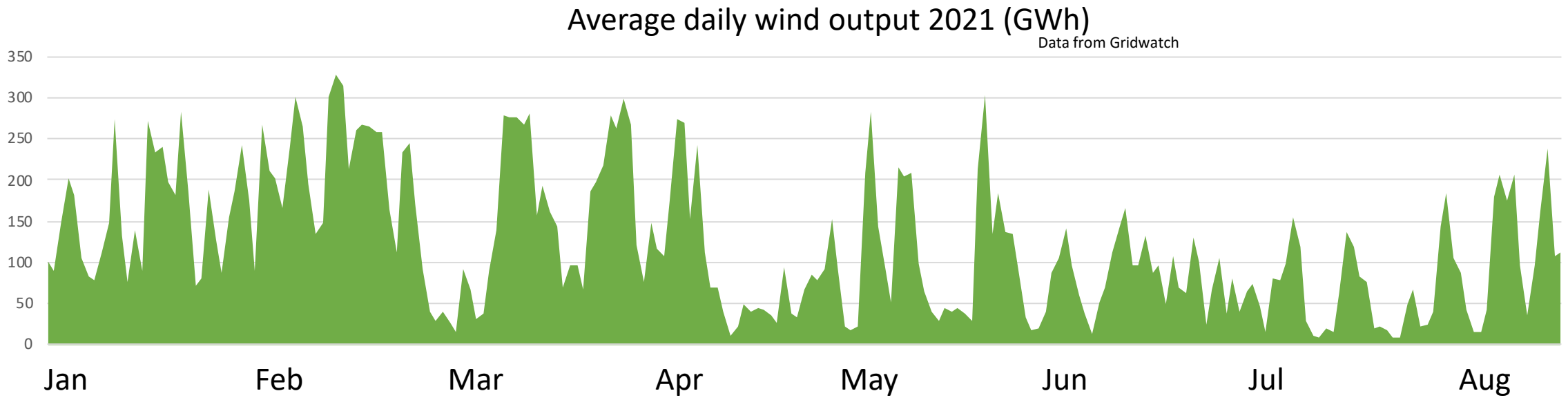
Potential energy storage opportunities

	Intra-day	Inter-day / season
Electricity	○ Vital for balancing / grid services (frequency, inertia etc.) ○ Hydro, batteries, compressed air, gravity, VTG etc. ○ Valuable at domestic and commercial scale	○ Scale becomes prohibitive
Hydrogen	○ Vital for balancing production and use ○ Challenging round trip efficiency for electricity generation	○ Vital for balancing production and use ○ Is inter-seasonal storage scale realistic?
Heat	○ Valuable at domestic and commercial scale ○ Challenging round trip efficiency for electricity generation	○ Valuable at domestic and commercial scale ○ Challenging round trip efficiency for electricity generation

Energy storage of all forms will be important – but large inter-day / season storage capability is particularly challenging

Returning to the system capacity challenge

using the ‘existing’ Rough gas storage facility for illustration



11 days
Approx 1,450 GWh / day gap (2050)

18 days
Approx 1,450 GWh / day gap (2050)

3 x Rough gas storage capacity (H_2 to elec) — then — 5 x Rough gas storage capacity (H_2 to elec)

Rough can deliver 1.5 billion Cu Feet gas per day – equates to approx 80 GWh / day of electricity (H_2 to elec)

Storage will be a vital component of the 2050 system, but what scale is it realistic to plan for?

Potential non-intermittent electricity supplies

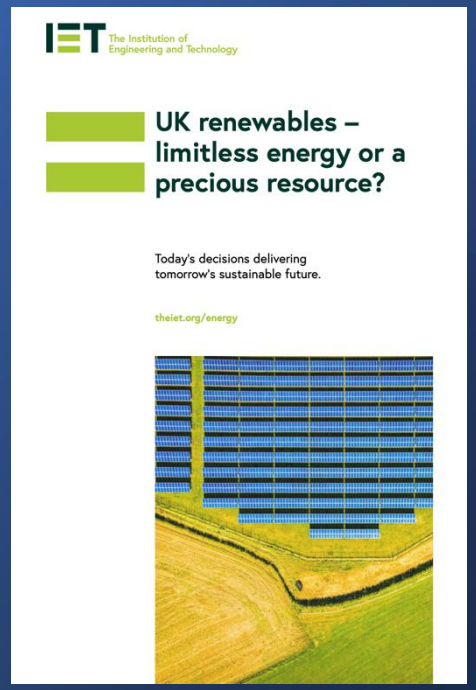
	Positives	Negatives
Natural gas	○ Readily available technology for peak power generation	○ Consolidates dependence on fossil fuels, even with CCS ○ Limits energy independence ○ Exposed to volatile markets
Biofuels	○ Absorbs atmospheric CO_2 ○ Negative emissions possible with CCS	○ Planting, harvesting, transport, processing incur emissions ○ Vast quantities needed, mostly imported ○ Limits energy independence ○ Potential habitat and food chain impacts ○ Competition from other applications
Nuclear (fission)	○ Controllable output, potentially stable prices ○ Potential for development of modular plant	○ Not 'renewable' but 'sustainable' ○ Imported materials, albeit low volumes ○ Requires new, safe long-term storage ○ Societal concerns

Potential 2050 capacity requirement ~ 100 GW

Summarising – limitless energy or precious resource?

- Renewables resources (TWh) challenging but possible
- They are precious - efficient design and energy use
- Limited non-intermittent capacity options
  - Biofuels, natural gas (with CCS), nuclear
  - Storage is important - inter day / season is a challenge
  - Major nuclear power capacity component (large and small designs)
- Securing intermittent renewables is challenging
  - Sustain a ~100GW system using ~2 TWh / day
  - Provision shapes system design / services etc.

Is the challenge about the integration of renewables, or designing an architecture to incorporate renewables?
Profoundly impacts transition and outcomes - technical / commercial / societal



Report Recommendations

Strategic direction is vital

- Consistent direction
- Whole system coordination and accountability – not currently a feature

The scale is huge

- Step change in planning, investment, engagement and action

Technology exists

- We have the technology for heat, transport and industry
- We have smart applications for management and control
- Must integrate the human dimension

Focus on energy efficiency

- Energy efficiency is vital to reduce the scale of assets and costs
  - As a fundamental system design characteristic
  - For buildings

Transition can help energy independence

- Move from fuel-based costs to asset-based energy costs
  - More stable prices
  - Greater energy independence

However it's not just about technology - there are many dimensions…

Some non-technical factors -

Social

- Can we create products that people want to buy?
- Media / social media influence?
- Are society's decisions rational or emotional?

Political

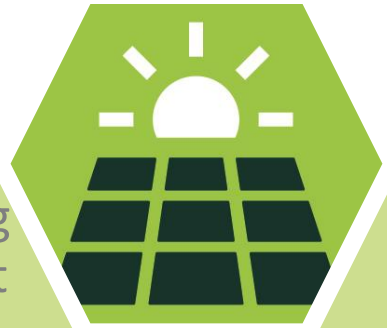
- Energy costs / inequality?
- How might the politics play out?
  - Short / long term imperatives?
  - New populist movements?
  - Climate change deniers?
- Can COP 27 show confidence in the international system?

Economic

- Is the transforming 'energy ecosystem' being properly considered?
  - skills
  - materials
  - unintended political consequences?
- Risk sharing - should Ofgem's RAB model be extended?

Encouraging signs…

Bright young people want jobs in low carbon companies



Growing percentage of industry with plausible reduction targets

Investors protecting against diminishing value of carbon assets

More people relating to climate change

Energy is now seen as important

Perhaps we have the capability to build a world that is better than any world we've had before!

Survey

Questions

- Over to you…

The Institution of Engineering and Technology

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