Energy: a sustainable future built on an unsustainable past

Jon Gluyas

Durham Energy Institute

Integrity Engineering for a Sustainable Future

NEIMME-ICorr Conference, Neville Hall, Newcastle
22nd – 23rd June 2023

Jon Gluyas

- Geologist
- 28 years in petroleum industry
  - BP, Monument, Lasmo
  - Founded Acorn Oil & Gas, Fairfield Energy and Steam Oil Production Company
- 13+ years in academia
  - CCS, geothermal energy, human induced seismicity, helium & hydrogen exploration
  - Founded energy transition company: GeoEnergy Durham
  - Founded Earth observation companies: Geoptic, TerraMotion
  - Founded helium exploration companies: Helium Resources (Europe), Green Helium (Canada), Peak helium (Aus) and Global Helium (Aus)
  - Hydrogen exploration company in formation

Jon Gluyas – alternative cv

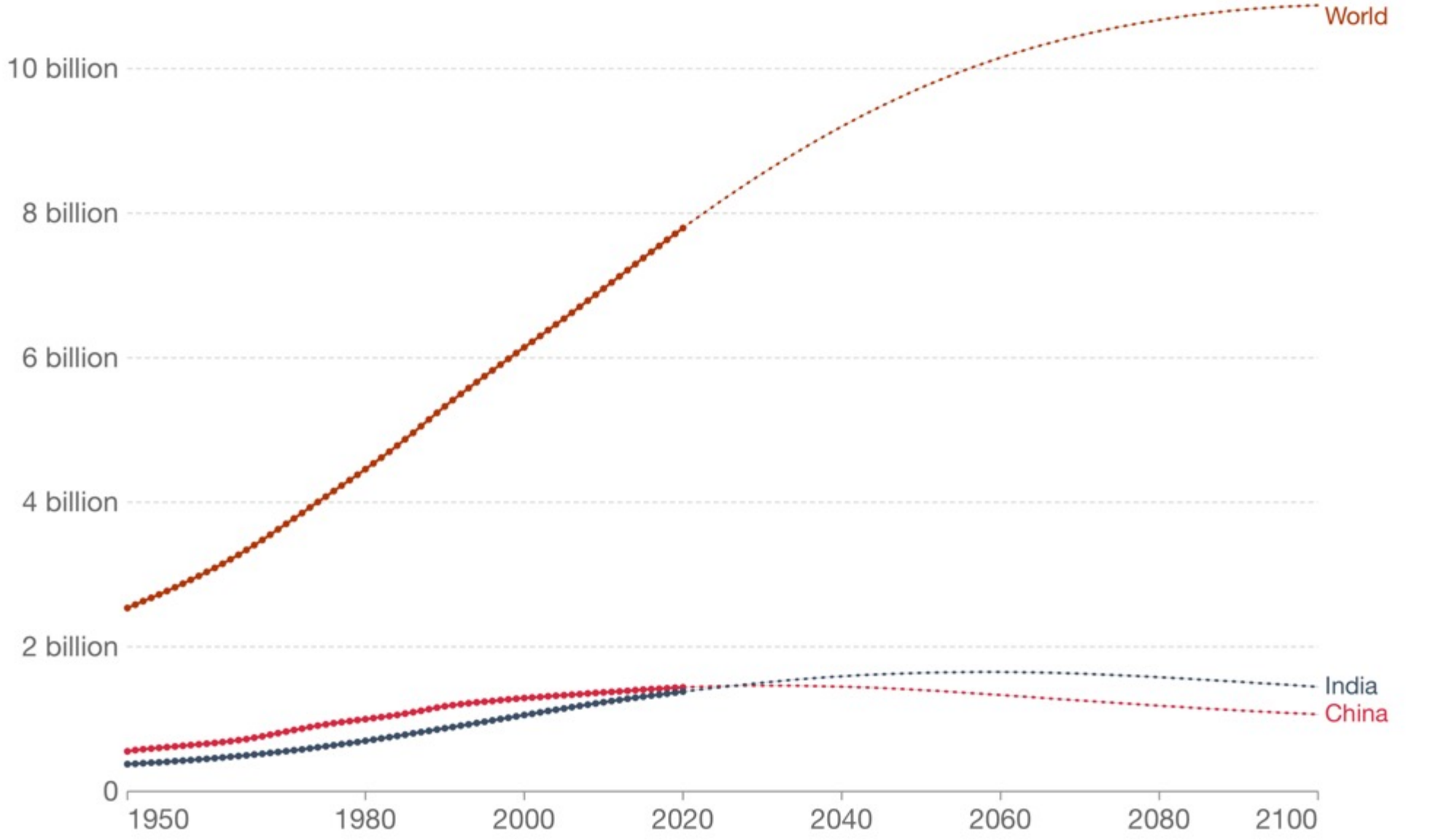
- Geologist
- 28 years getting carbon out of the ground
- 13+ years trying to shove it back in

Durham University
Durham Energy Institute

GLOBAL POPULATION

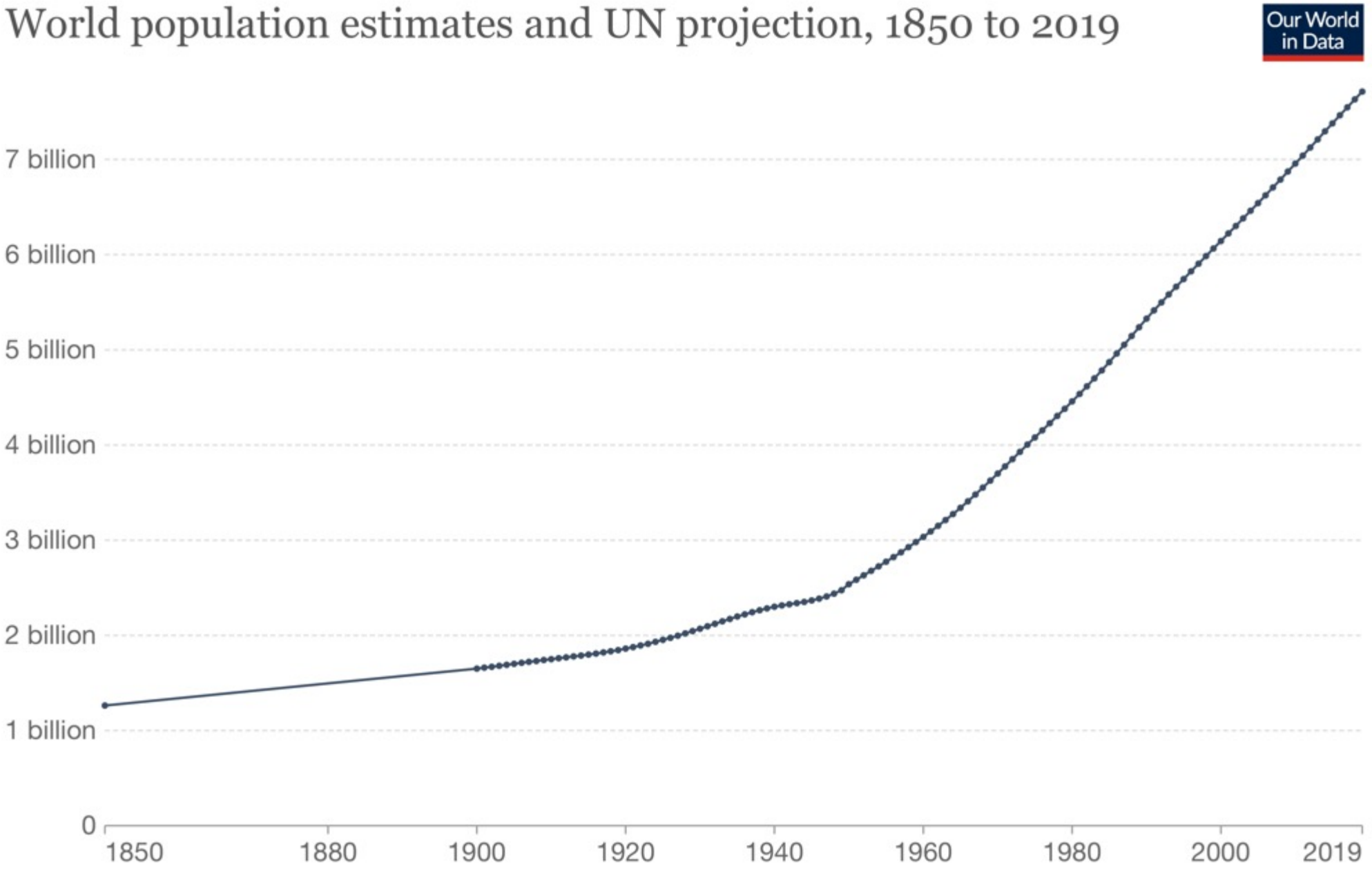
Historic and projected population

Past and projections of total population from the UN's medium fertility growth scenario.



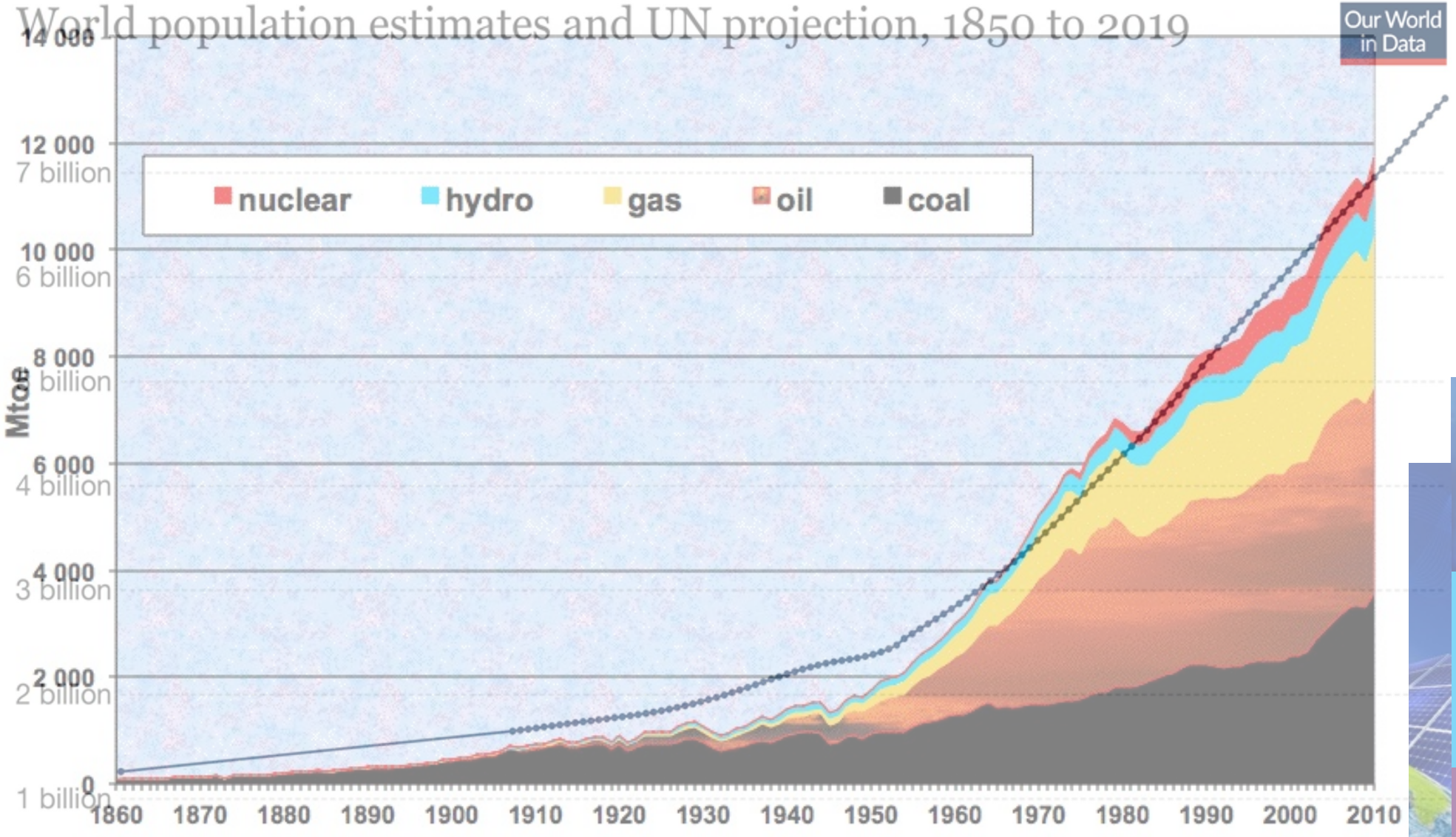
Source: United Nations – Population Division (2019 Revision)

World population estimates and UN projection, 1850 to 2019



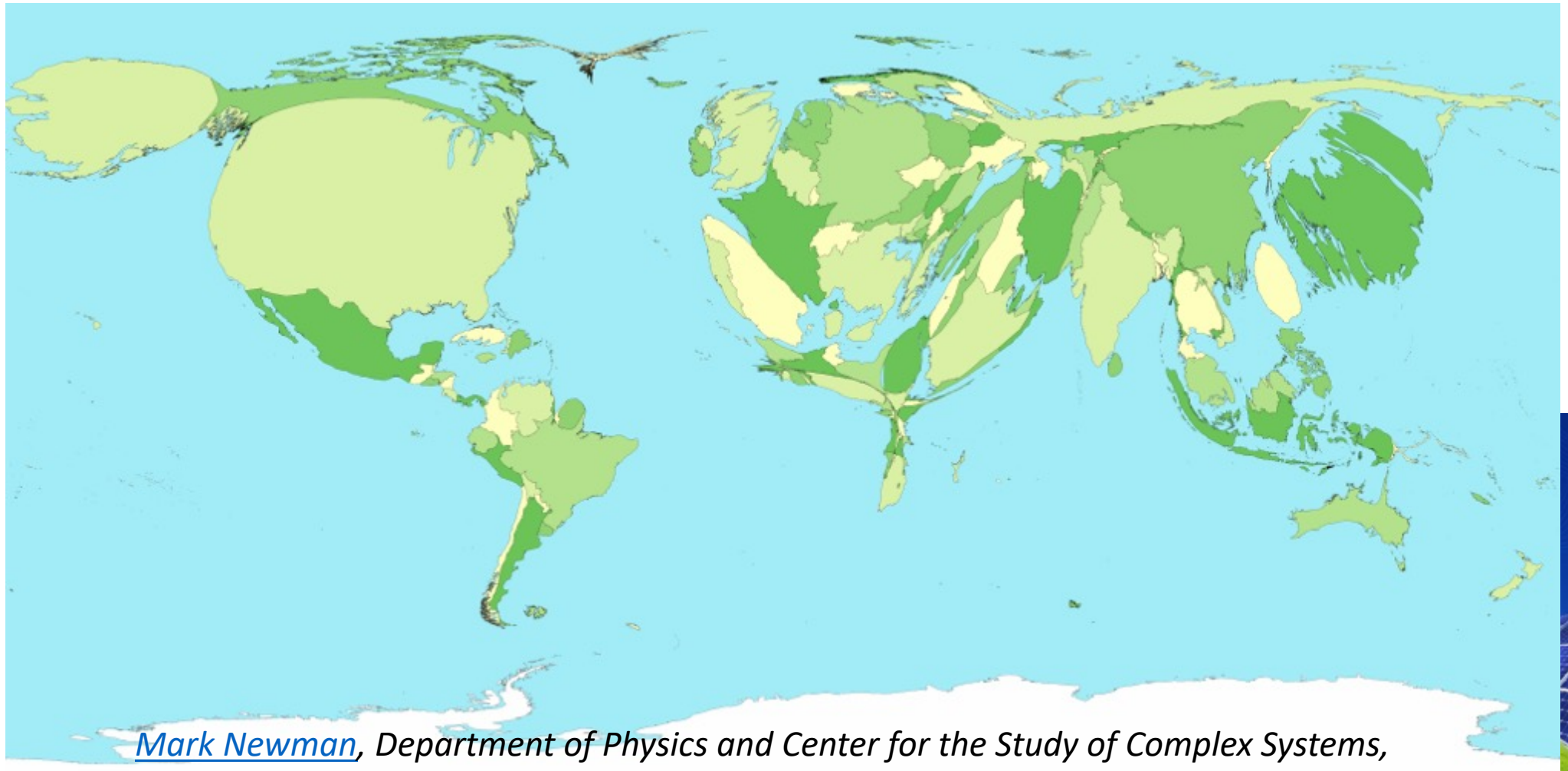
Source: World Population over 12000 years - various sources (2019), Medium Projection – UN Population Division (2019 revision)
OurWorldInData.org/world-population-growth/ • CC BY

Growth of energy use



Durham University
Durham Energy Institute

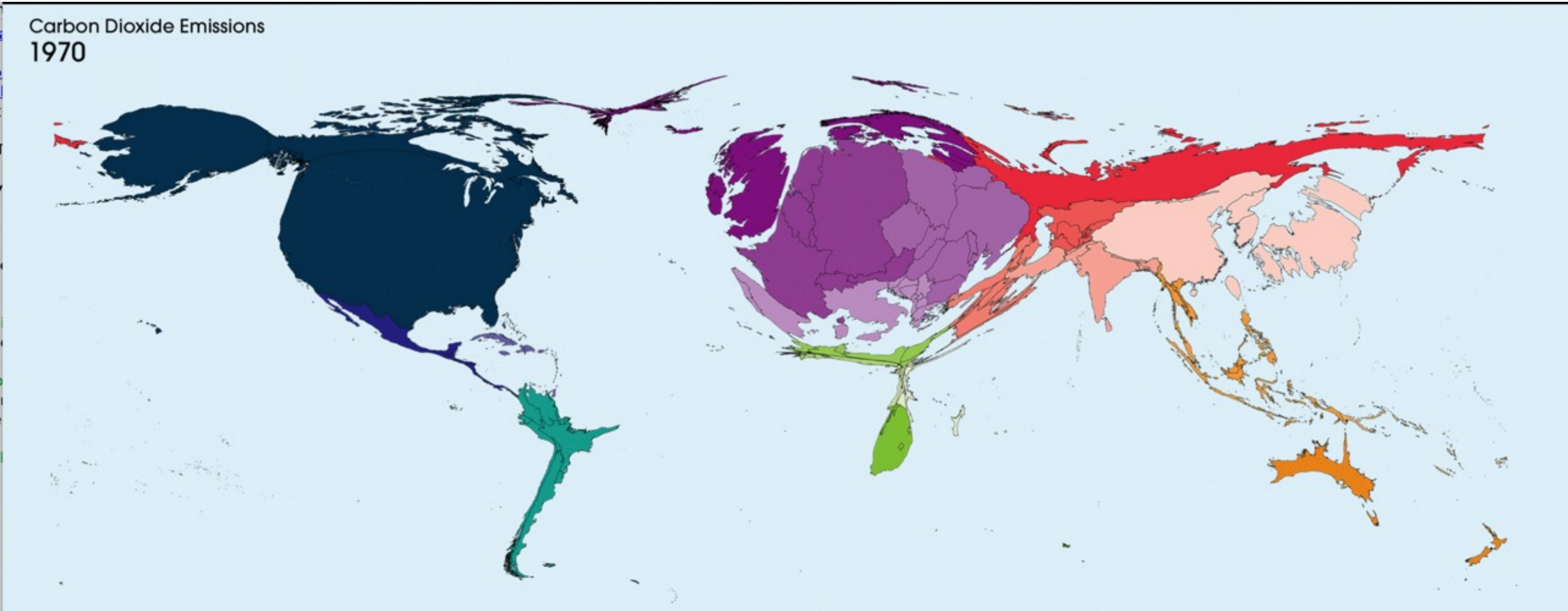
Energy consumption



Mark Newman, Department of Physics and Center for the Study of Complex Systems, University of Michigan
Email: mejn@umich.edu
Updated: April 22, 2009

Durham University
Durham Energy Institute

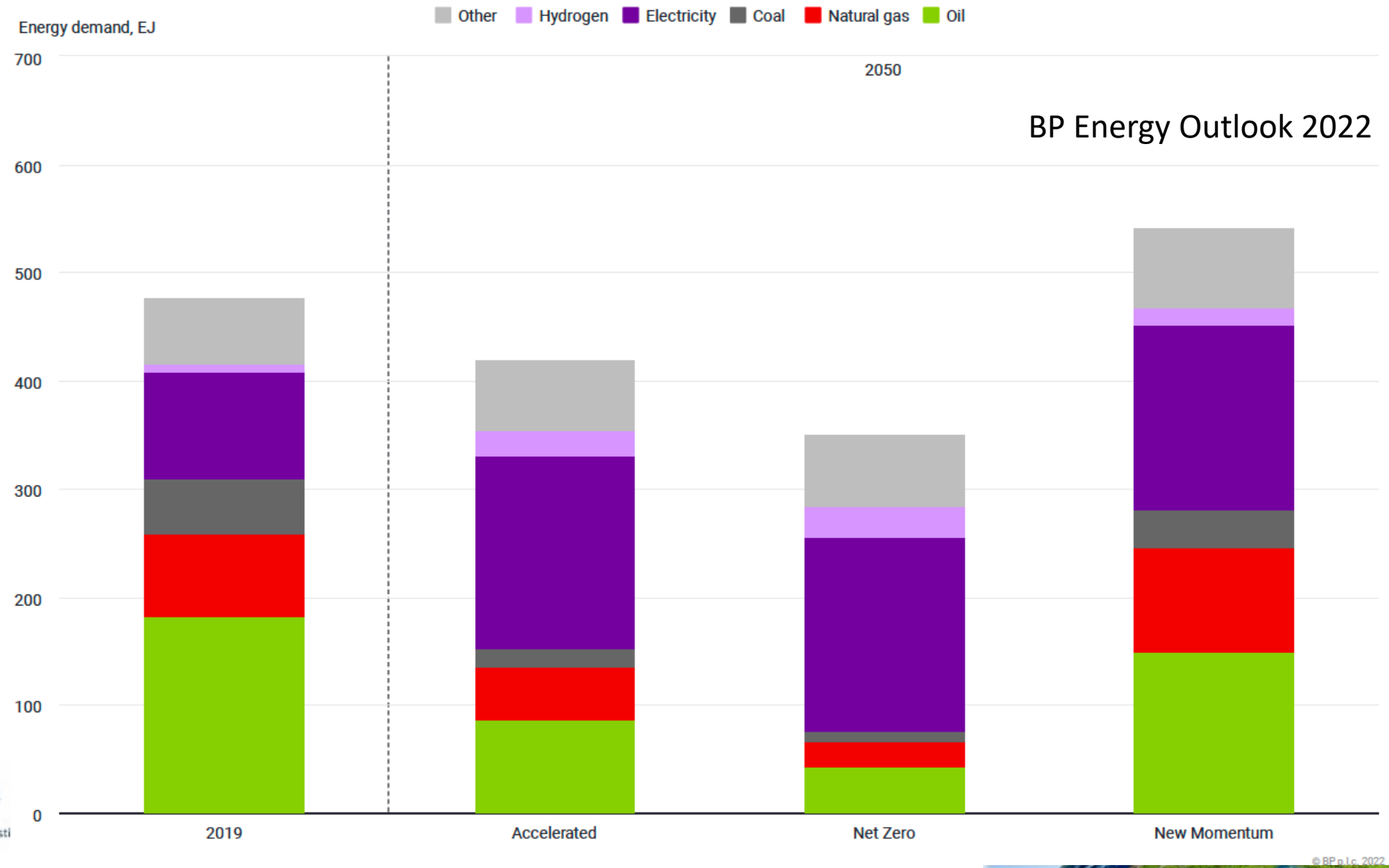
Energy demand as CO_2 emissions



Durham University
Durham Energy Institute

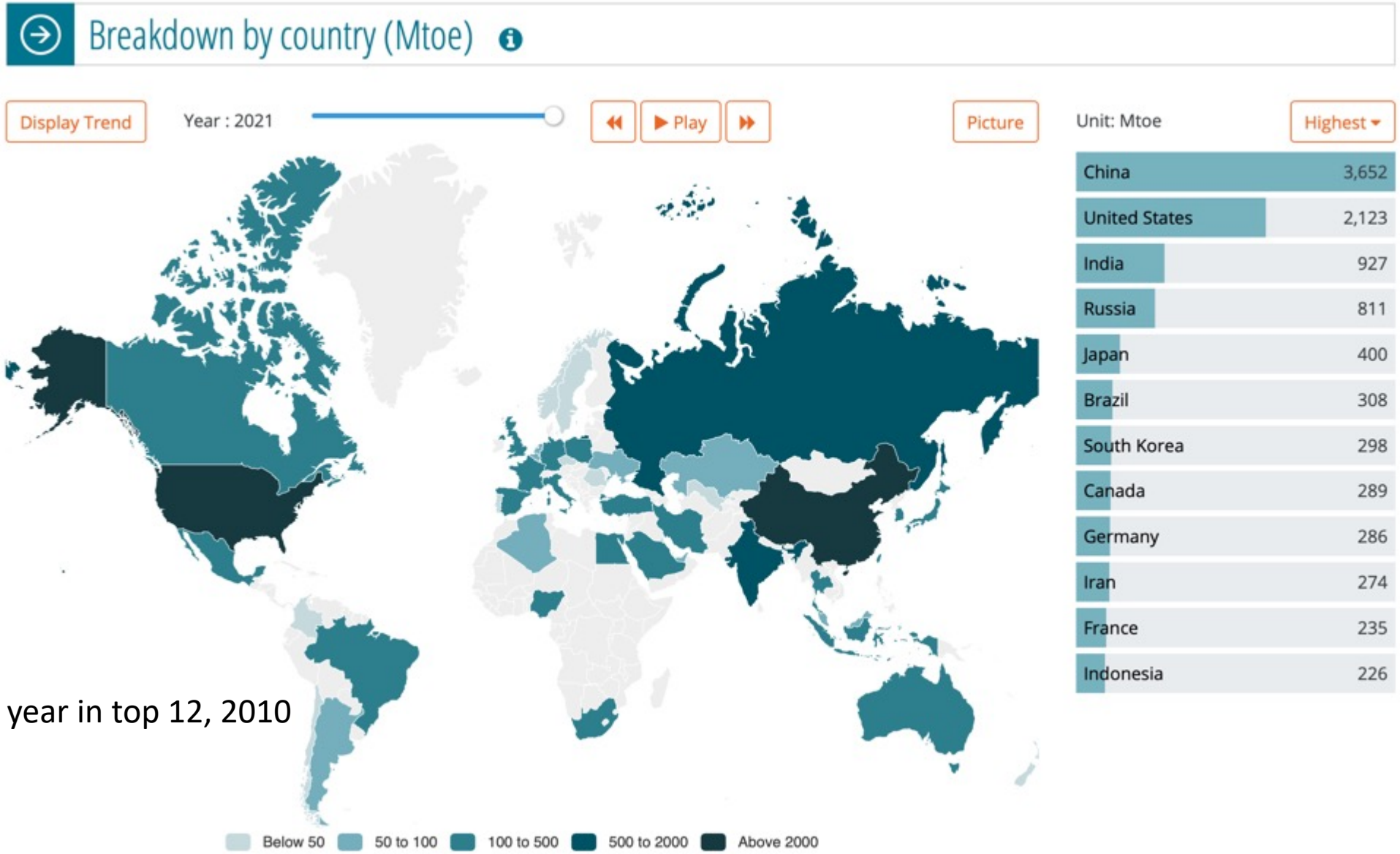
HOW MUCH ENERGY DO WE USE?

Energy Demand



Durham University
Durham Energy Insti

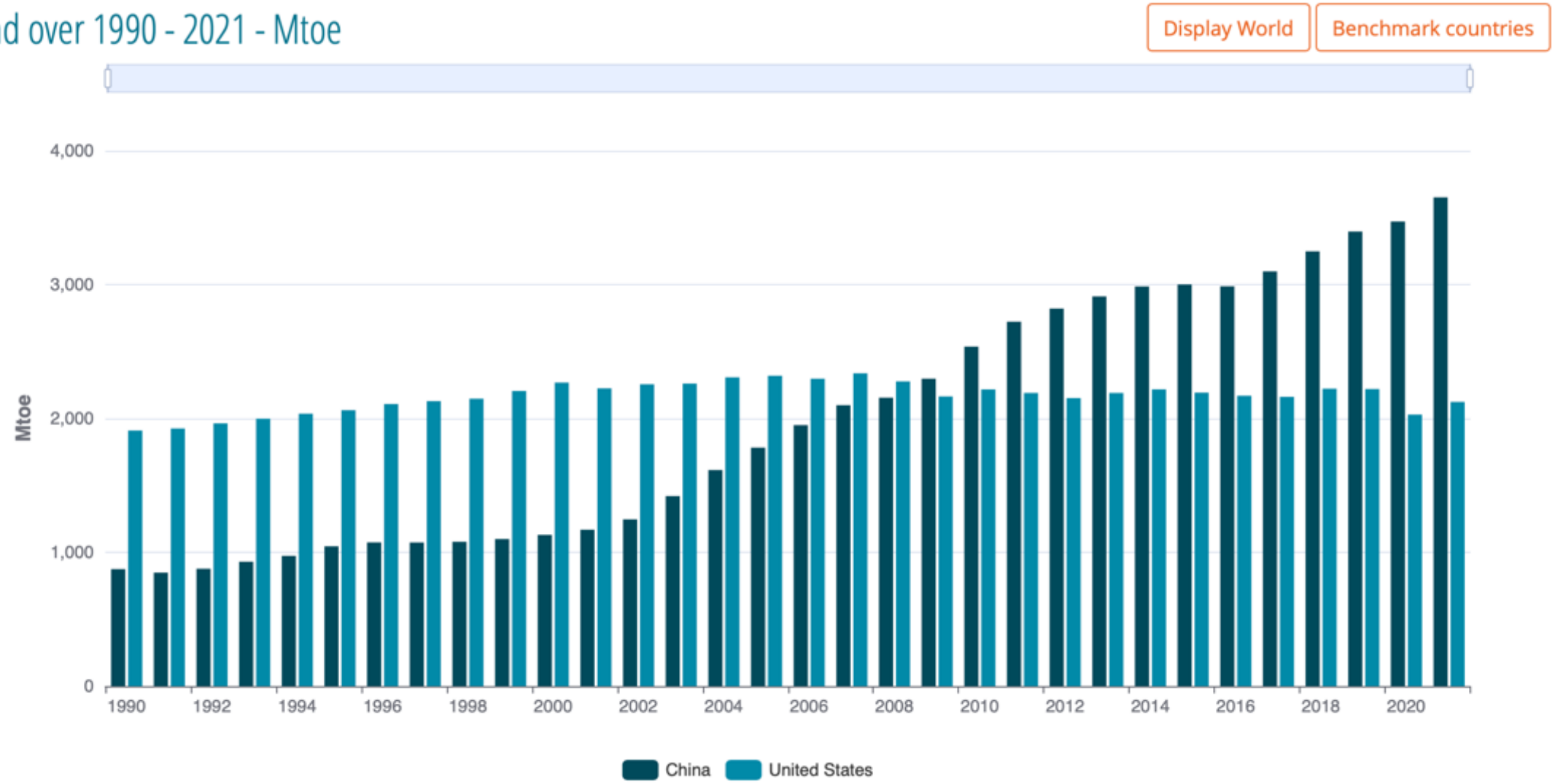
Energy consumption 2019



UK last year in top 12, 2010

Enerdata World Energy & Climate Statistics Yearbook 2022

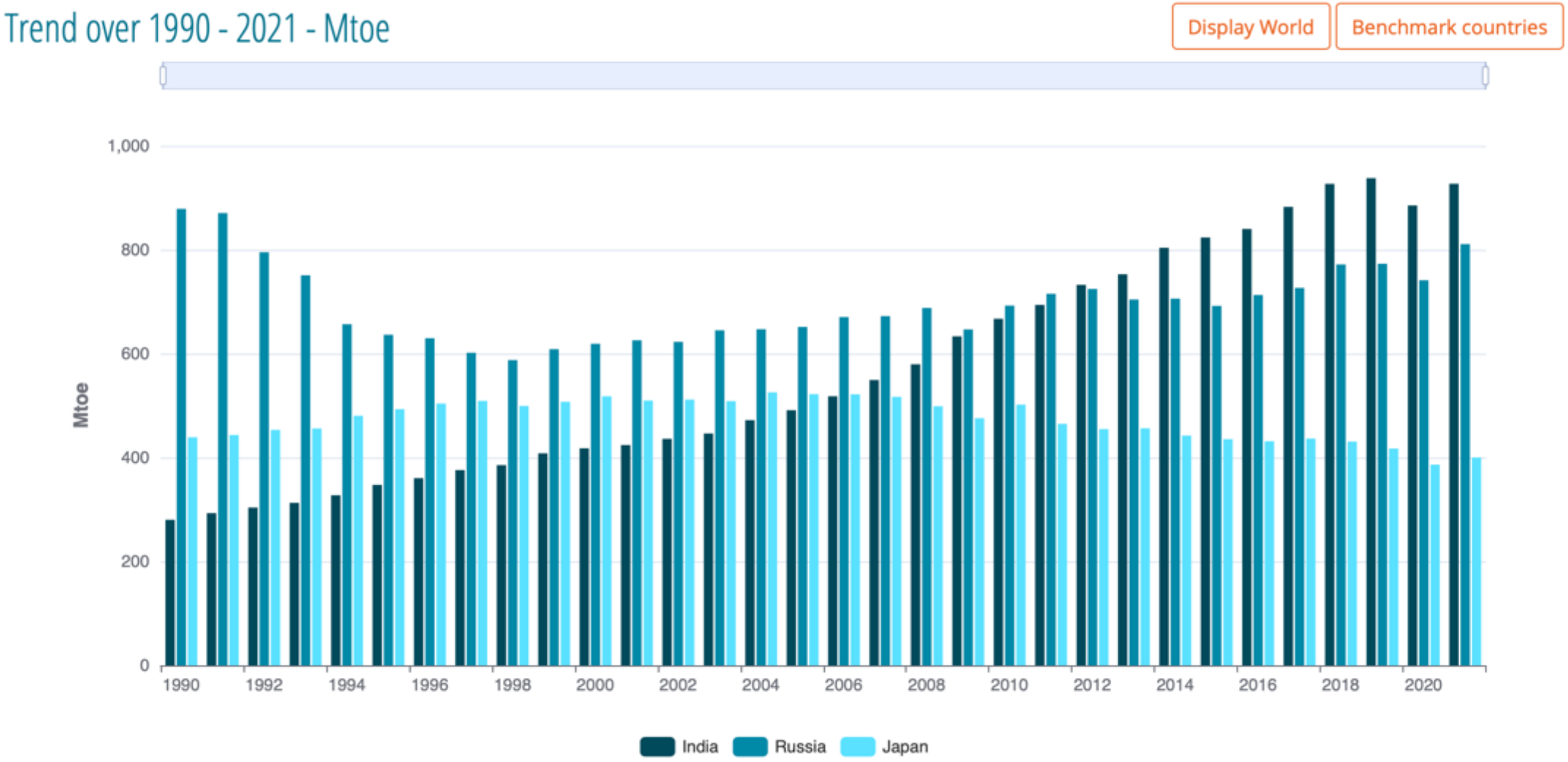
China & the USA



Durham Energy Institute

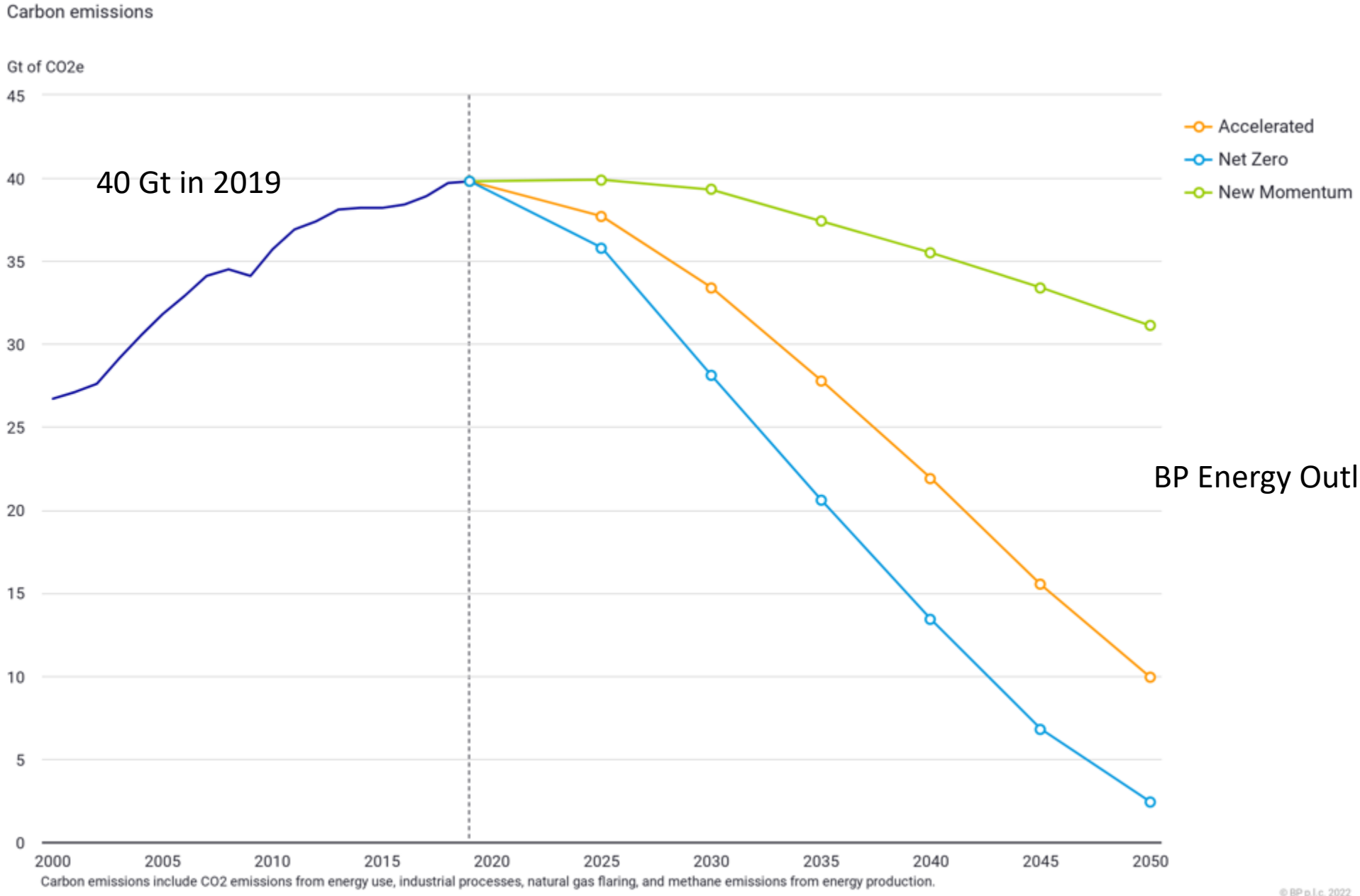
Enerdata World Energy & Climate Statistics Yearbook 2022

India, Russia, Japan



Enerdata World Energy & Climate Statistics Yearbook 2022

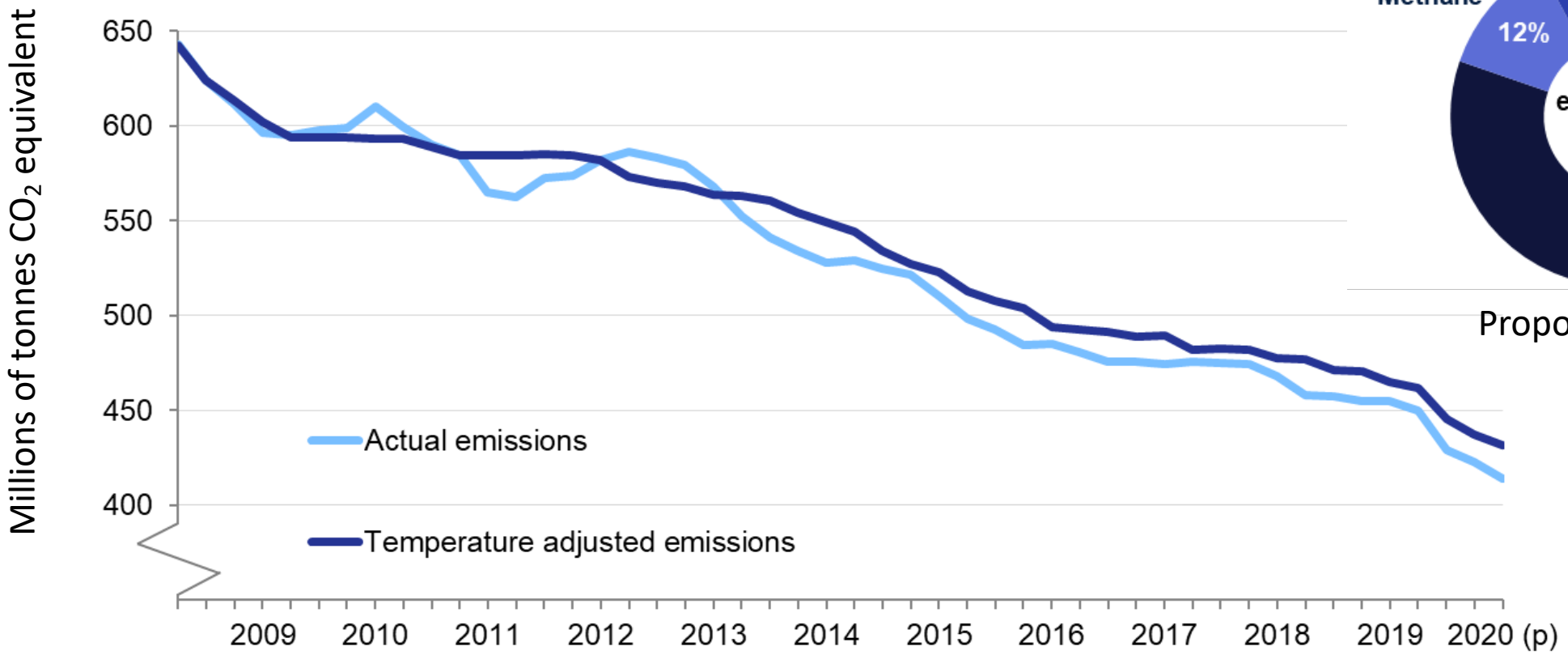
CO_2e emissions

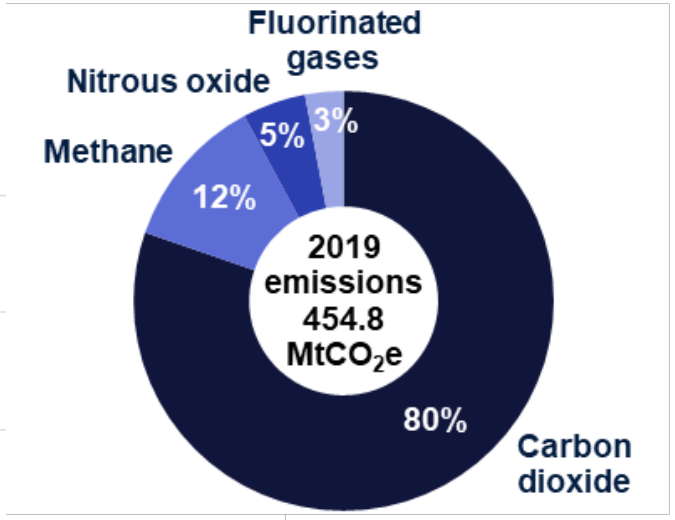


BP Energy Outlook 2022

Durham University
Durham Energy Institute

Emitting less - decarbonisation of the UK Economy

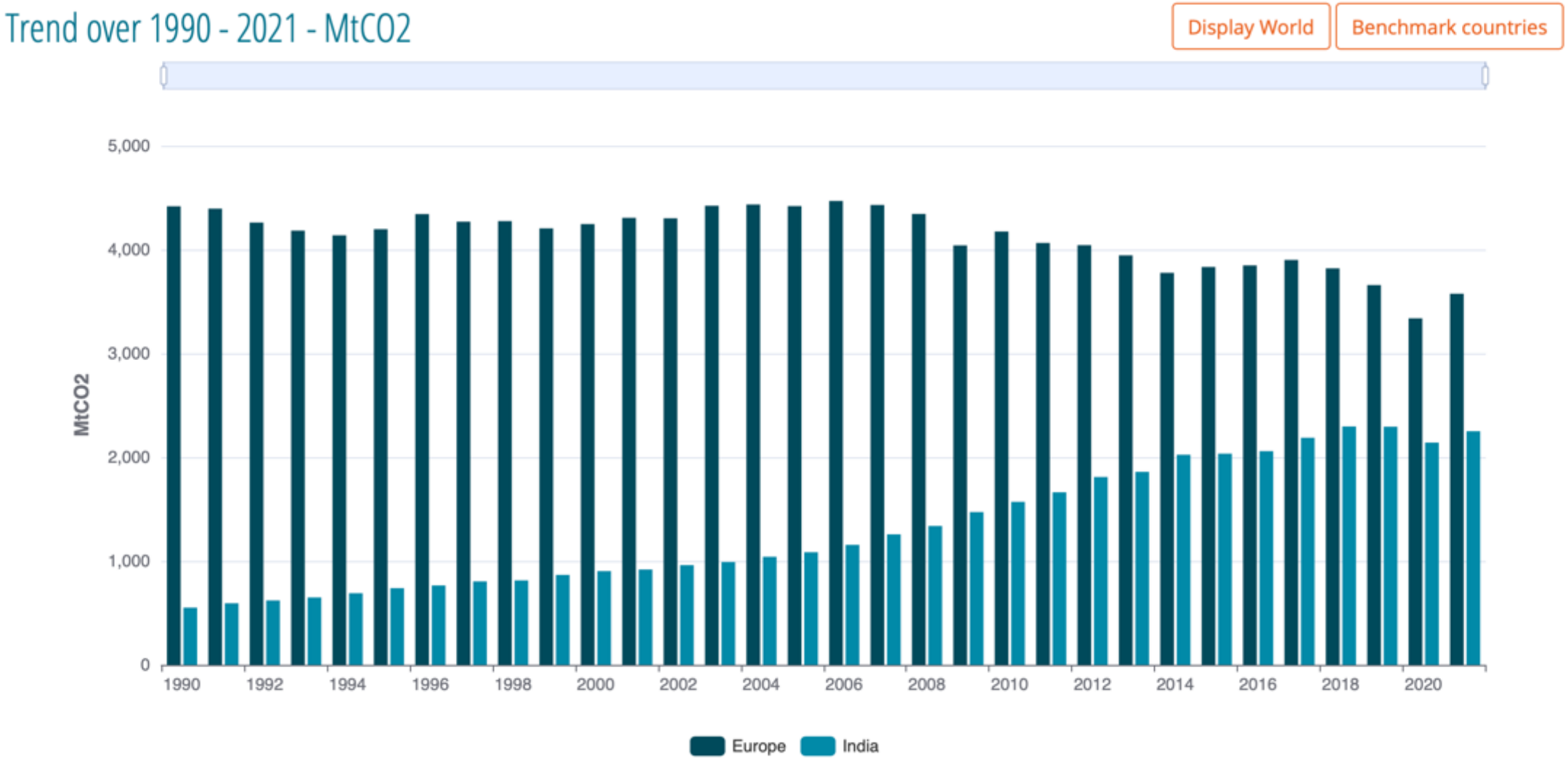




Proportions 2019

BEIS March 2021

CO_2e emissions Europe, India



Durham University
Durham Energy Institute

CONSEQUENCES OF FOSSIL FUEL USE

Earth – bursting at the seams

- Biosphere - Extinction rate
  - Background 1 species per million species per million years
  - Today x10 to x100
- Hydrosphere – Ocean acidification
  - Tipping point on calcite skeletal matter
- Atmosphere – GHG emissions
  - Temperature rise
  - Weather patterns
  - Sea level rise
- Geosphere
  - Induced seismicity, subsidence & elevation

Durham University
Durham Energy Institute

DELIVERING A JUST ENERGY TRANSITION

What is net zero (carbon)

- a target of completely negating the amount of greenhouse gases produced by human activity, to be achieved by reducing emissions and implementing methods of absorbing carbon dioxide from the atmosphere.
- Eliminate emissions &
- Offset emissions
  - Direct air capture of CO_2
  - BECCS (BioEnergy & CCS)
  - Plant things

Is net zero achievable?
Energy density (Mj/kg)

• Uranium	80,620,000
• Thorium	79,420,000
• Hydrogen	142 but low physical density
• Methane	55.5
• Gasoline	44.4
• Coal	24
• Wood	16.2
• Lithium Battery	<0.875
• Lead acid battery	0.17
• Cooling water by 30℃	0.126

National Academies (USA) – say yes!

- Policy
- Investment
- Commitment by:
  - Government
  - Industry
  - People

Low/zero carbon renewable and sustainable

- Wind – renewable and sustainable
- Solar PV – renewable and sustainable
- Solar thermal – renewable and sustainable
- Wave – renewable and sustainable
- Tidal - renewable and sustainable
- Biofuels –sustainable and renewable
- Hydropower – sustainable and renewable
- Geothermal – sustainable
- Nuclear fission – sustainable?

17% of global energy in 2021

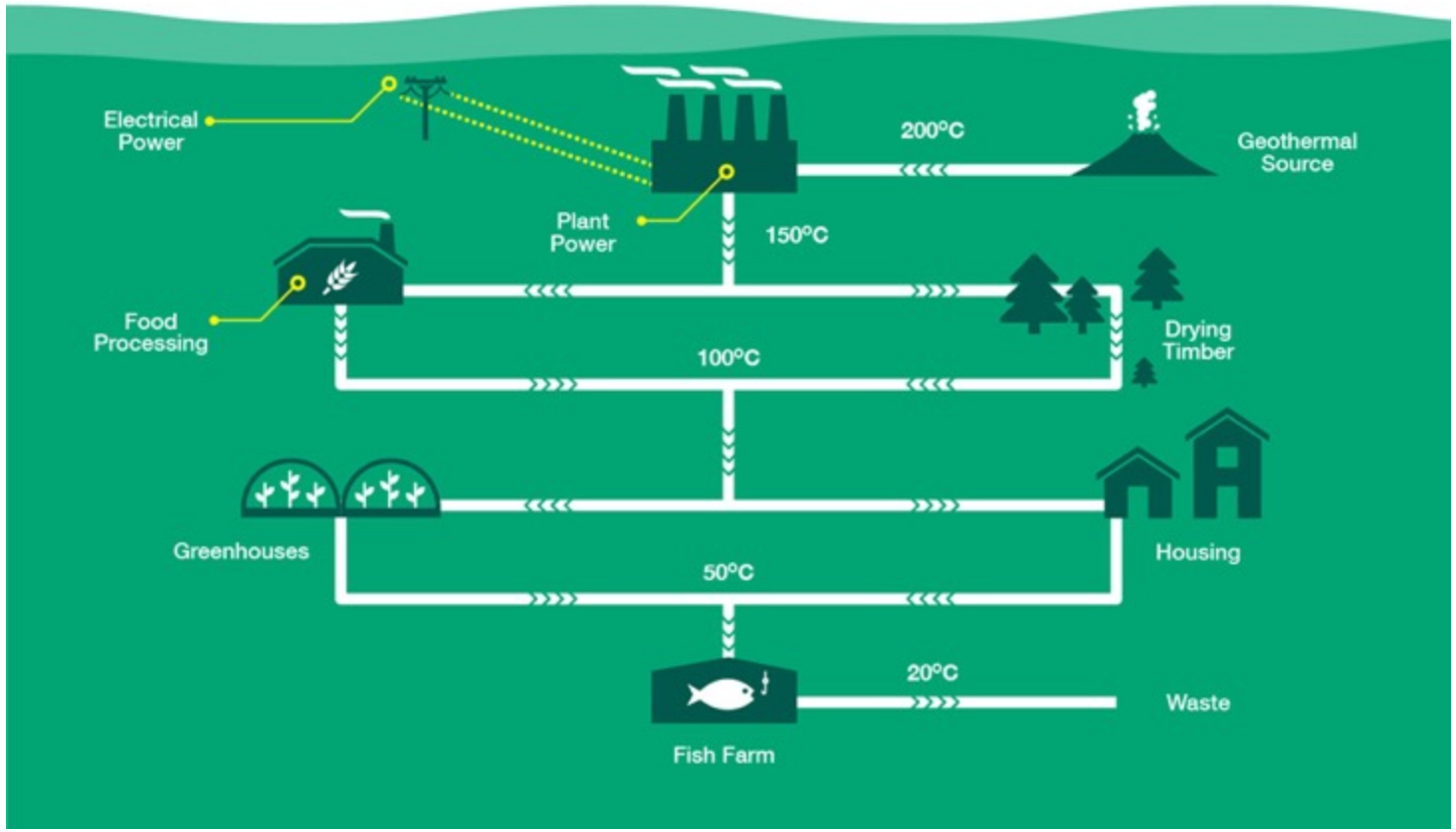
Can there be a circular economy in energy?

- Energy materials – yes
- Energy – no
  - Forbidden by the laws of thermodynamics
  - But we can make much better use of the energy we have
  - Example, gas fired power station converts only 50% of the energy in the gas into electricity, the rest is waste heat. So, use the heat.

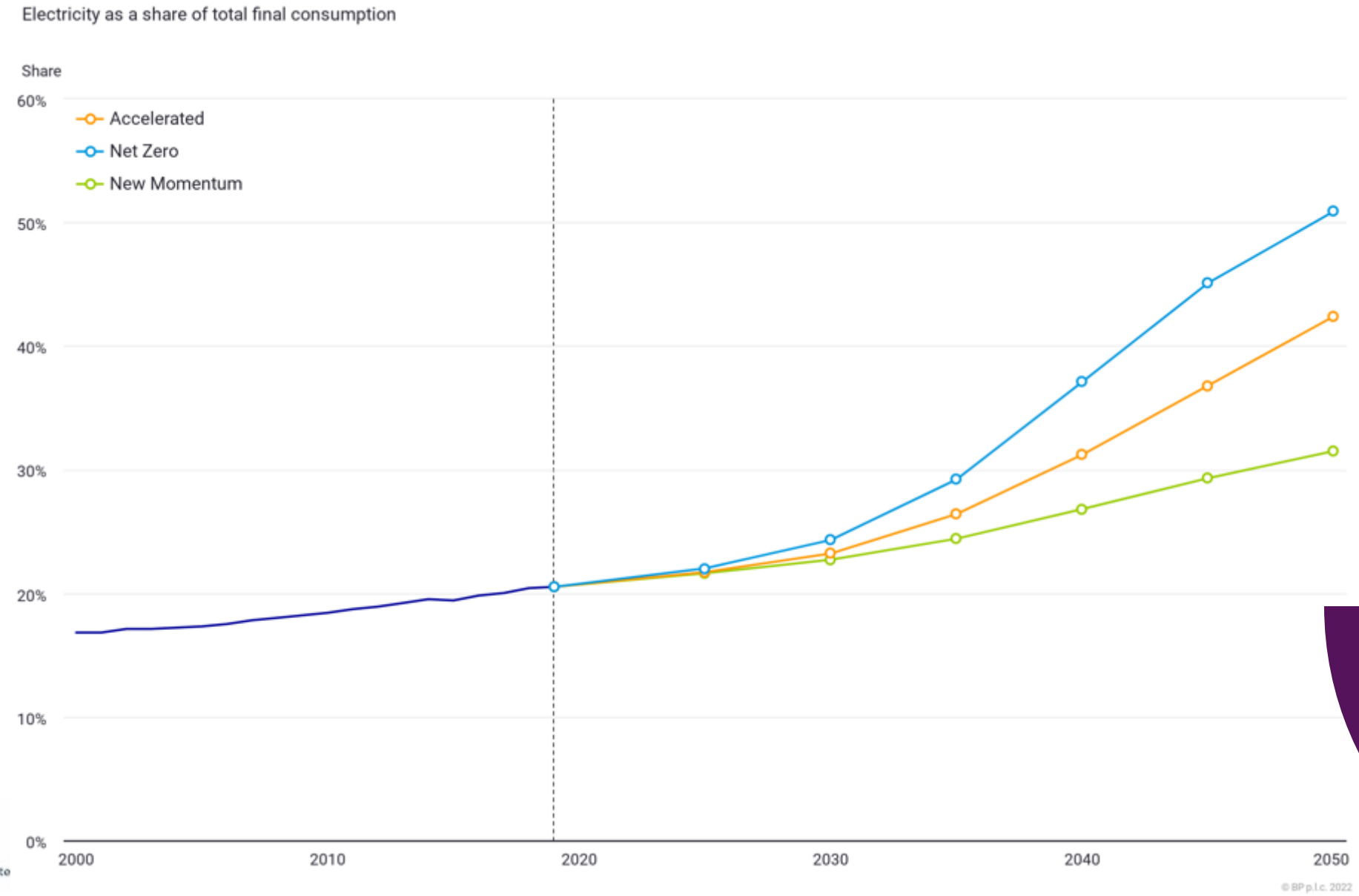
How do we displace fossil fuels?

- Use less
- Waste less
- More wind & pv
- Add wave & tidal
- Harvest solar heat
- Add geothermal
- Heat cascade
- Add hydrogen
- Add thorium fission
- Add fusion

Heat cascade



Electricity supply and demand growth (global)



Durham University
Durham Energy Institute

Increase electricity – UK government's words!

- Use more coal, gas and oil
- Install more low-carbon capacity

UK Government plan – May 2022

- Further utilize North Sea reserves
- A scientific review of shale gas extraction
- 4 new CCS clusters by 2030
- 40% reduction in gas consumption by 2030

https://commonslibrary.parliament.uk/where-will-britains-future-energy-supply-come-from/

UK Government plan – May 2022 – jgg comment

- Further utilize North Sea reserves
  - Makes sense if it is done with low/no emissions
- A scientific review of shale gas extraction
  - A waste of time and money – we have approx. zero technical reserves
- 4 new CCS clusters by 2030
  - Important but peanuts! This might add 10 Mt pa to CO_2 reduction
- 40% reduction in gas consumption by 2030
  - Possible at a stretch but government do not say how

Impact on biodiversity of energy transition

- In truth there are no renewable energy pathways that have zero environmental impact
- …large-scale deployment of renewable energy can have some biodiversity tradeoffs.
- …determining the hidden “green-economic” trade-offs of renewable energy expansion is crucial for understanding better both the role of biodiversity within a Green Economy, as well as the economic costs and benefits that its conservation may yield.

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Renewable energy and biodiversity: Implications for transitioning to a Green Economy

Alexandros Gasparatos[a,*], Christopher N.H. Doll[b], Miguel Esteban[c], Abubakari Ahmed[c], Tabitha A. Olang[c]

Durham University
Durham Energy Institute

ENERGY TRANSITION TECHNOLOGIES

Energy transition technologies

- Wind
- Solar PV
- Geothermal and solar thermal
- Hydro, tidal, wave
- Nuclear fission (and fusion)
- Hydrogen
- Carbon capture & storage
- Development of electricity networks and interconnectors
- Pace of development

Geothermal and solar thermal energy potential UK

- Low grade geothermal heat in granites, saline aquifers and flooded mines could supply UK heat demand for a minimum of 100 years[1].
- Geostorage of solar and waste thermal energy has a potential that exceeds UK heat demand[2].

Drilling for mine water heat, Stanley Co Durham, Photo by S. McDonald

1 Gluyas et al 2018 https://journals.sagepub.com/doi/abs/10.1177/0957650917749693
2 Gluyas et al 2020 https://www.sciencedirect.com/science/article/pii/S2352484720317078

Durham University
Durham Energy Institute

EARTH

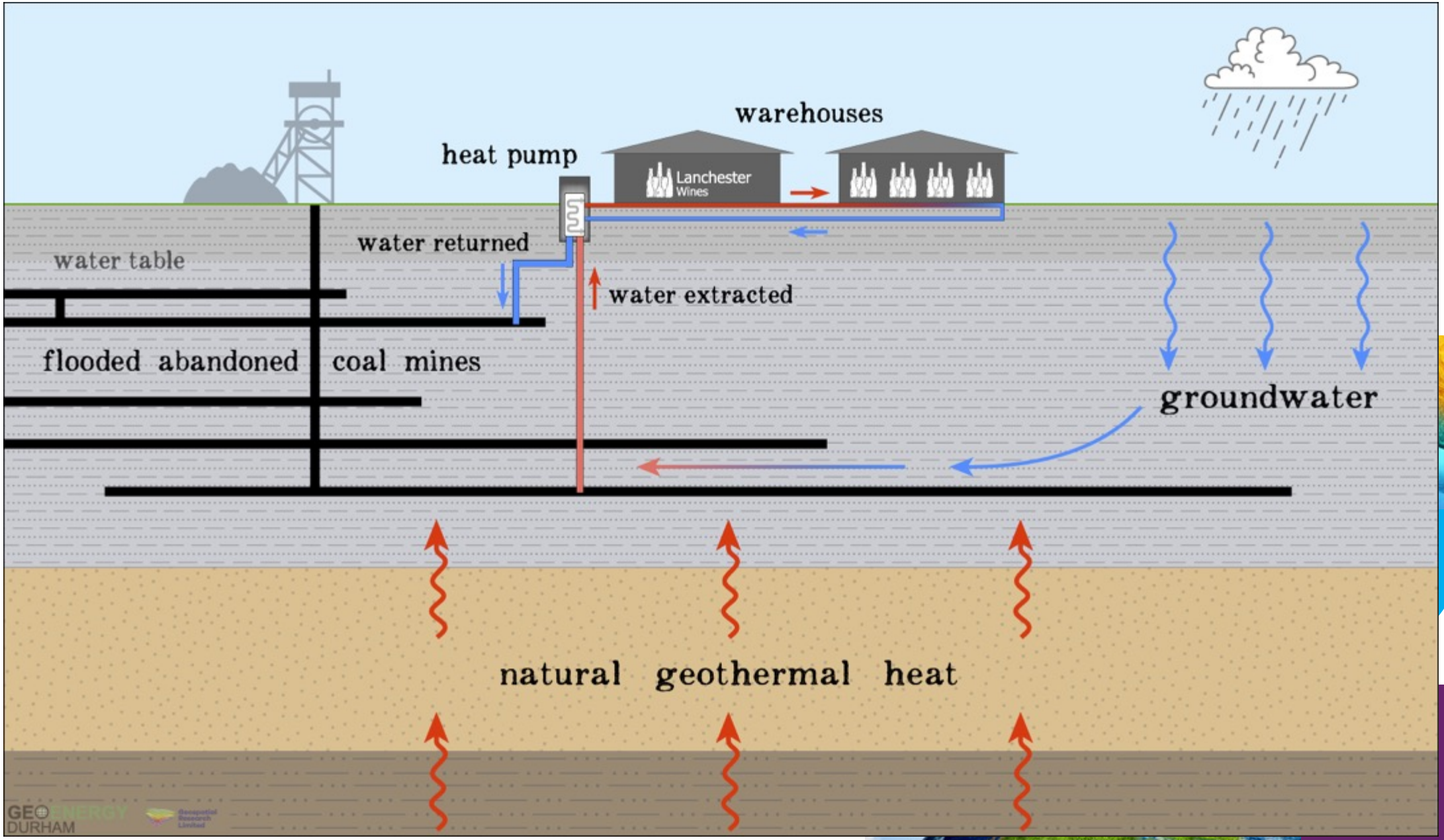
Distribution of coal and people

UK former coal mining areas

England heat demand

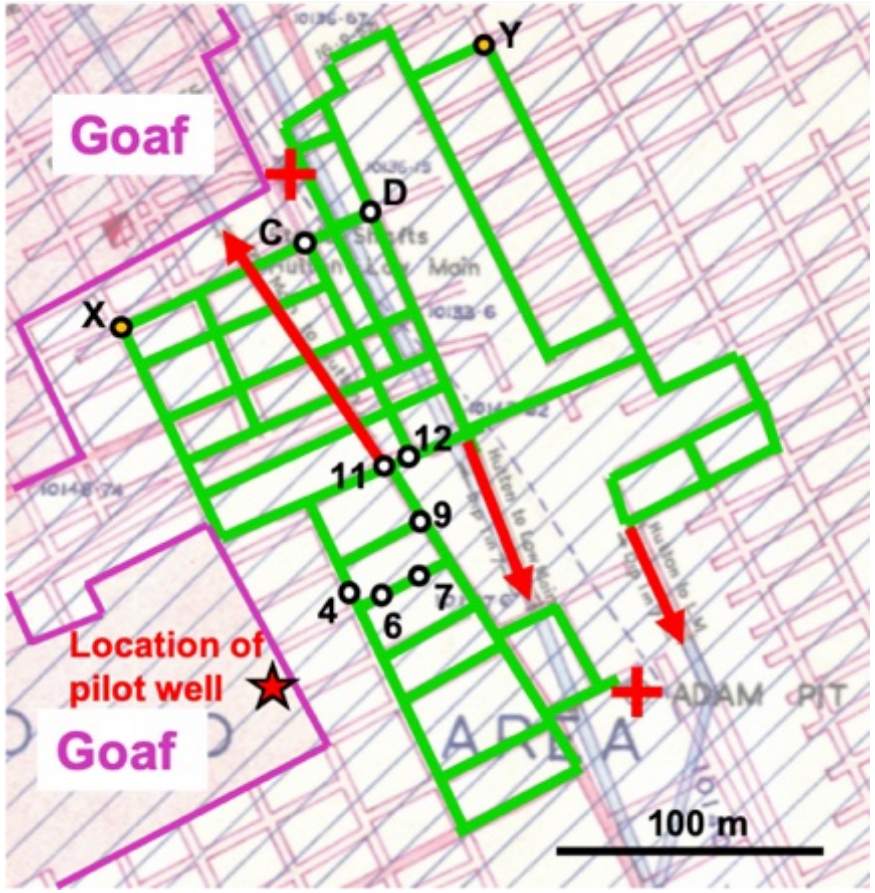
Durham University
Durham Energy Institute

Mine Energy – how it works



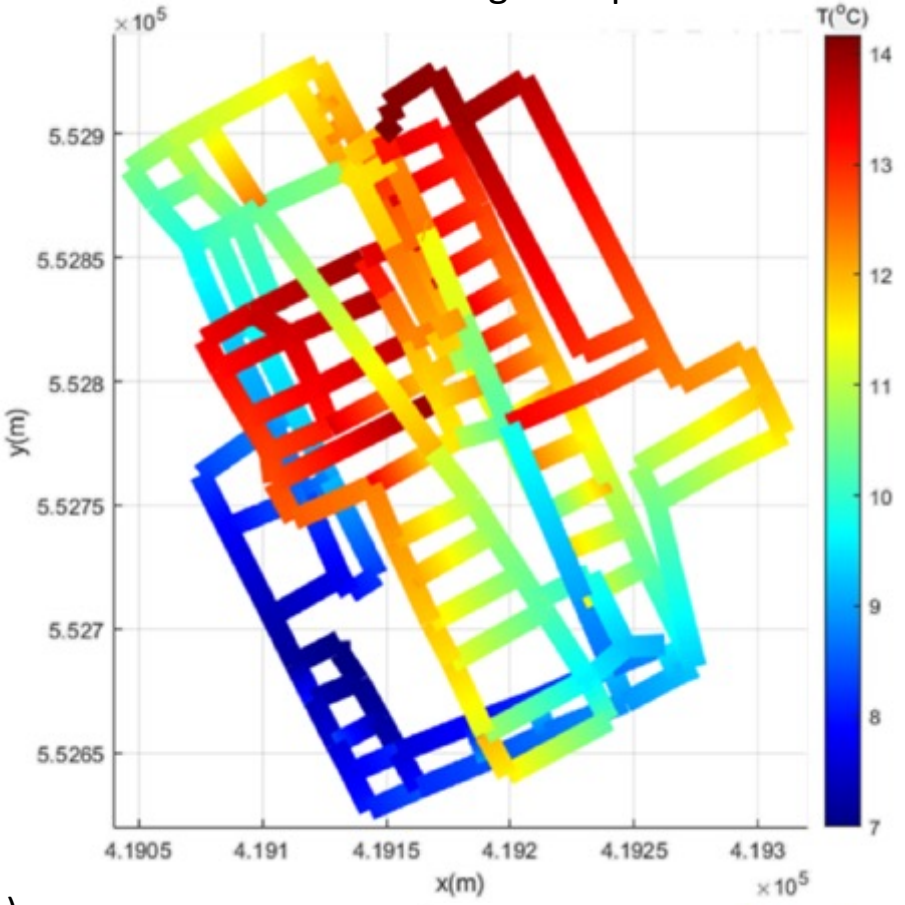
Durham University
Durham Energy Institute

Methodology



- Low Main Moadlin & Hutton Seams (top seams)
- Pilot Well (for re-injection) already drilled
- 5 possible sides for extraction wells (in black)
- Green area = dominant mine water pathway

2-seam modelling example



Mine data extraction

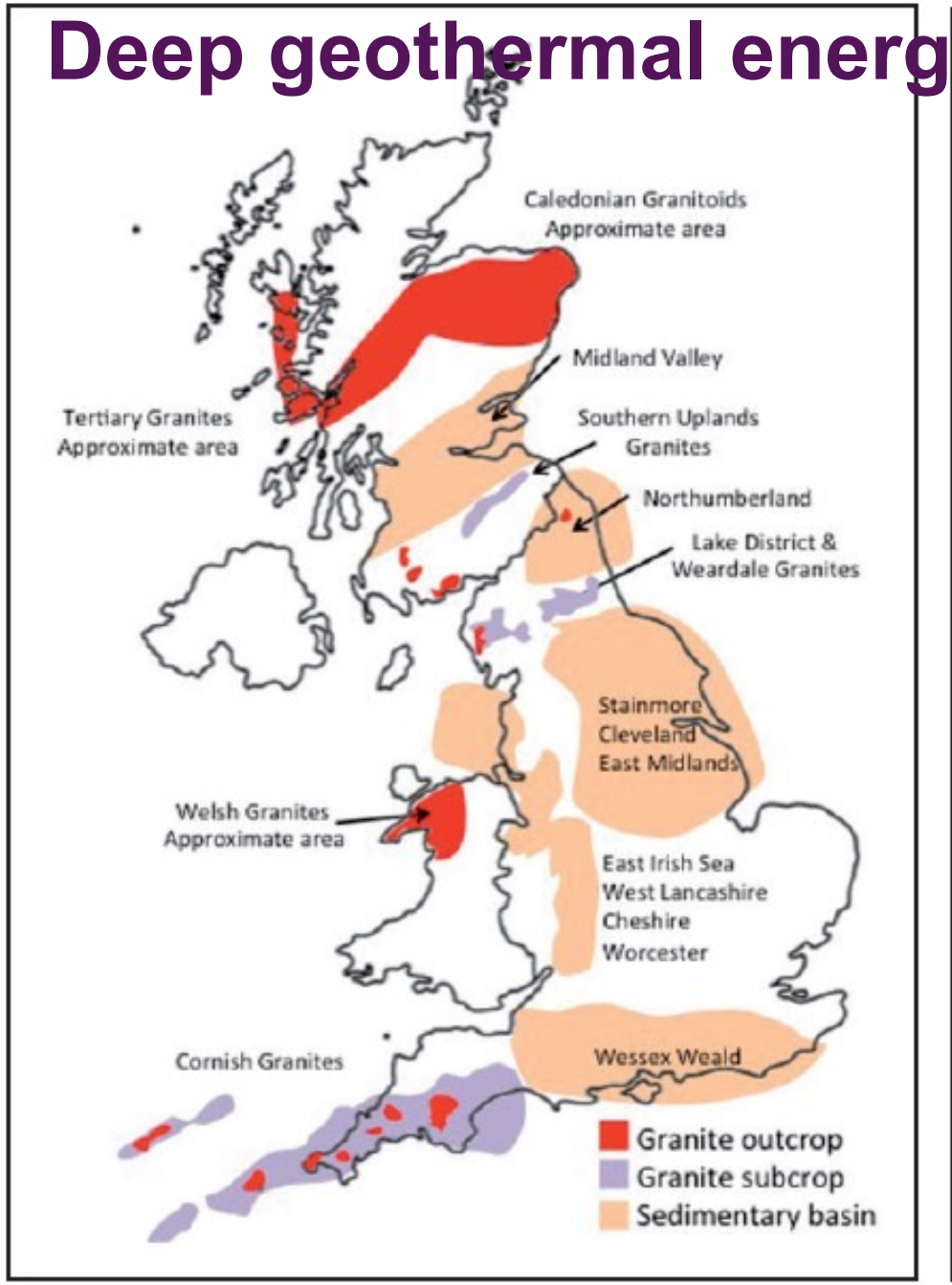
- Mine plans from UK Coal Authority
- Digitising seam location data for all 3 seams using GIS

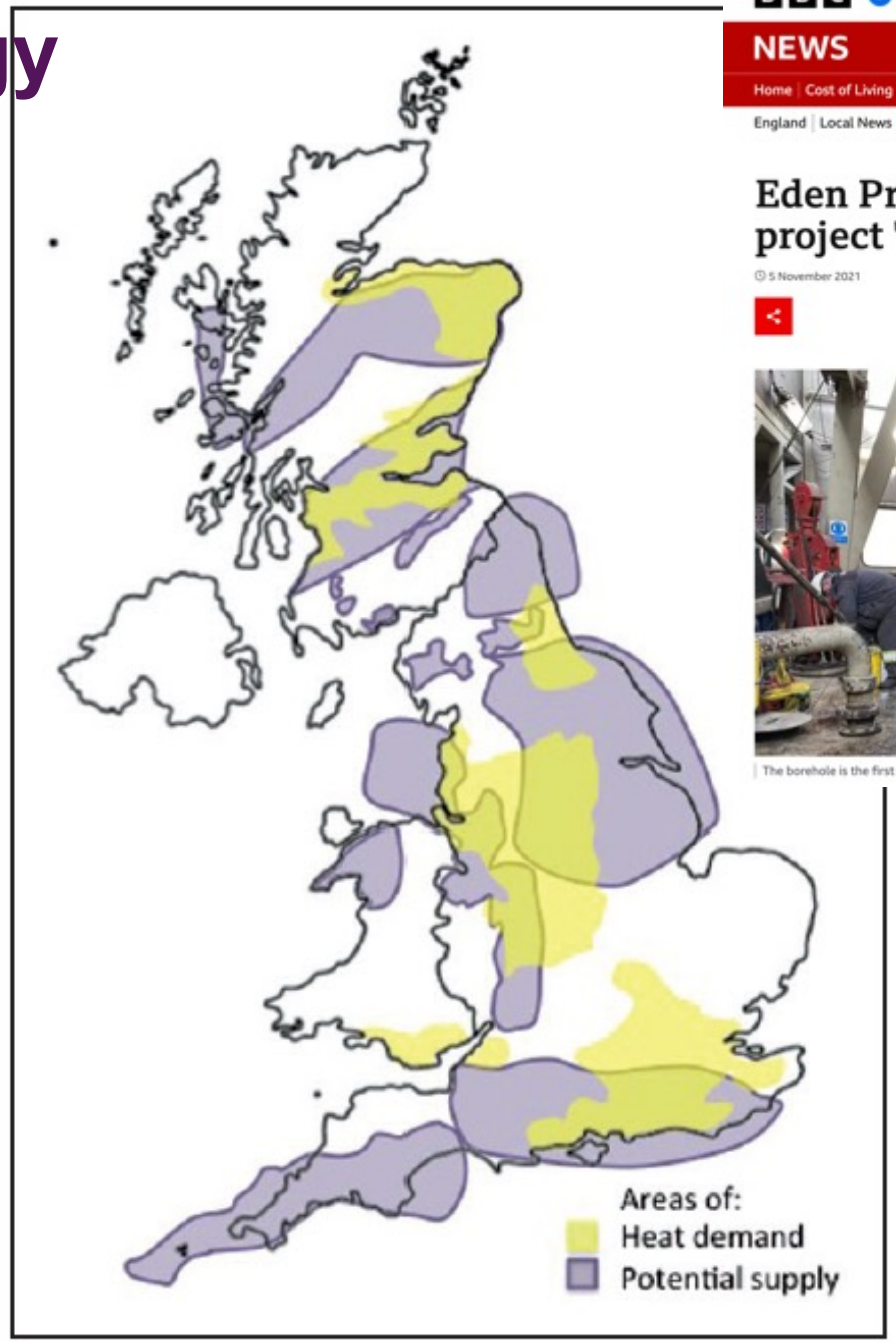
Heat and fluid flow model

- Model setup in Matlab
- Fluid flow with gradient method (Todini & Pilati, 1987)
- Methods as used for EPANET software (Rossman, 2000)
- Heat transfer using Rodríguez & Díaz (2009)

Parameter	Range	Default
Tunnel diameters (m)	1.7-2.7	2.2
Initial rock temperature, LMM & Hutton seams (°C)	14.5-15.5	15
Initial rock temperature, TB seam (°C)	17-18	17.5
Rock heat conductivity (W m^{-1} K^{-1})	2.3-3.9	3.0
Rock specific heat capacity (J kg^{-1} K^{-1})	740-920	800
Rock density (kg m^{-3})	2100-2700	2400

Deep geothermal energy





BBC NEWS

Home | Cost of Living | War in Ukraine | Coronavirus | Climate | UK | World | Business | Politics | Tech

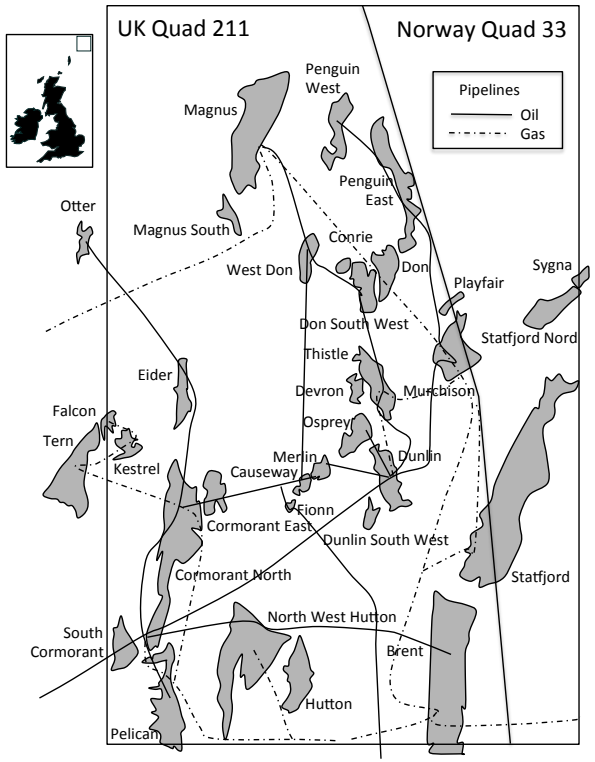
England | Local News | Regions | Cornwall

Eden Project: Geothermal heat project 'promising'

5 November 2021

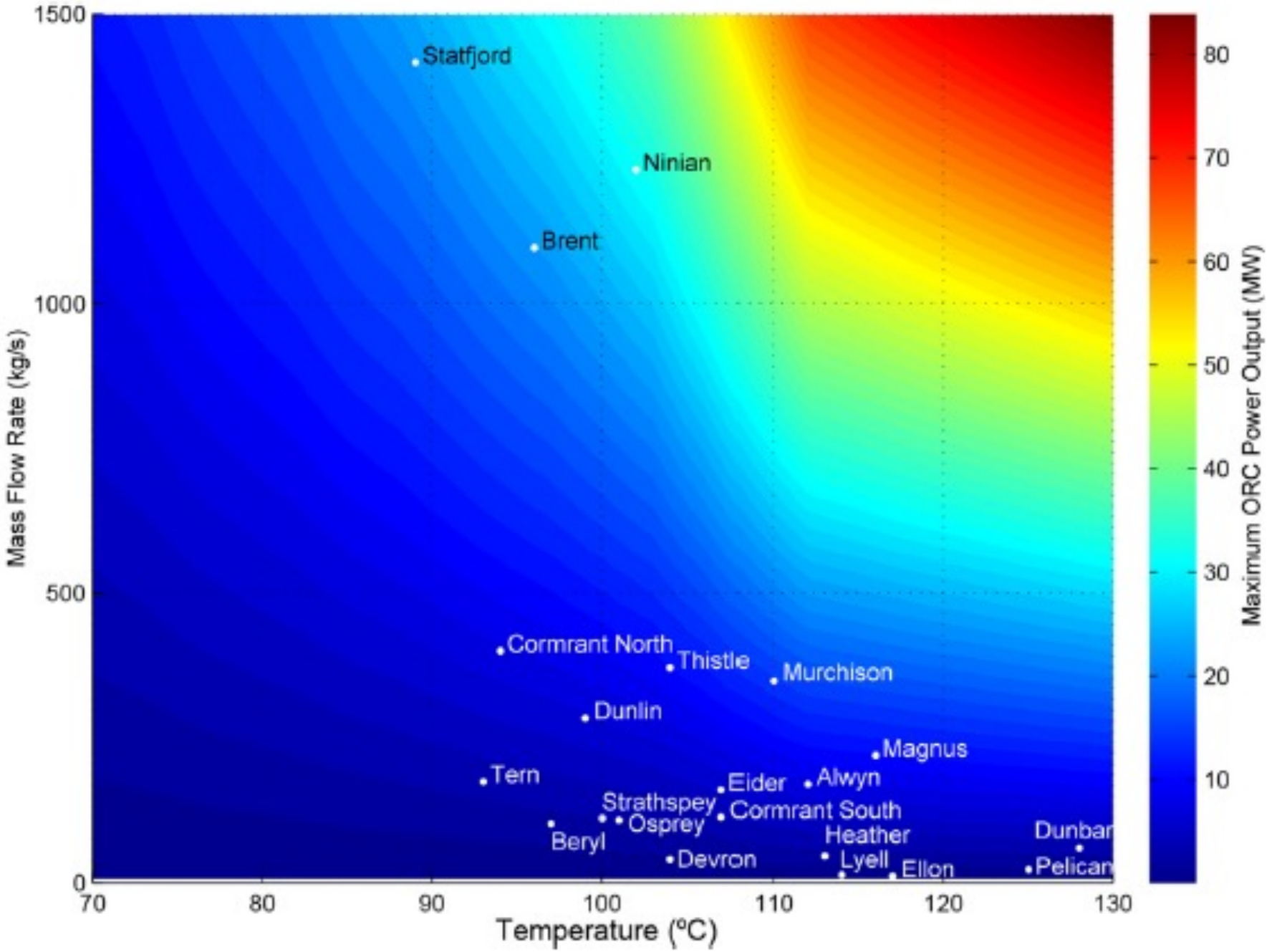
The borehole is the first of two on the site which could supply heat to Eden and nearby industries

> 100 years supply



Produced water: power potential

From Auld et al, 2014



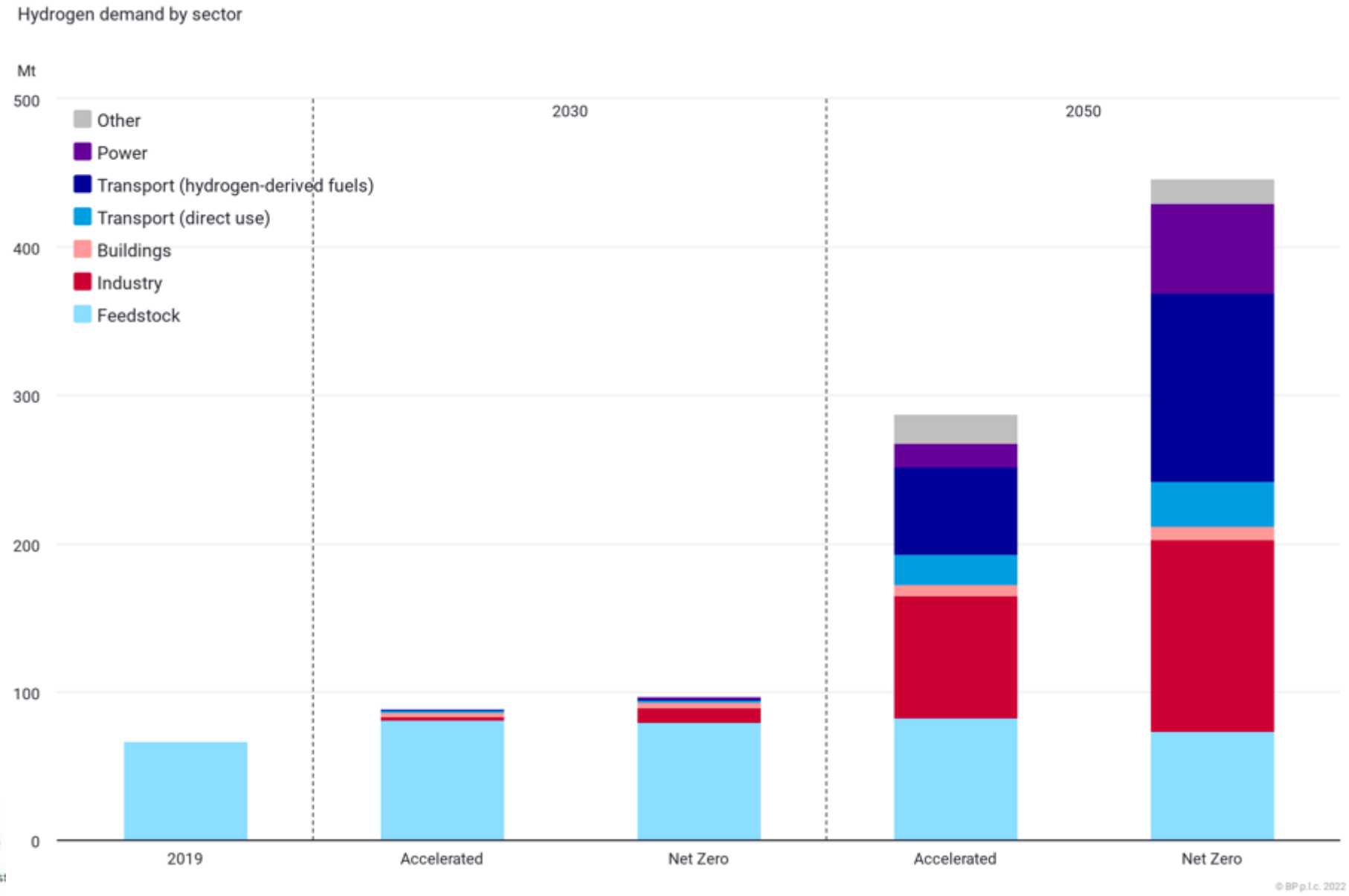
Durham University
Durham Energy Institute

Geothermal

Summary

- Reducing the emission of GHGs associated with heating is imperative if the UK is to meet its commitments to tackle climate change
- Water is the key for large scale displacement of gas from heating systems, heat storage and even some power generation

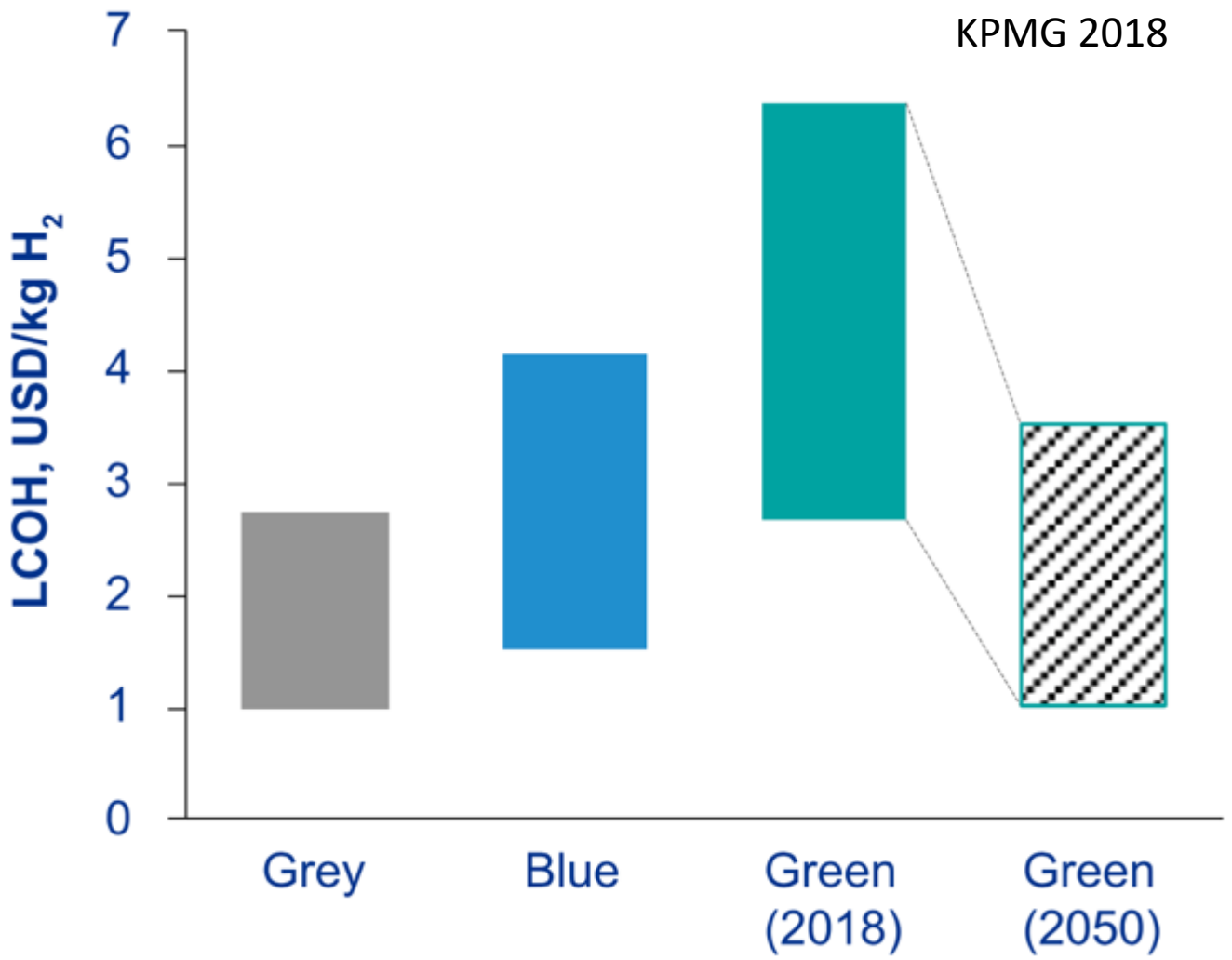
Hydrogen – demand by sector



Hydrogen's coat of many colours

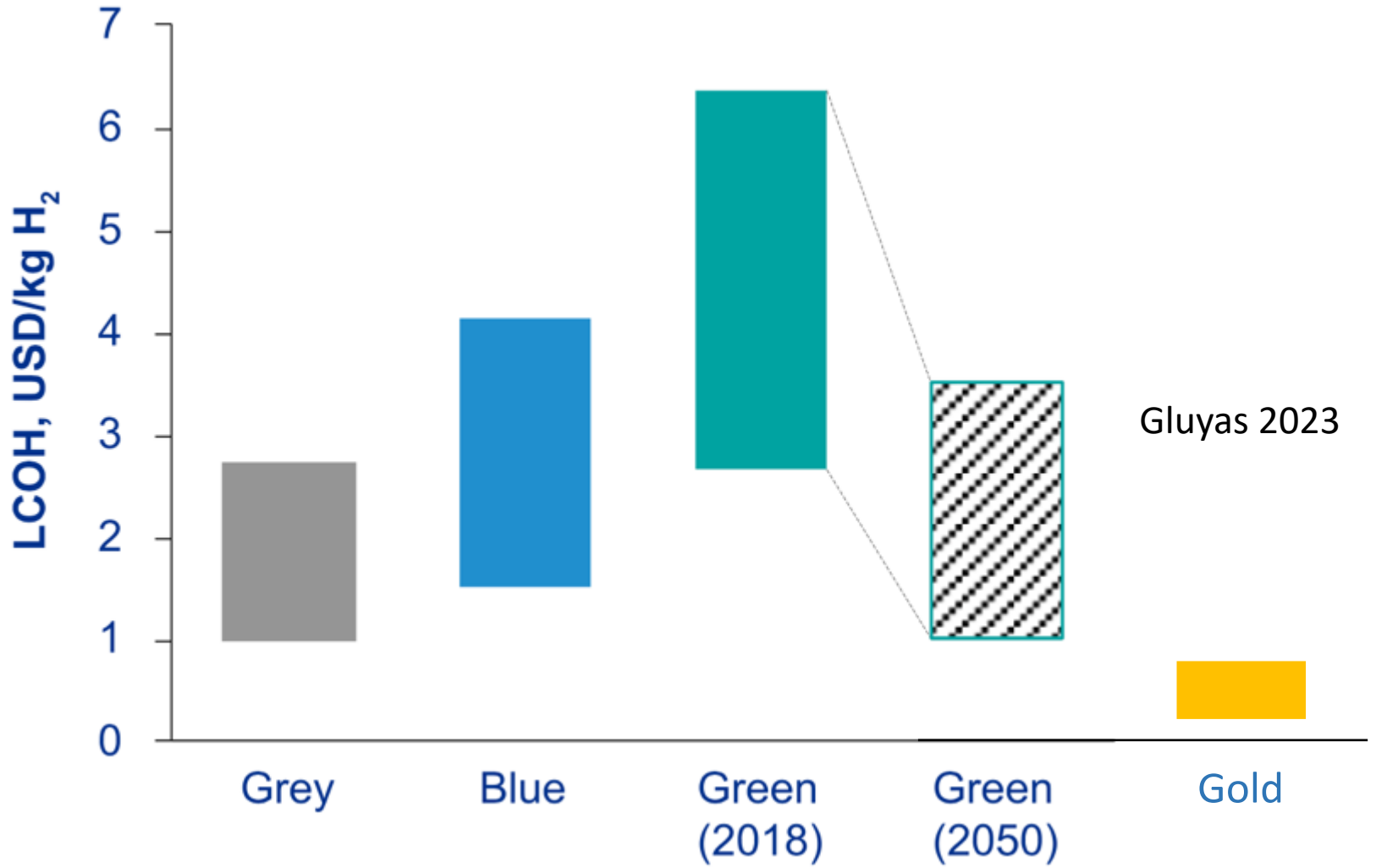
- Black – coal gasification
- Grey – steam reforming
- Turquoise – pyrolysis of natural gas
- Blue – steam reforming with CCS
- Green – hydrolysis with renewable electricity
- Pink – hydrolysis with nuclear
- Yellow – hydrolysis with solar energy
- Gold – natural molecular hydrogen
- Orange – human enhanced oxidation of iron minerals

The cost of hydrogen



Durham University
Durham Energy Institute

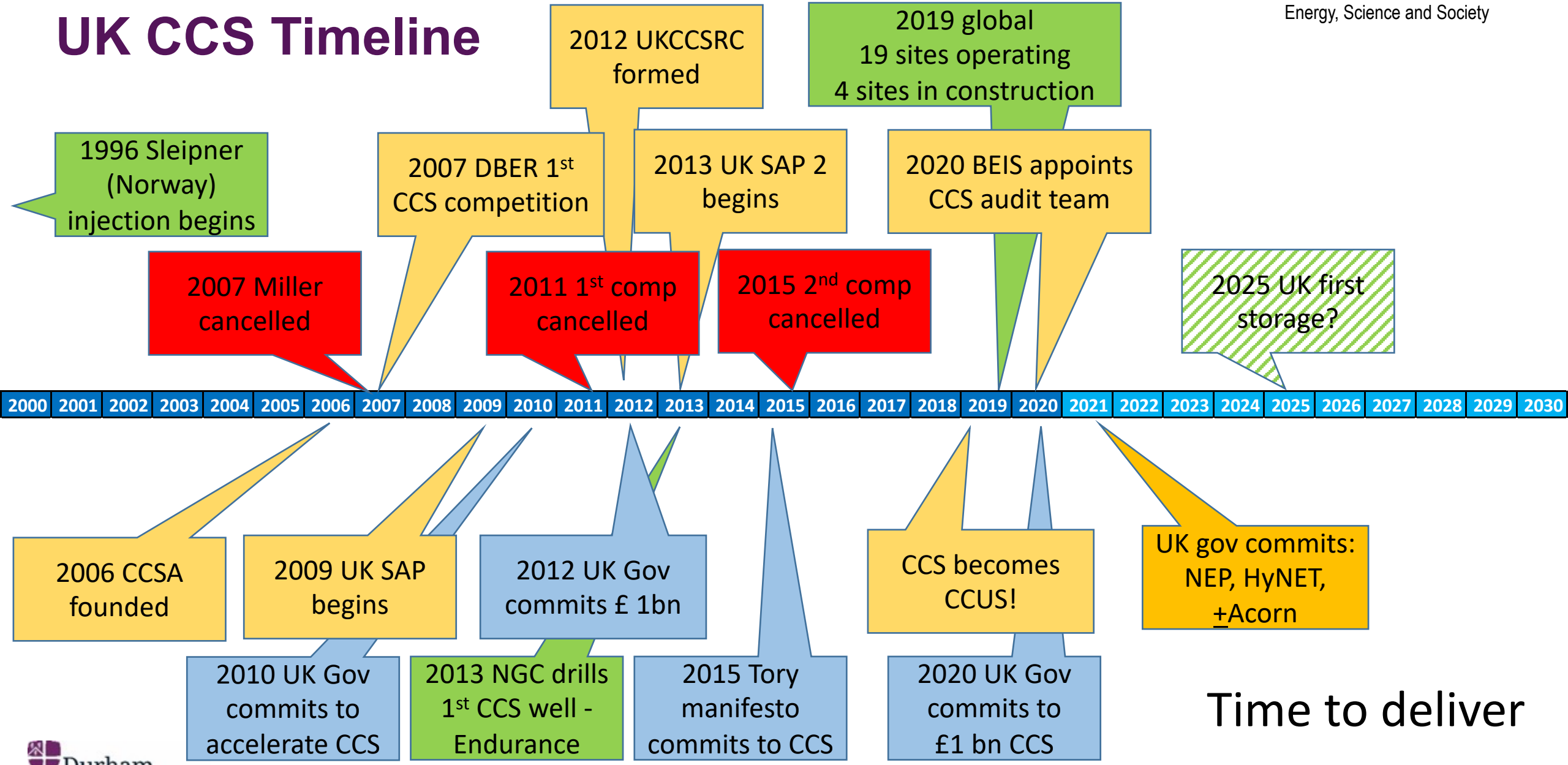
The cost of hydrogen?



Gluyas 2023

Durham University
Durham Energy Institute

UK CCS Timeline

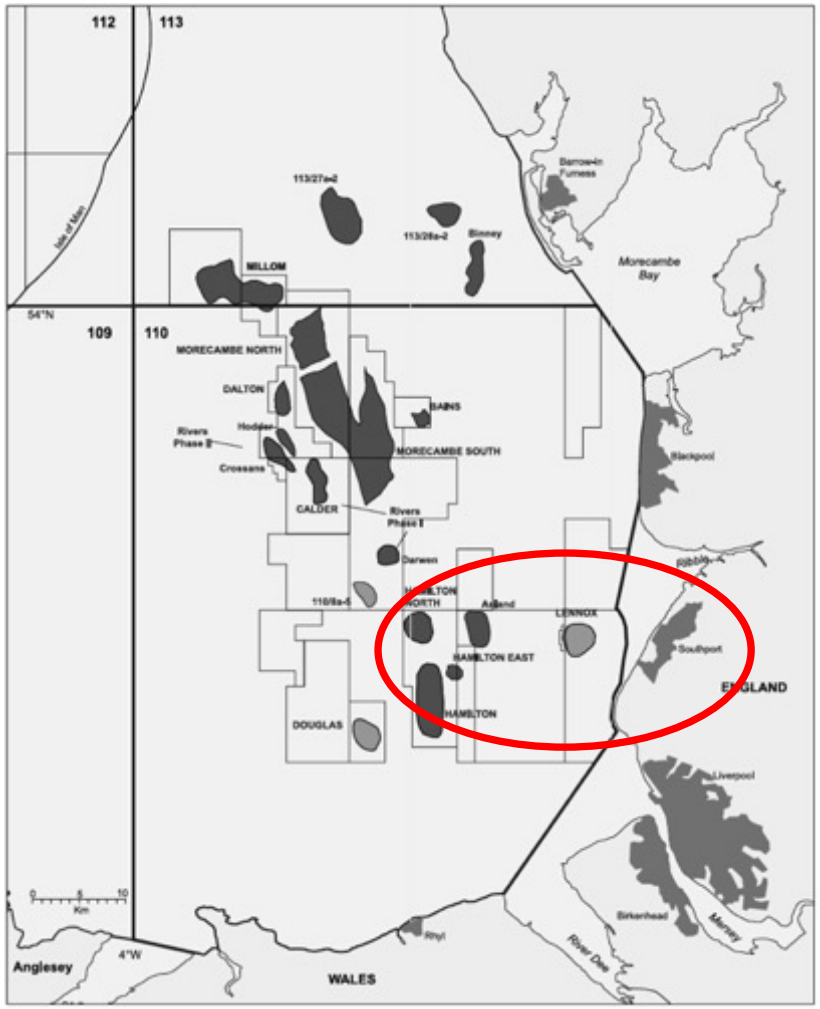


Time to deliver

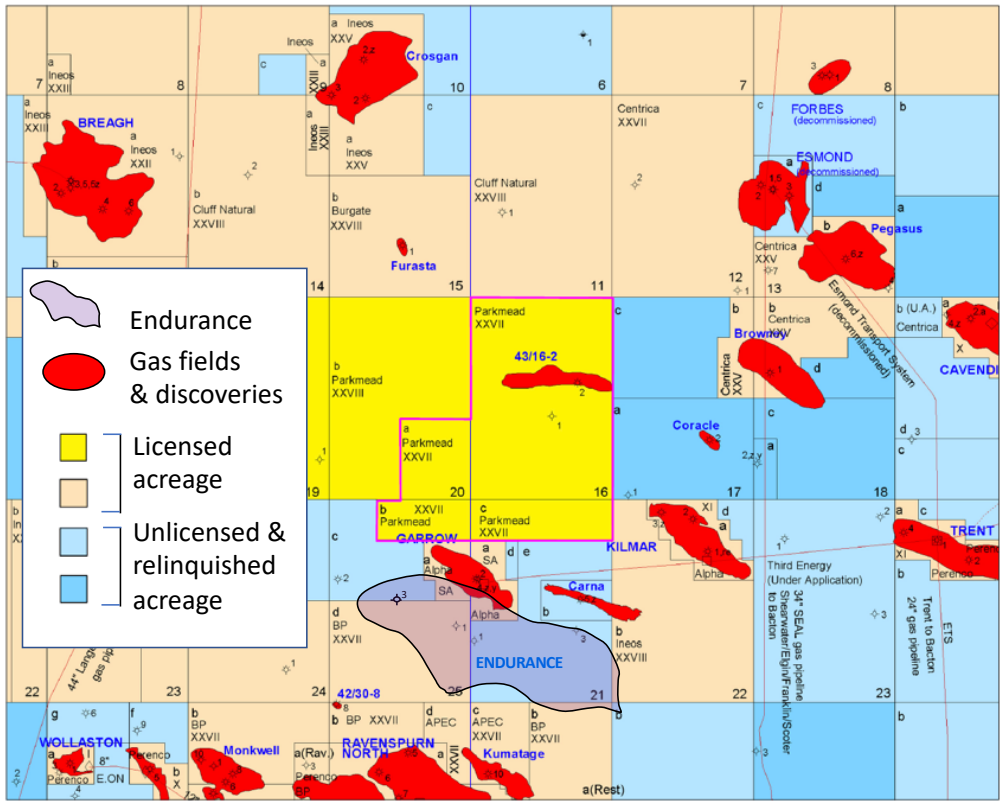
Durham University
Durham Energy Institute

Carbon capture and storage UK - status

HyNet



Endurance



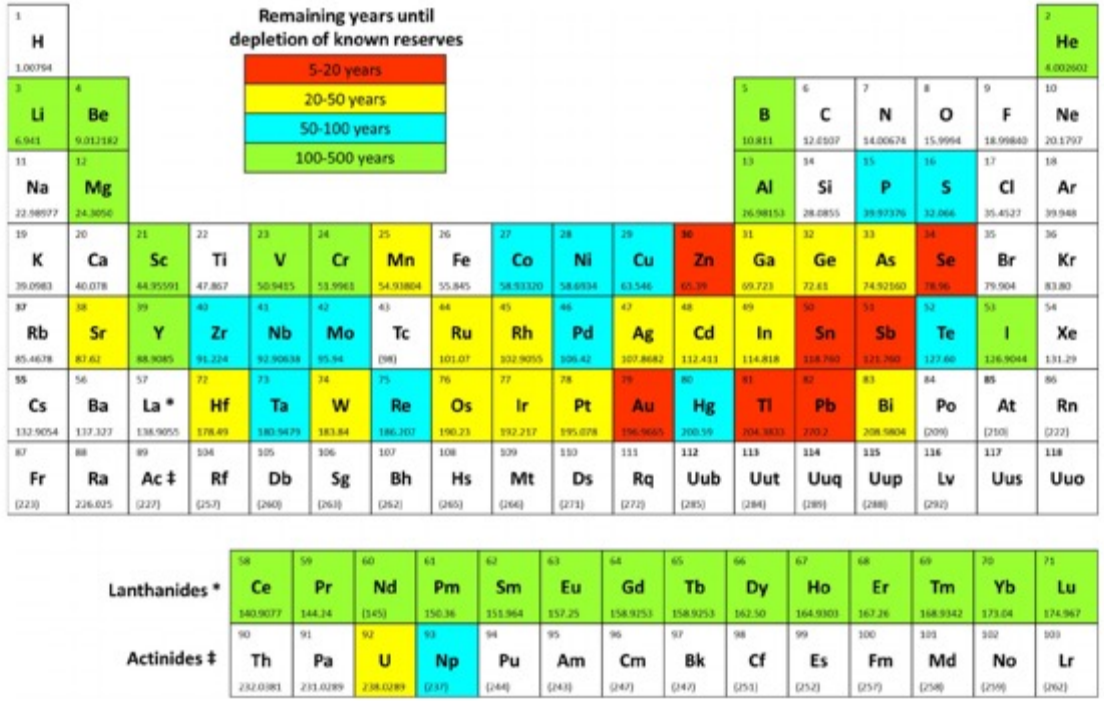
+4 additional clusters by 2030
600 potential sites on UKCS

Durham University
Durham Energy Institute

Durham University
Durham Energy Institute

ENERGY TRANSITION RESOURCE REQUIREMENTS

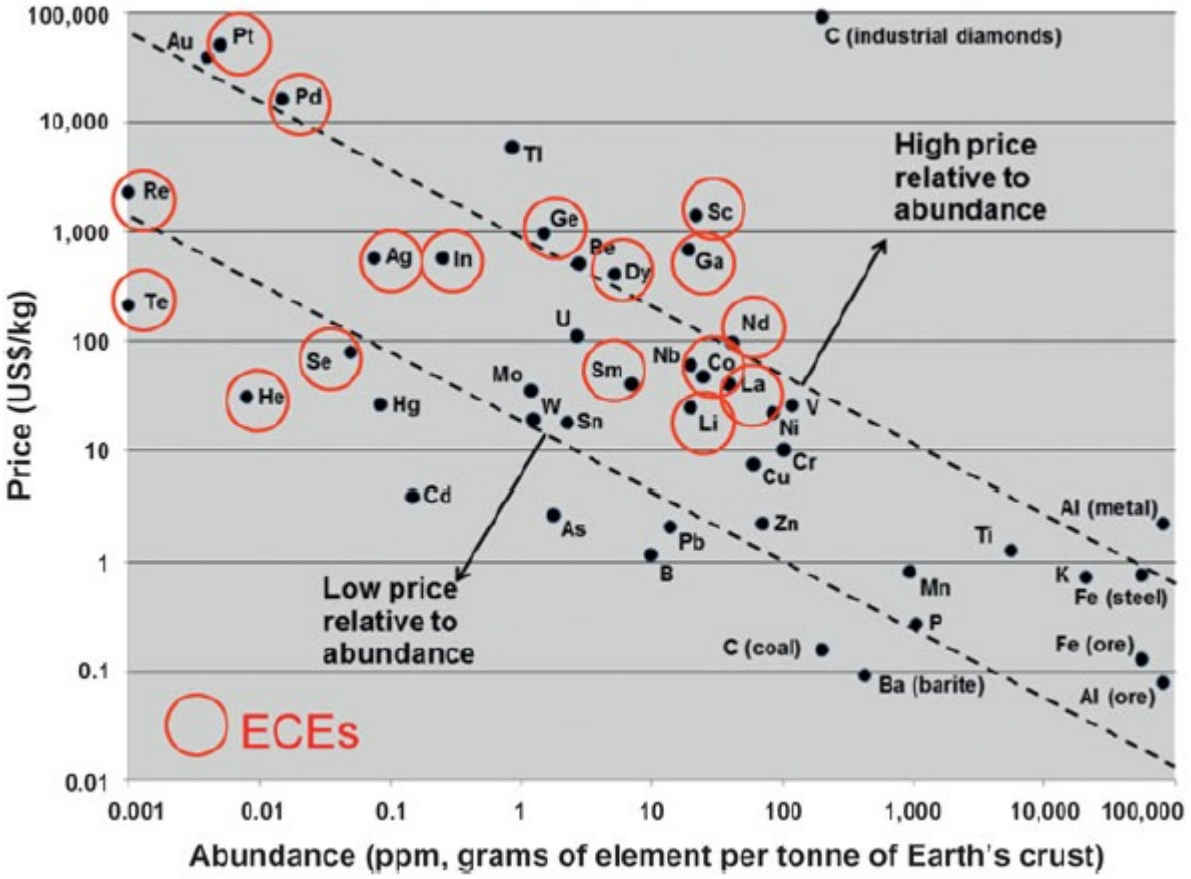
Critical elements



Nontipa Supanchaiyamat and Andrew J. Hunt 2019

https://chemistry-europe.onlinelibrary.wiley.com/doi/epdf/10.1002/cssc.201802556?saml_referrer

- …but it is finite



Energy-critical elements for sustainable development 2012

Alan J. Hurd, Ronald L. Kelley, Roderick G. Eggert, and Min-Ha Lee

DOI: https://doi.org/10.1557/mrs.2012.54

Critical perceptions

BBC jon Home News Sport Weather iPlayer

NEWS

Home | Cost of Living | War in Ukraine | Coronavirus | Climate | UK | World | Business | Politics | Tech

Wales | Wales Politics | Wales Business | North West | North East | Mid | South West | South East | Cymru | Lo

Powys wind farm protesters threaten legal action against council

14 December 2018

BBC jon Home News Sport Weather iPlayer

NEWS

Home | Cost of Living | War in Ukraine | Coronavirus | Climate | UK | World | Business | Politics | Tech

England | Local News | Regions | York & North Yorkshire

Hambleton Council: Solar farm rejected over impact to 'finest view'

3 days ago

BBC jon Home News Sport Weather iPlayer

NEWS

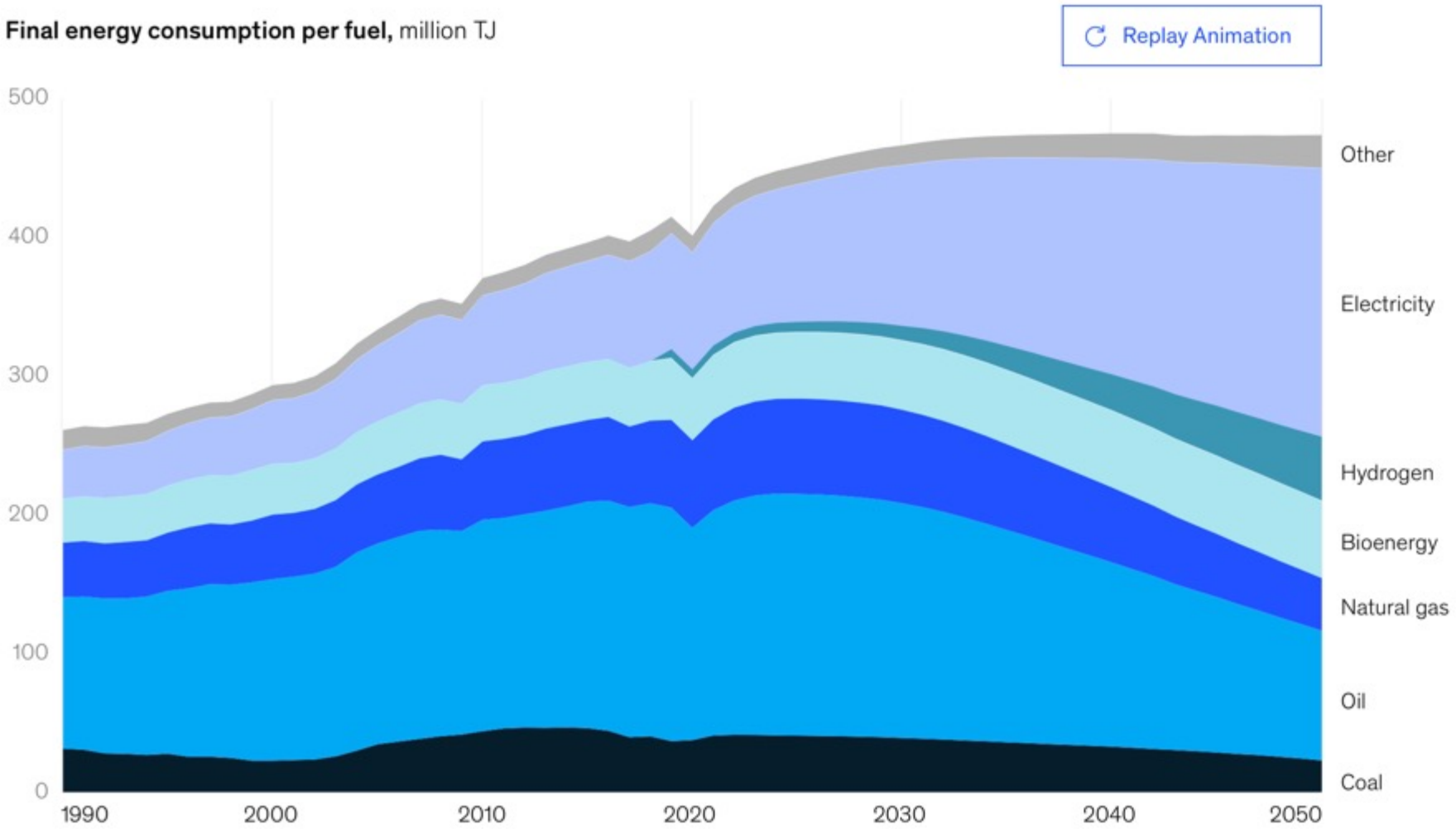
Home | Cost of Living | War in Ukraine | Coronavirus | Climate | UK | World | Business | Politics | Tech

England | Local News | Regions | Cornwall

Seismic activity stops geothermal drilling at Eden Project

10 March 2022

Where will we be in 2025 & 2050



McKinsey
Global Energy Perspective 2022

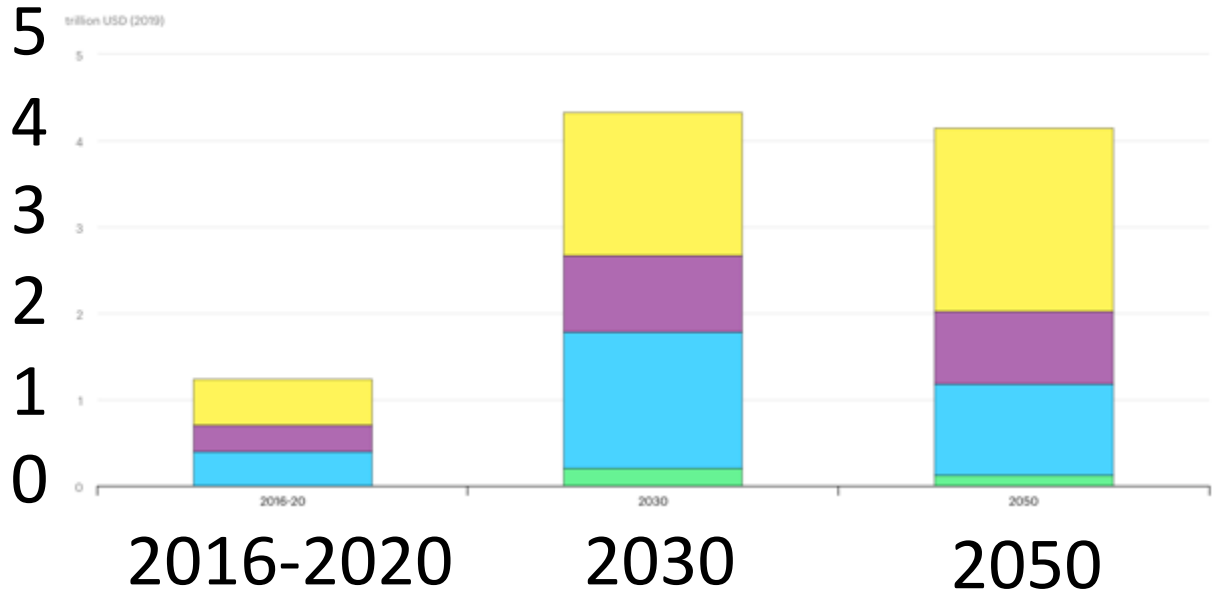
50%
by 2050

Electricity – x3 by 2050
Hydrogen – x5 by 2050
Bioenergy – 37% of transport fuels by 2050
Natural gas – peak 2035 at x1.1 of present
Oil – peak 2025, 75% decline by 2050
Coal – peaked 2013, 60% decline by 2050

Investments

- Electricity - $977 billion in 2021 & growing at 5-6% pa – IEA
- Hydrogen - $4 trillion by 2050 - IRENA
- Bioenergy -$35-45 billion by 2025 – McKinsey 2022

US$ trillions



IEA graphic

Conclusions and discussion

- Critical for ‘planet health’ to decarbonize
- Energy density of fossil fuels and ‘doing what we have always done’ makes this tough
- Easy stuff has been done – wind, solar PV
- Will impact people
- Needs to be a just transition…
- It is now not tomorrow!

Contact Durham Energy Institute…

E-mail: dei.admin@durham.ac.uk
Website: www.durham.ac.uk/dei/
Twitter: @DEI_Durham
Phone: 0191 334 2649
Location: Durham University, Durham, UK

Durham University