

HALLIBURTON

**Hydrocarbons, Geoscience & The Energy
Transition**

Andy Davies & Mike Simmons*

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Good morning all,

My name is Andy Davies and I am a principal geoscience advisor at Halliburton.

Halliburton are one of the largest oil and gas field service companies in the world employing around 50,000 people across the globe

I work in a part of Halliburton called Landmark where we generate software and geological products to help companies explore and produce hydrocarbons

I am also a senior visiting research fellow at the university of Leeds

The talk I want to give you today is entitled “Who Needs Geoscientists? Career Options Through The Energy Transition”

It stems from some work I have been doing with my colleague Mike Simmons to provide insights into the value of geoscientists to society, especially in light of the ongoing energy transition

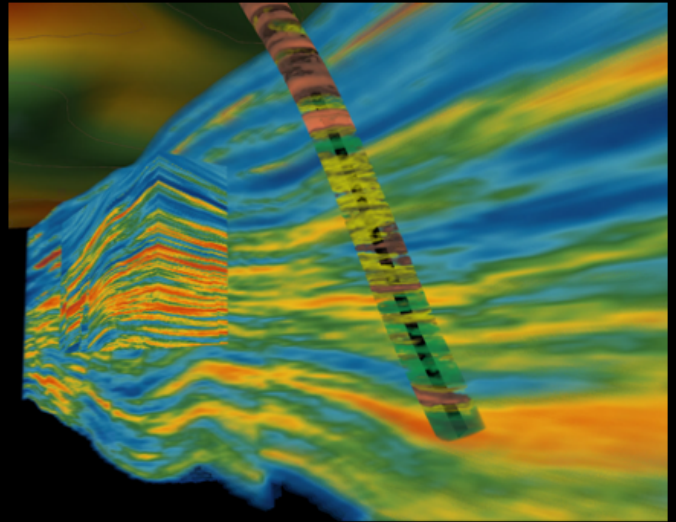
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Outline

- Introduction: Geoscience in the 21st Century
- Energy and Society
 - Energy demand
 - The energy mix – the role of hydrocarbons
- Evolving Geoscience Needs
 - Advantaged hydrocarbons
 - Carbon capture and storage
 - Renewables
- Geoscience Research and the Digital Transformation
- Conclusions



Slide 3

Let me begin by giving you an overview of the talk

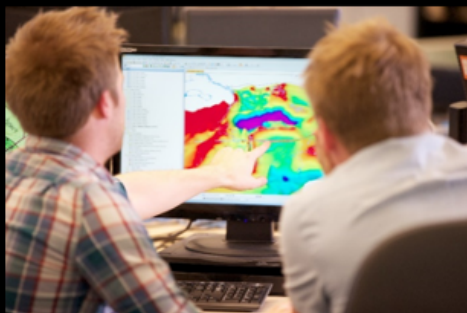
I'll start with an introduction to set the scene, then look at energy and society.

This will lead us into assessing future Geoscience Careers in relation to the energy transition

I'll then assess some aspects of future geoscience research and the digital transformation

Before wrapping up with some conclusions

Who are Geoscientists?



Slide 4

Who are geoscientists and what do they do?

The world of geoscience is hugely varied and this is reflected in where geoscientists work

This can range from the field, the lab, the office or onsite - at a rig or mine.

My work is routinely done in the office (which of course now means “at home”) with occasional research and teaching trips into the field

Geoscience Skills

- Geoscientists also have desirable transferable skills facilitating career development outside of geoscience
- In addition to key domain skills, geoscientists also typically possess skills in:
 - Problem solving/deductive thinking
 - Data integration/holistic thinking
 - Dealing with uncertainty and risk
 - Presentation skills/communication
 - Teamwork
 - Leadership
 - Visualization in 3D/4D
 - Numeracy
 - Data science - increasingly important!



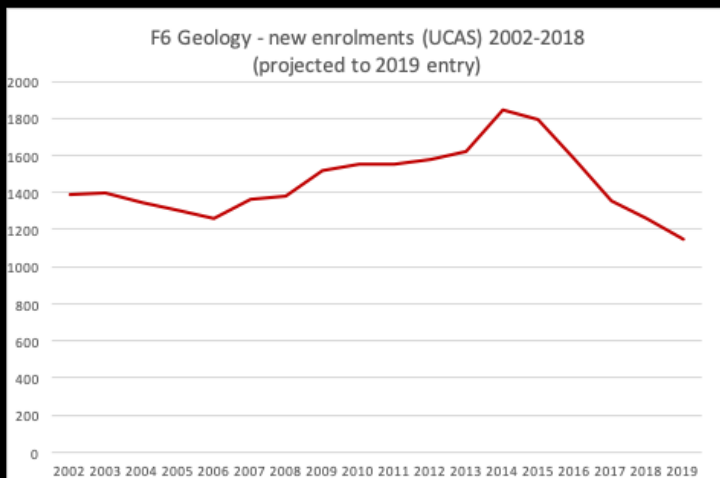
Slide 5

Geoscientists also gain desirable transferable skills facilitating career development outside of geoscience

So along with your domain knowledge, you will also develop skills in

Problem solving or deductive thinking

Declining student numbers in geology - 35% decrease in the UK the last 5 years – similar in many other western countries (including USA)



Boatright et al. (2020)

Slide 6

However we know in recent years that less students want to study geoscience

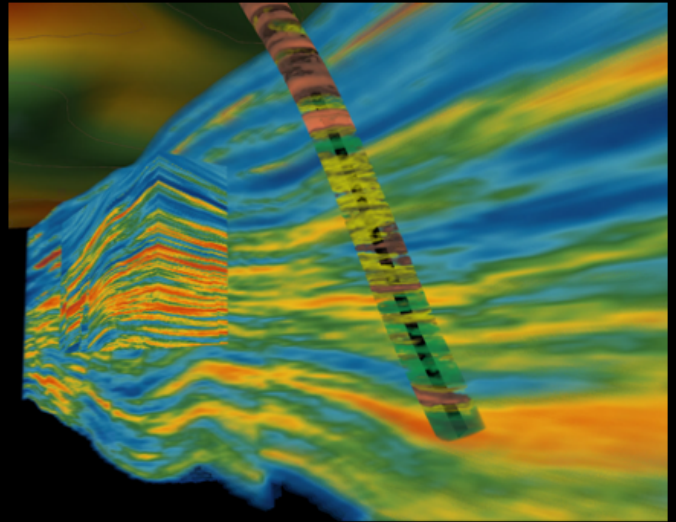
The graph on the left shows that over the past few years there has been a 35% drop in the number of geoscience students in UK universities

There are lots of reasons behind this, including the public perception of geoscience, and the industries it is associated with, when seen through the lens of climate change

but I'm sure another reason is the perception of reduced career opportunities within the field

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Poll Question 1

Compared to 2019, by how much has global energy demand (from all energy sources) dropped in 2020 because of the pandemic and its socio-economic consequences?

- a. Less than 10%
- b. 10-25%
- c. 25-50-%
- d. More than 50%

Slide 8

To further highlight this, take a look at this graph showing the fluctuations in energy demand since 1900

You can see that most of that time, energy demand has been positive – year on year society has used more energy.

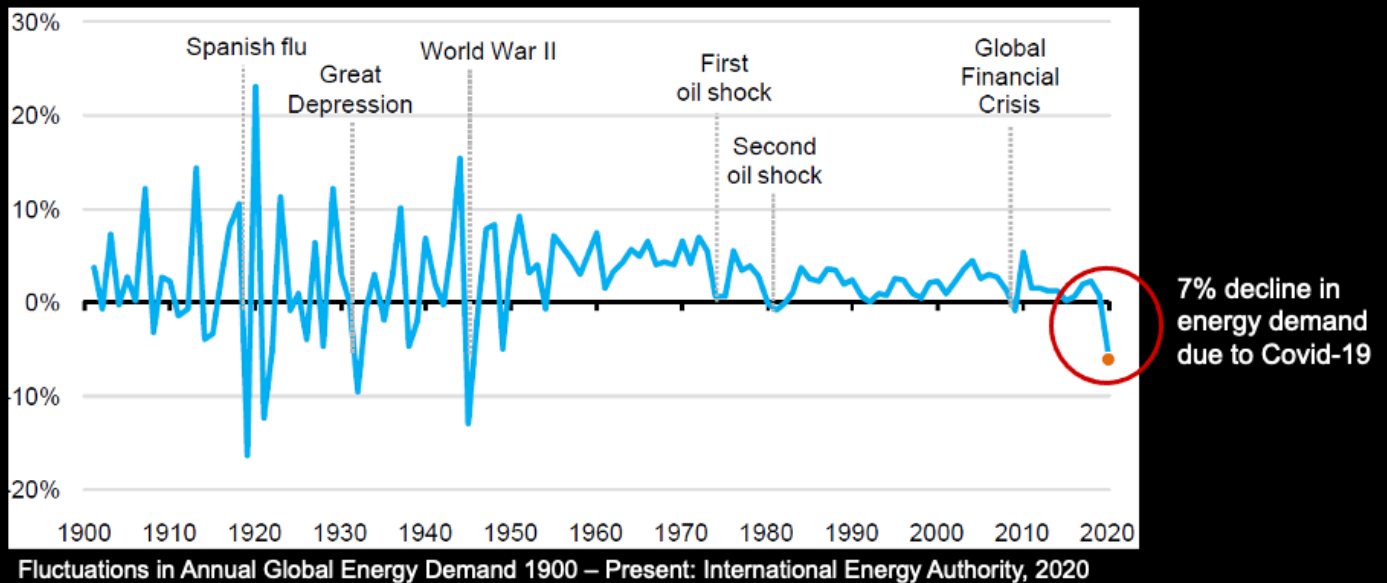
The only times energy demand has been negative is during major recessions and global events, including the Spanish Flu pandemic, the great depression, WW2, the oil shocks, the 2008 financial crisis and the COVID pandemic we are currently going through

However, note that despite month long lockdowns across the globe and the collapse of international air travel, energy demand is only down ~7% due to COVID.

Its therefore very difficult for us to reduce energy demand without major impacts on or lives.

Therefore access to affordable energy is crucial for many of the **UN** goals, including reducing poverty, ending hunger and improving health

The Importance of Energy to Society



Slide 9

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UN Sustainable Development Goals



Slide 10

These are the United Nations sustainable development goals which are the blueprint for us to achieve a better and more sustainable future

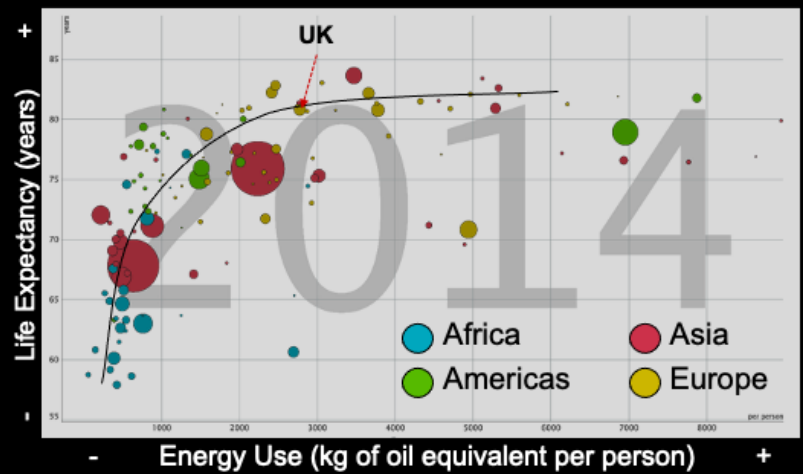
The goals include eradicating poverty and hunger, improving health and wellbeing, ensuring all get access to quality education and clean water and ensuring gender equality

You can see that at number 7 we have affordable and clean energy.

For me it should be number 1 because as you'll see in the next section, without affordable energy its difficult to achieve may of these other goals.

Access to Energy and Quality of Life

- Strong link between energy consumption and life expectancy
- In the UK, we consume ~2800 kg of oil equivalent/ year
 - In developing nations, people consume ~500 and as a result may have a life expectancy of 20 years less
- Do all nations have the right to use the same amount of energy as the richest nations?



FREE VIZUALIZATION FROM
GAPMINDER.ORG, CC-BY LICENSE

Slide 11

This chart, **modified from Gapminder**, shows the average energy consumed per person, versus life expectancy for every country in the world

Each dot represents a country and the size of the dot reflects the total population. The different colours reflect different continents.

You can see that there is a clear link between energy use and life expectancy

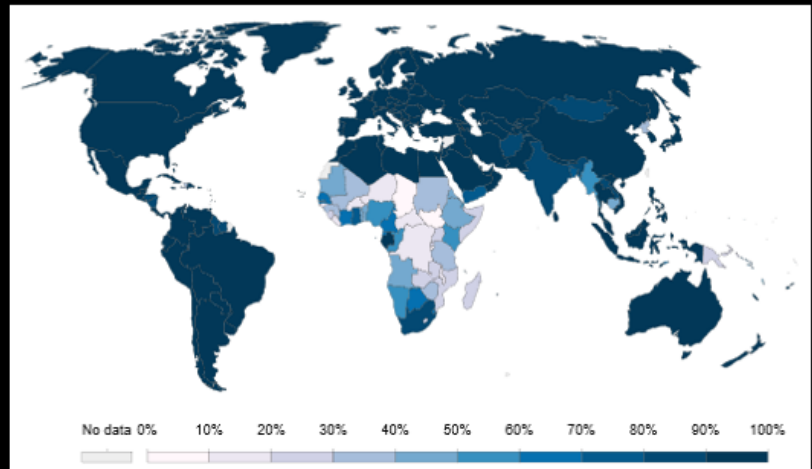
I've highlighted the UK, where each person consumes ~2800 kg of oil equivalent/ year

In many developing nations, people consume just 500 – 5 times less and as a result may have a life expectancy of 20 years less

This raises important moral questions, such as do all nations have the right to use the same amount of energy as the richest nations?

Access to Energy and Quality of Life: Energy Poverty

- **"Access to electricity"** = 280 kWh per person/year
 - enough to power 4 lightbulbs operating at 5 hours per day
 - one refrigerator
 - a fan operating 6 hours per day
 - a mobile phone charger
 - a television operating 4 hours per day
- In Europe each person uses ~6,000 kWh per year, in the USA ~13,000 kWh per year
- 4 billion people are unable to do the same
- See work of Scott Tinker for more on this topic



Source: Our World in Data

Slide 12

The uneven access to energy is highlighted in this map, showing the share of population of each country with access to electricity

Access to electricity may not be what you imagine

Poll Question 2

Global oil consumption (pre-pandemic) was c.100 million barrels a day. What would you predict it to be in 2050 in a rapid energy transition scenario (i.e. maximum effort by governments to meet the Paris Agreement)?

- a. More than 75 million barrels per day
- b. 75 – 50 million barrels per day
- c. 10 - 50 million barrels per day
- d. Less than 10 million barrels per day

Slide 13

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The Vision

- Today ~85% of the world's energy comes from fossil fuels (coal, oil, gas)
- In the near future, we want to:
 - enjoy the same, or better, quality of life
 - but with zero carbon
- How challenging is this?



Slide 14

Therefore, most of the public share a collective vision whereby we move from the situation of today, where 85% of the world's energy comes from hydrocarbons,

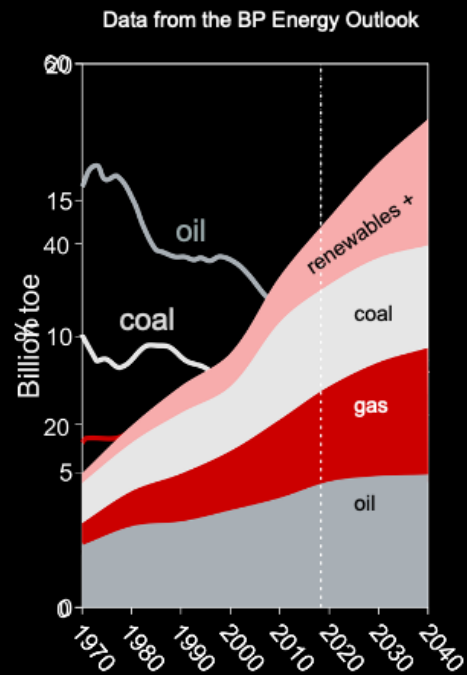
To a world where we enjoy the same, or better quality of life, but with zero carbon emissions.

And it sounds simple doesn't it? It just takes political will, right?

In this talk we'll explore the practicalities of this vision

Future Energy Demand

- Hydrocarbons will provide a smaller share of the energy supply
- Energy demand will continue to rise
 - In 2100 there will be ~11 billion people
 - » >3 billion more than today
 - Countries and individuals continue to pursue prosperity
- Hydrocarbons will continue to be a crucial part of the energy mix
 - Why?



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So what does this mean for the future?

Well, we know that hydrocarbons will provide a smaller share of the global energy supply in future. This is **the continuation of a trend that's has been playing out for some time.**

However Energy demand will continue to rise as the **global population becomes wealthier and grows in number.**

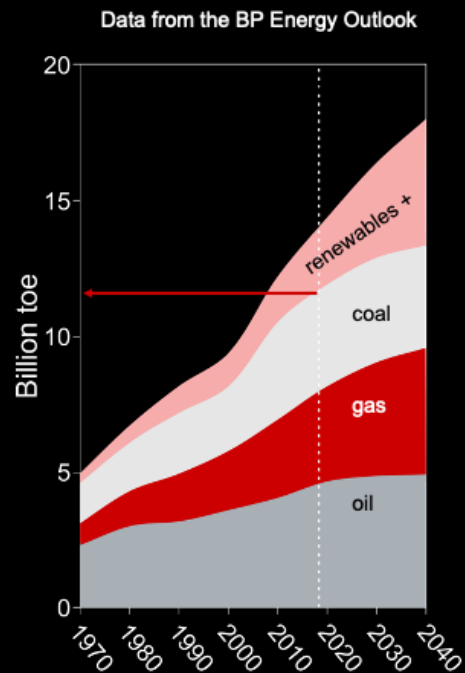
The **UN forecast** is that by 2100 there will be ~11 billion people on the planet; 3 billion more than today

As such, even in light of climate change, hydrocarbons are predicted to be a crucial part of the energy mix for decades to come

Why is this?

Remove Hydrocarbons?

- How hard is it to remove hydrocarbons from the energy mix by 2050?
- The world used 11,865 mtoe of fossil fuels/year
- There are ~10,700 days until 2050
- We therefore need to replace >1 mtoe every day from now until 2050
 - 1 mtoe =
 - » 1 nuclear plant, or
 - » ~2,000 wind turbines
 - » ~4 million solar panels
- This assumes no growth in energy demand
- Answer = very!



Slide 16

We can therefore ask the question; how hard is it to remove hydrocarbons from the energy mix by 2050?

Currently, the world used 11.8 billion tons of oil equivalent energy from fossil fuels per year

There are ~10,700 days between now and 2050, and so we need to replace >1 million tons of oil equivalent energy every day between now and then

But what does 1 million tons of oil equivalent energy represent?

- 1 nuclear plant, or
- ~2,000 wind turbines
- Or 4 million solar panels

This assumes no growth in energy demand

Answer to the question is = very!

The Real Value of a Barrel?

- 1 BBL of oil has 5.7 Million BTU of energy and costs c. £50
- This is the same amount of energy as a human working
 - 8 hours a day
 - 5 days a week
 - For 10 years
- Assuming UK minimum wage = £170,560
- This cheap energy fuels the modern world, providing
 - Low priced goods
 - Higher profit
 - Higher wages



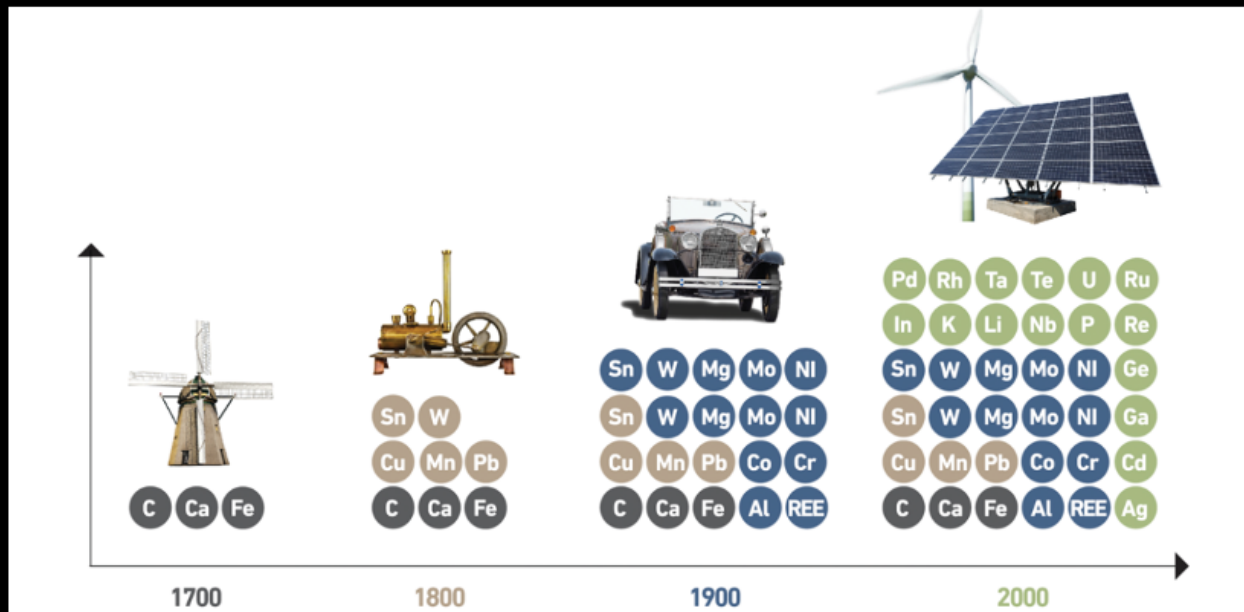
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So how much energy is there in a barrel of oil?

1 barrel of oil, which can be bought for ~£35, contains 5.7 Million BTU of energy

This is equivalent to a human working

Minerals



<https://www.ngu.no/nyheter/rapport-det-gr-nne-skiftet>

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The energy transition will also be associated with an unprecedented demand for mineral resources and hence mining geoscientists

Not only will there be a growing demand, but the demand will be for a larger range of minerals than ever before.

As can be seen in this graph, the digital revolution and energy transition mean we now need to source an ever growing list of elements from the periodic table.

The mining industry is going through its own paradigm shift. Resources have been traditionally found close to surface, but increasing the mining industry will need to use techniques from the hydrocarbon industry, such as the use of seismic and an understanding of geological processes to map fairways, to find more deeply buried reserves.

Raw Materials & Renewables

- The metal resource needed to make all UK cars and vans (not including LGV and HGV), electric by 2050, assuming they use the most resource-frugal next-generation batteries:
 - x2 annual global production cobalt
 - x1 annual global production neodymium
 - x0.75 annual global production lithium carbonate
 - x0.5 annual global production copper



UK Minerals Research Group Data

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However, mineral demand itself is a barrier to the rapid transition and is a further demonstration that becoming net zero is not simply a case of political will

If we look at the metal resource needed to make all UK cars and vans (not including LGV and HGV), electric by 2050 we get some staggering statistics

To do this we need to use

- x2 annual global production cobalt
- x1 annual global production neodymium
- x0.75 annual global production lithium carbonate
- x0.5 annual global production copper

Clearly this is a difficult ask!

Renewable Energy: Resources



Modern plastic blade of a wind turbine: energy intensive to make, transport, and install. Difficult to recycle

Slide 20

The successful deployment of wind turbines also requires expert geoscience input.

As an example, in the North Sea, the Quaternary glaciations have left a buried landscape of glacial and fluvial channels, as can be seen in the shallow seismic image and geological map

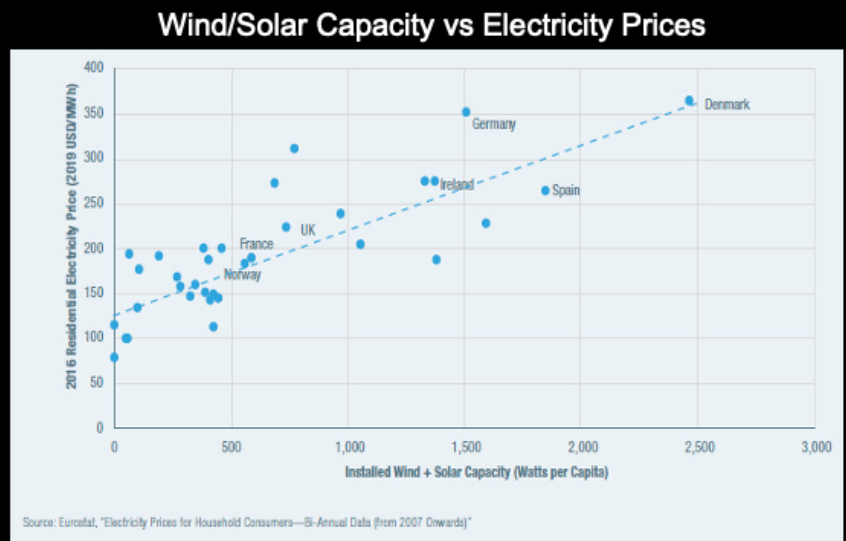
These pose a risk to the foundations of wind turbines

Geoscientists are therefore needed to interpret seismic data to help plan wind turbine placement and foundations

If this isn't done correctly there can be very costly mistakes!

Differing Costs of Energy

- Levelized cost of electricity in 2023 (Smil, 2020):
- \$48/MWh solar photovoltaics
- \$40/MWh onshore wind
- \$10/MWh combined cycle gas turbines



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All of this, plus things like building missing infrastructure, means the cost of the transition is huge

Most emissions reductions will not be profitable to society.

For instance, CCS may be profitable to some companies but you can think of it as "waste disposal". Waste disposal is a good thing but it has to be paid for.

CCS will therefore act as a tax on energy. This cost acts as a brake on the speed of the transition.

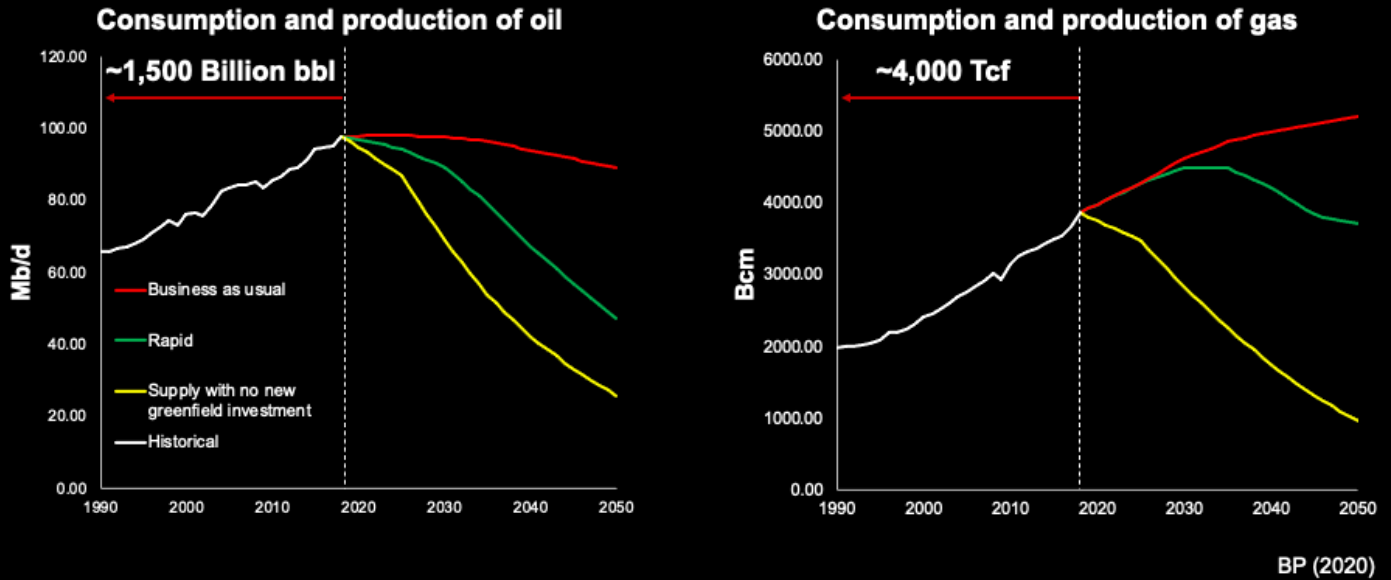
Who will pay for this? Ultimately all of us.

We can see this playing out already. The graph on the right shows the Wind/Solar Capacity of each country in Europe vs Electricity Prices for each country in Europe

It clear that a higher reliance on renewables equals higher prices.

What may be the consequences of these rising energy costs?

Demand and Supply of Hydrocarbons



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So what does this mean for those seeking careers in the hydrocarbon industry?

These graphs show the consumption of oil and gas

The vertical dashed line is today and left of that the white line shows historical consumption going back to 1990.

In the whole of human history, we have produced and used 1.5 trillion barrels of oil and ~4,000 Tcf of gas

To the right of the dashed line are future projections

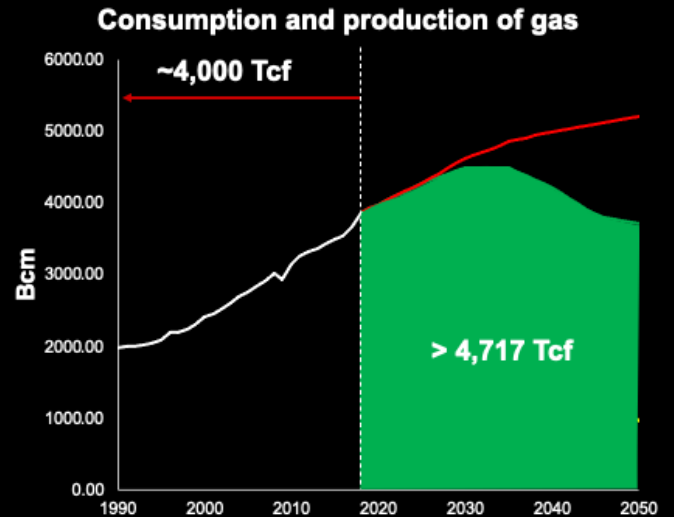
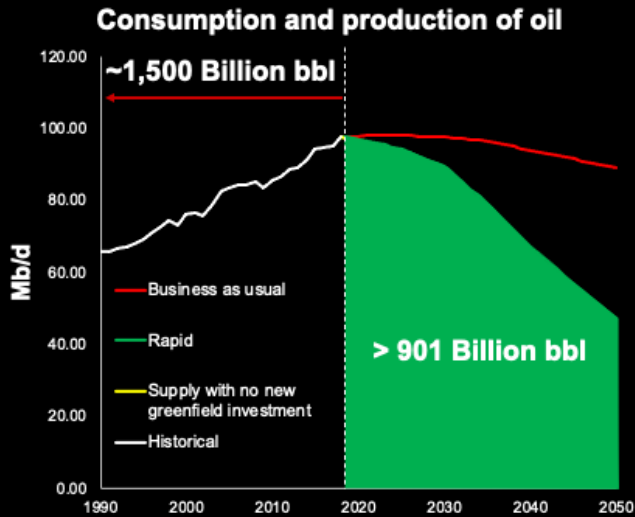
The red line shows business as usual demand with moderate CO2 reduction policies equalling a 10% on modern outputs by 2050

The green line shows demand that will be required in an ambitious rapid energy transition scenario where CO2 emissions fall by 70% compared to current – this roughly equates to the Paris agreement

The yellow line is the supply with no new exploration.

Lets look at what the rapid scenario may mean for our industry

Demand and Supply of Hydrocarbons



In a rapid energy transition we will require oil equivalent to 60% of that previously used and 125% of all the gas previously used

Data after BP (2020)

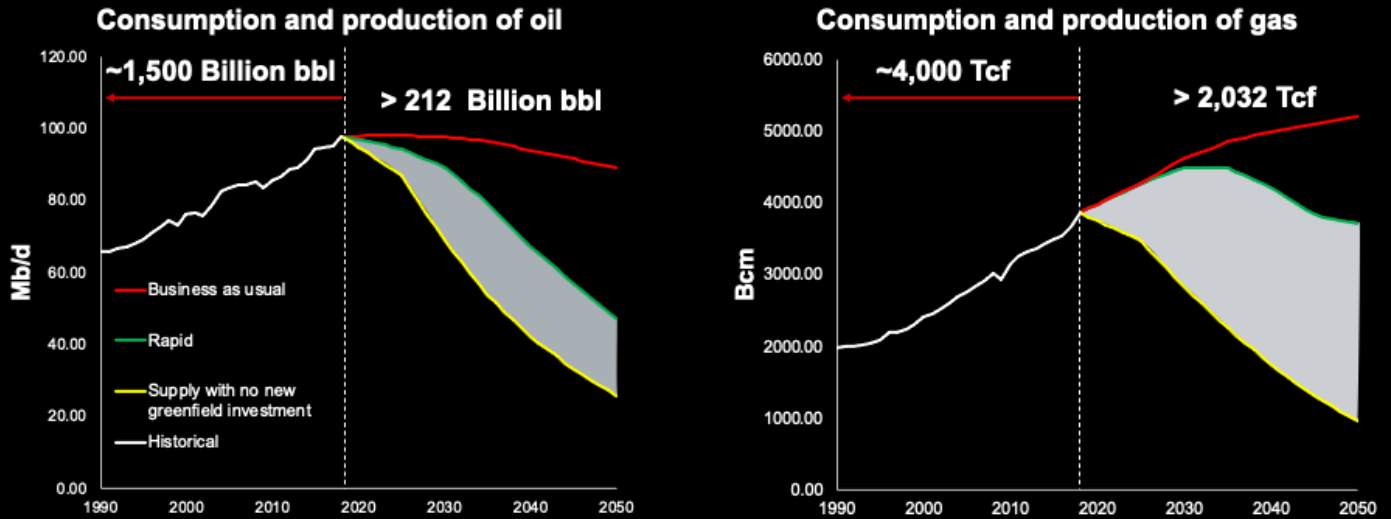
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In this scenario we will need to produce over 900 billion barrels of oil and over 4700 Tcf of gas in next 30 years

This equates to two thirds of all the oil we have ever produced and used and all the gas we have used to date plus another quarter – a really big ask

Of course, some of this will come from current oil fields. So what do we need to actually find?

Demand and Supply of Hydrocarbons: Mind the Gap



In a rapid energy transition we will need to find oil equivalent to finding 'a new Saudi Arabia' and gas equivalent to finding 'a new Russia'

Data after BP (2020)

Slide 24

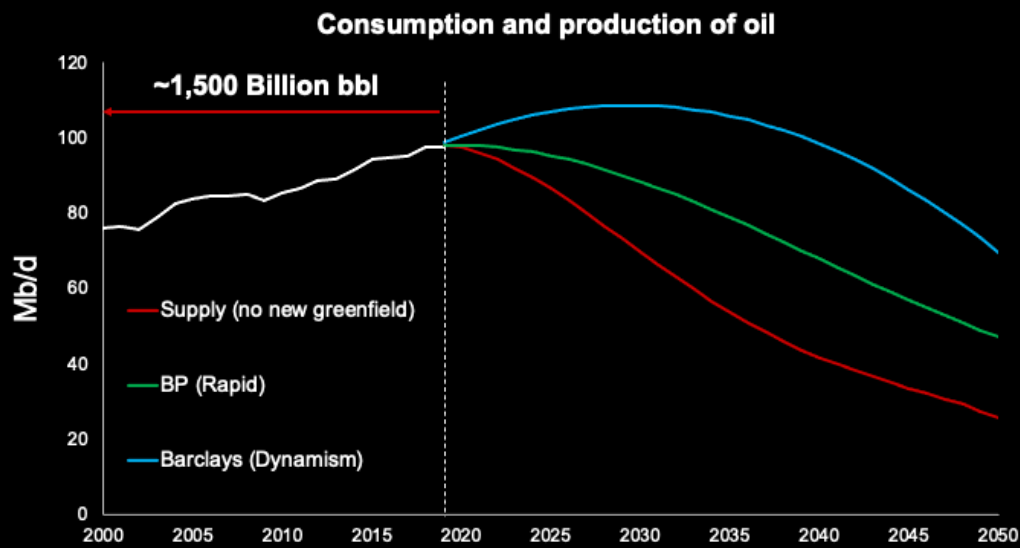
If we look at the gap between production from existing fields and demand, we will need to find and produce >212 billion barrels of oil and 2,032 TCF of gas in the next 30 years

So, about a fifth of ALL the oil we have ever used and half of all the gas we have ever used.

Put another way, at minimum we need to find another Saudi Arabia for oil and another Russia for gas

Therefore there is still a huge amount of work that needs to be done over the next 30 years at least

Barclays (2020) View



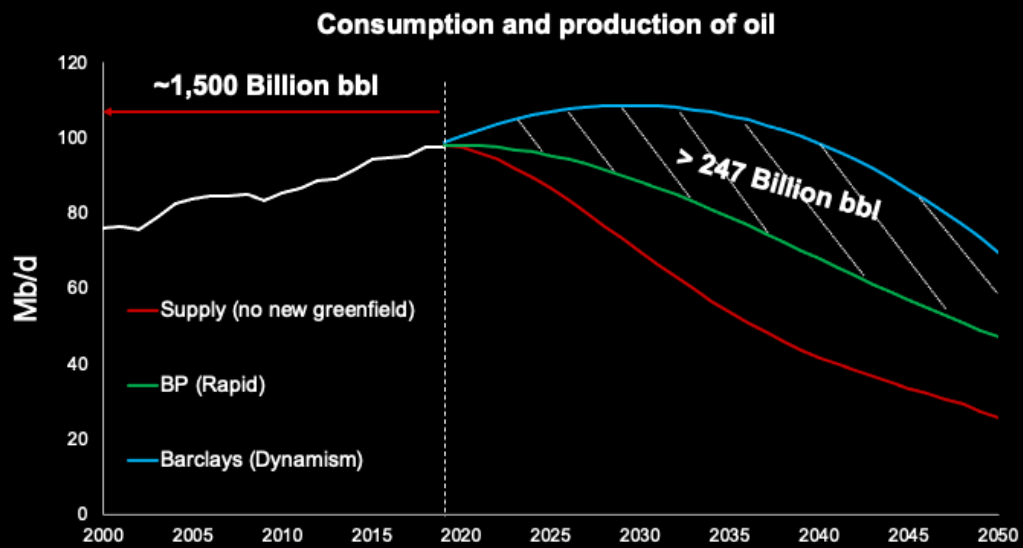
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This might be reflected in other future projections which often show a greater hydrocarbon demand than BP in rapid energy transition scenarios

In this graph you can see the oil demand in the BP rapid scenario, in green, compared against the rapid energy transition scenario of Barclays Bank in blue

You can see that the Barclays are forecasting a far higher demand for oil in the next 30 years than BP

Barclays (2020) View



Adds a further 247 B Bbl to be found to that in the BP "Rapid" scenario— assuming all known discoveries can be produced to end of field life

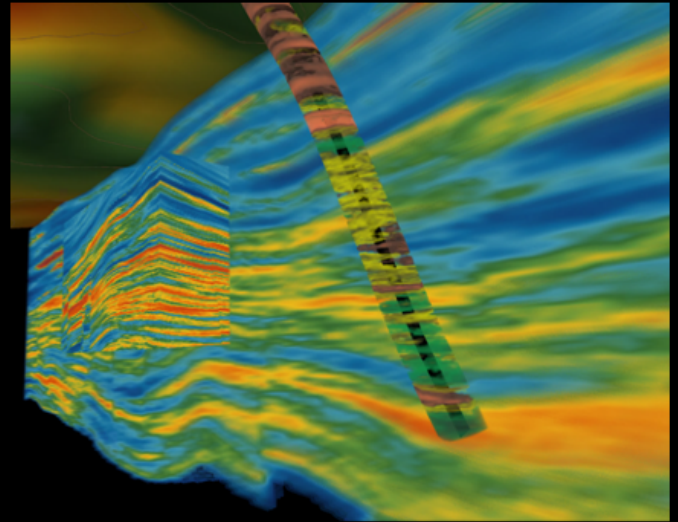
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This demand forecast by Barclays amounts to an additional 247 billion barrels compared to BP's forecast

And indicates a need to produce 1.1 trillion barrels of oil and find almost 500 billion barrels in the next 30 years

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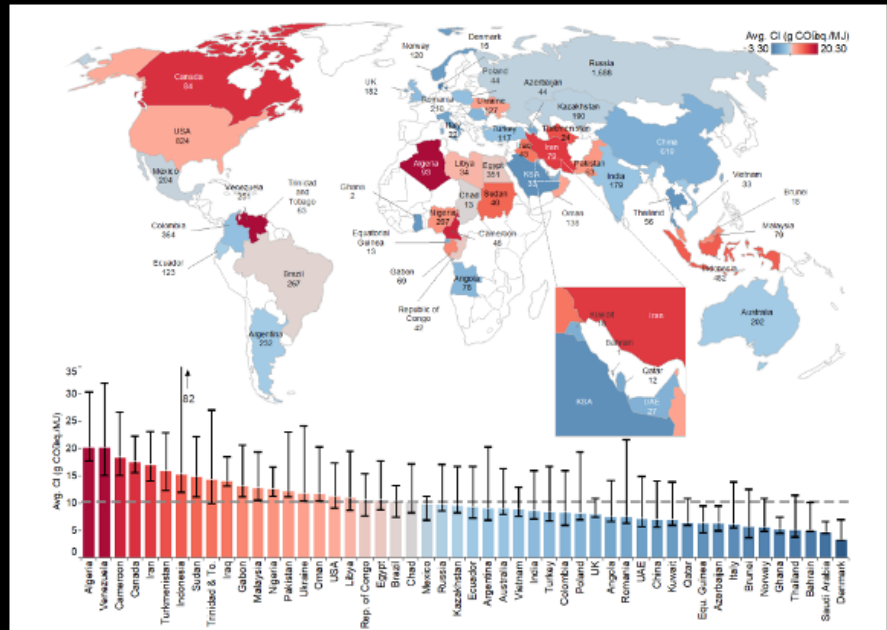
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The Search for Hydrocarbons: Focus on Carbon Intensity

- We need to be more efficient
- Finding oil and gas by using the least amount of energy & carbon intensity
- Exploration projects are now being risked and sanctioned based on carbon intensity
- Carbon intensity not only relates to efficiency, but the type of hydrocarbons produced



Slide 28

Masnadi et al. (2018)

Carbon intensity not only relates to efficiency, but also the type of hydrocarbons produced

This map shows the carbon intensity to produce hydrocarbons in different countries

We'll need to employ some clever approaches to help target low carbon intensity reserves

The Search for “Advantaged Hydrocarbons”

- Proximity to existing infrastructure
- Maximise use of existing data
- Superior subsurface understanding
 - Low risk, Light, pure crude and pure gas
 - Easy to exploit, large volume, reservoirs
 - High pressure to reduce artificial lift and stimulation
 - Drillable by long-reach laterals exposing max pay to the well bore
- Reinject CO₂ for production enhancement
- Utilise geothermal energy at wellsite



Sedimentary basins and hydrocarbon producing areas

<http://media.web.britannica.com/eb-media/67/112067-004-F4BB0E5C.gif>

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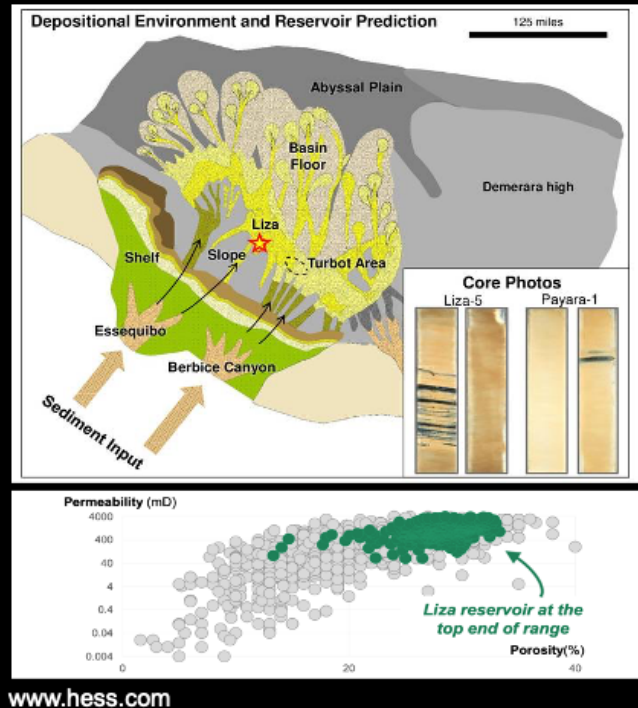
Carbon intensity not only relates to efficiency, but also the type of hydrocarbons produced

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Advantaged Hydrocarbons

- Offshore Guyana and Suriname are good examples of Advantaged Hydrocarbons
- \$35 break even price - ranks at the lower end of the global scale for breakeven prices
- 8 production wells per field – 56 MMBO per well
- Low sulfur light sweet crude
- Thick, high quality sandstone reservoirs in large structures
- High pressure reservoir



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Offshore Guyana and Suriname are good examples of Advantaged Hydrocarbons

The oil offshore Guyana and Suriname's are low sulfur, light sweet crude with API's of 32 and higher

The reservoirs are thick, high quality sands that are easy to exploit, and occur in large structures. As such there are large volumes of hydrocarbons in each field.

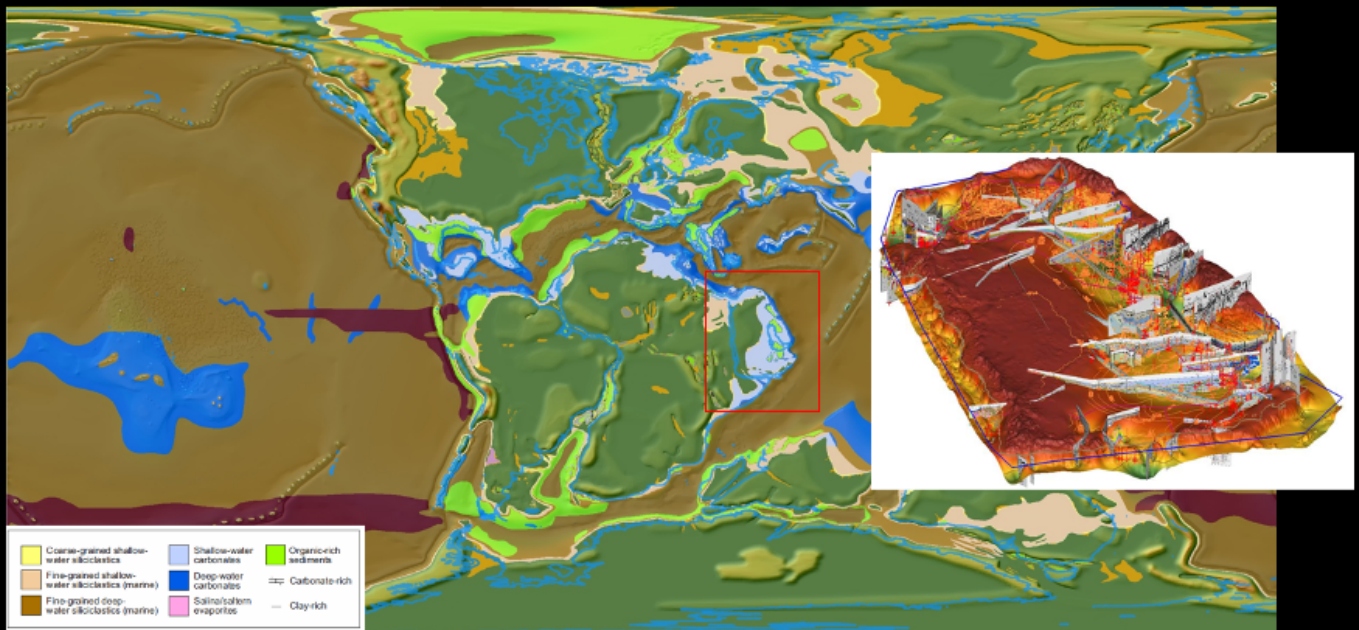
This, along with high reservoir pressures, means that the hydrocarbons can be easily produced from a small number of well – in Liza-phase 1, 8 wells, with 6 water and 3 gas injections wells.

Despite exploration being in deep water, the [breakeven even](#) price in the Stabroek block is \$35 per barrel and the price is expected to fall further as infrastructure is developed, and knowledge and technology improves.

Guyana therefore ranks at the lower end of the global scale for breakeven prices

Petronas is already employing an advantaged hydrocarbons strategy with its recent spudding of the Sloanea-1 well Offshore Suriname

The Search for Advantaged Hydrocarbons



Mid-Cretaceous palinspastic global GDE and Middle East depth map. DecisionSpace® 365 NefTex® Predictions product suite, Halliburton

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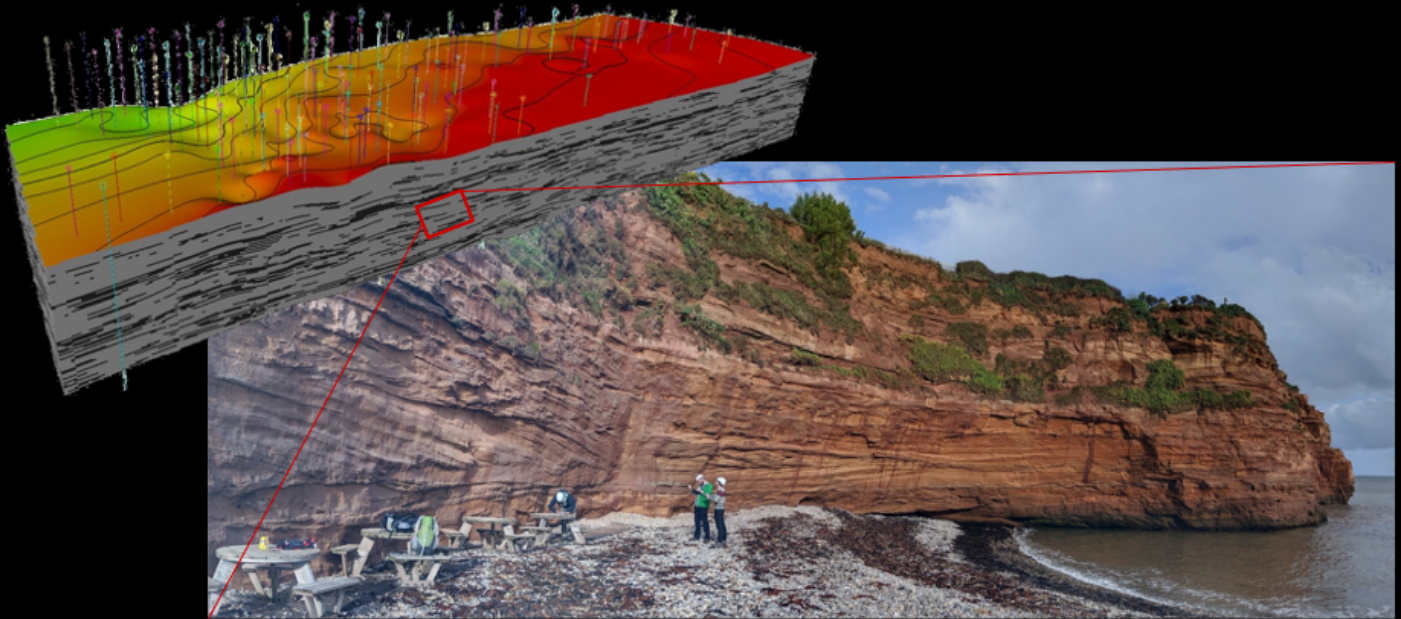
Well, as I just showed, there is a lot of work to do in the exploration of hydrocarbons

There will therefore be continued demand for exploration geologists and for exploration geoscience products and software, such as those shown here, to help with this task

We will need to be as efficient as we can at finding new reserves, so that it is done with the lowest carbon intensity

Exploration projects are now being risked and sanctioned based on the carbon intensity to find and produce new reserves

Producing Advantaged Hydrocarbons



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We need to continue to improve our solutions to help customers characterise and model reservoirs

This is needed for more efficient production of hydrocarbons

To help assess potential CCS sites

And to assess opportunities for geothermal

Poll Question 3

Current carbon storage capacity from power generation is 2.4 Mt/Year. By 2040, how much does it need to rise to meet the aims of the Paris Agreement?

- a. x10
- b. x50
- c. x100
- d. x500

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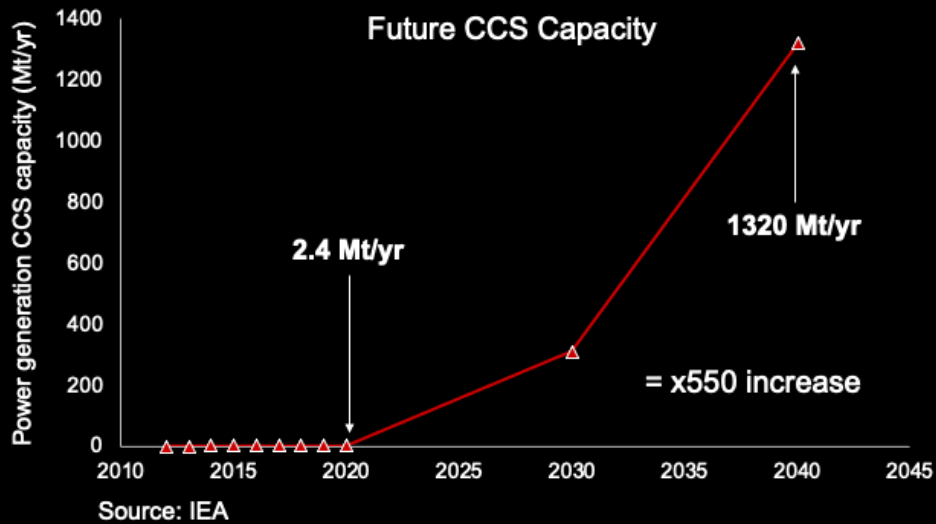
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CO₂ Capture & Storage

“CCS is a necessity, not an option.”

Committee on Climate Change, May 2019



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Ok, so we've tackled hydrocarbons but what other opportunities will there be for geoscientists as a result of the energy transition?

Clearly CCS will be part of the solution

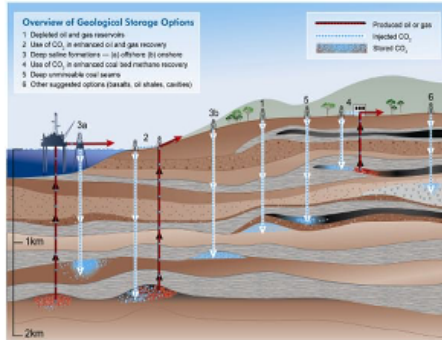
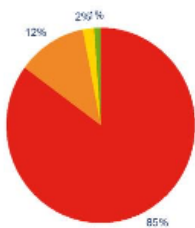
This not only reflected in what I have shown you so far, but is also the opinion others, including the committee on climate change.

Using renewables alone is unlikely to give society the energy density it needs

CO₂ Capture & Storage

Geologic CO₂ storage options

Estimated CO₂ Global Storage Capacity by storage type

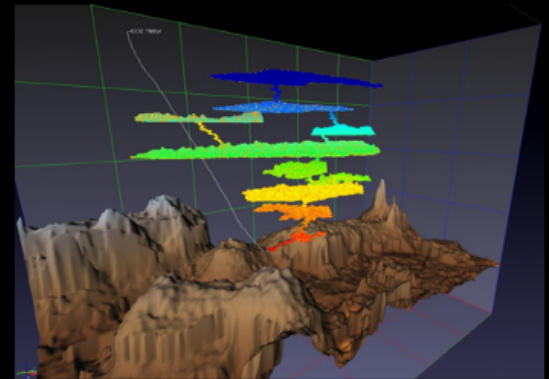


- Deep Saline Aquifers
- Depleted Gas Fields
- Depleted Oil Fields / CO₂ EOR
- Unminable Coal Seams

Source: IEA Greenhouse Gas R&D Programme



www.sccs.org.uk/map



Landmark Permedia® CO₂ Simulation, Halliburton

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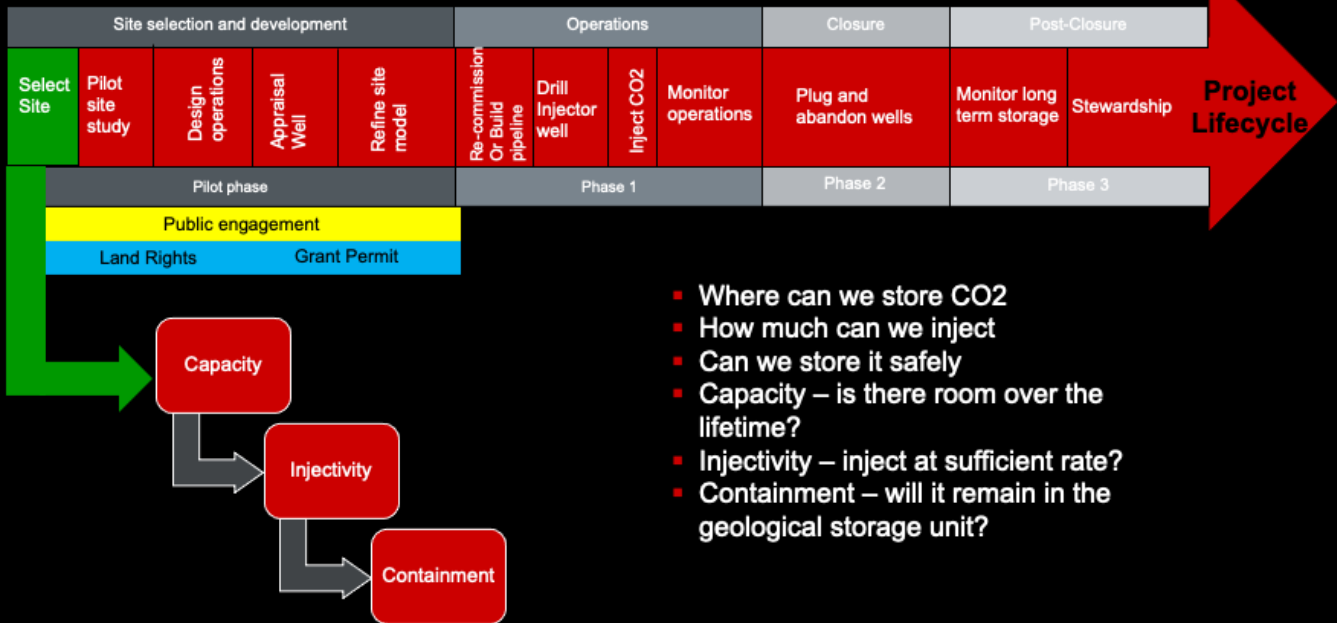
Halliburton already has CCS projects in all continents as can be seen in the map in the top right

However, we know that much of the storage will likely be taken up in previously ignored saline aquifers.

Geoscientists will be needed to help identify suitable CCS sites, create models of potential carbon reservoirs and use basin modelling software, such as Permedia, to explore the suitability of different storage sites

Subsurface CO₂ storage challenges

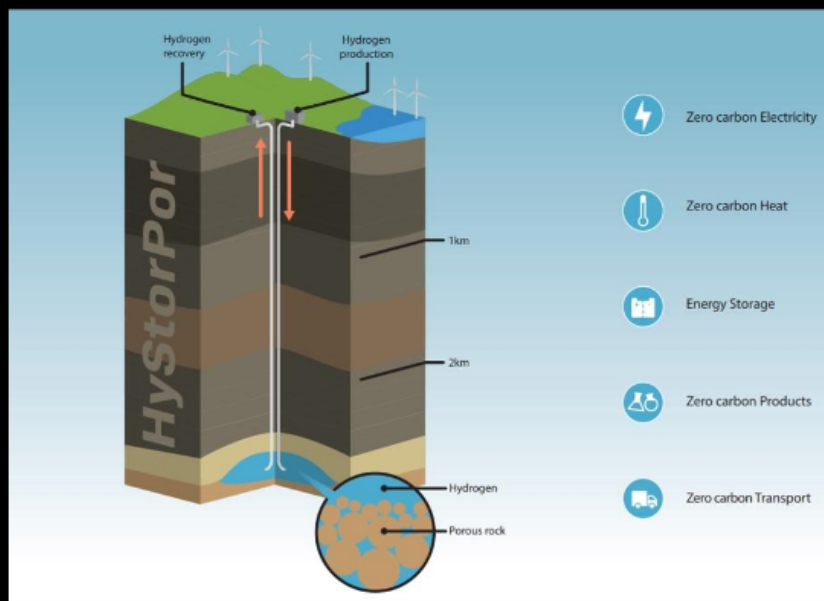
Adapted from www.CO2captureproject.org and Ringrose, 2020



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At the beginning of a carbon sequestration project it is important to address the following questions: Where can we store CO₂, how much can we inject, can we store it safely, is there enough capacity over the lifetime? can we inject at sufficient rate? and will it remain in the geological storage unit? Permedia CO₂ software can help reduce considerable risk and uncertainty over these questions and enable subsequent decision making on site selection more cost effective and ensure the critical elements of the subsurface are understood with more confidence.

Hydrogen Storage



<https://blogs.ed.ac.uk/hystorpor/>

Slide 37

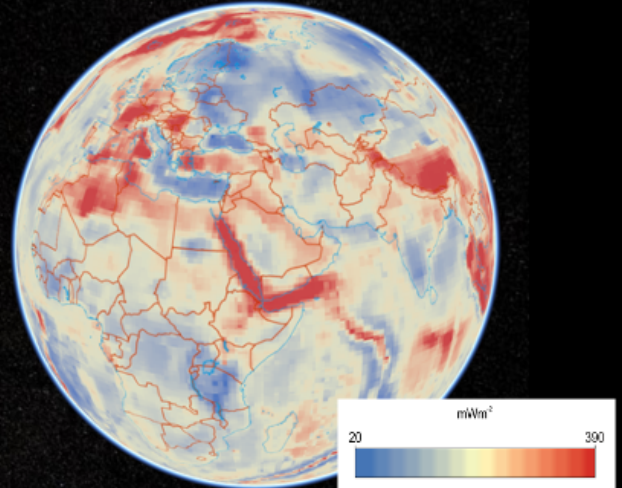
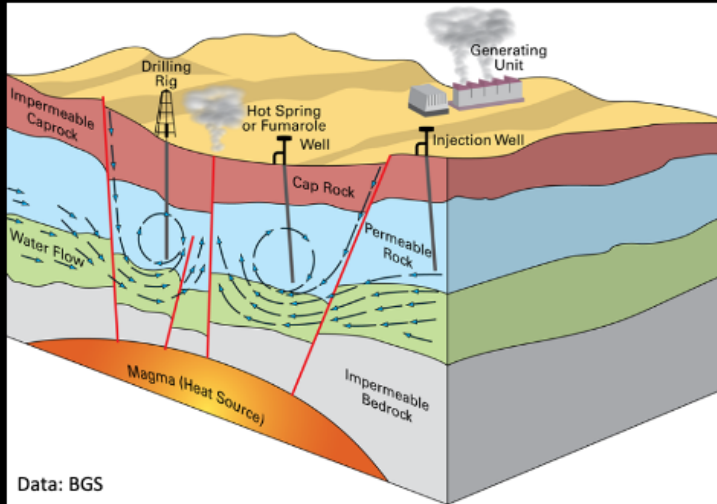
There may be further opportunities for geoscientists in the near future relating to subsurface storage.

Hydrogen is seen as a green replacement for liquid fuels and, as it can be stored for later use, it is seen as a way to fill the energy gap from renewables when the sun isn't shining, or the wind isn't blowing

Studies are already underway to explore the geological storage of hydrogen in salt caverns, [depleted oil](#) and [gas fields](#), and deep saline aquifers

Geothermal Energy

- Requires a good understanding of the subsurface at a variety of scales



Global geothermal gradient, DecisionSpace® 365 Neftex® Predictions product suite, Halliburton

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The focus on reservoir scale geology will not only be useful for hydrocarbons and CCS, but also for emerging geothermal opportunities

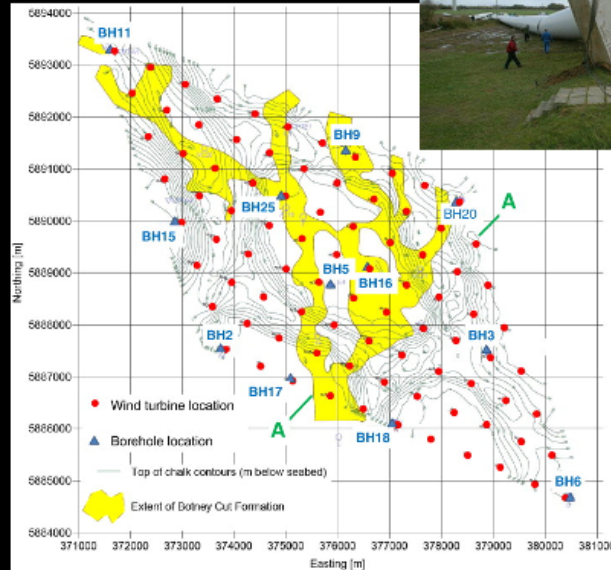
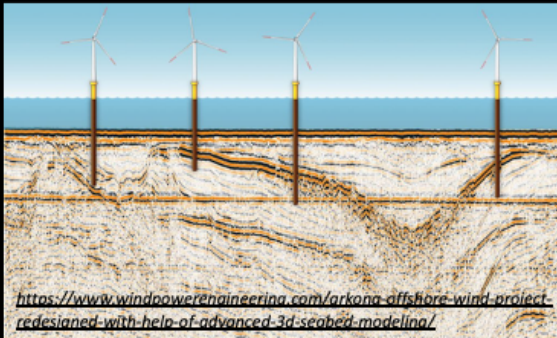
As a business, Halliburton already has significant geothermal experience with many projects already completed around the globe – but the interest in geothermal is certain to increase in the coming years

Whilst much of the G&G work on geothermal will be reservoir scale, the successful use of geothermal energy does require a good understanding of the subsurface on a variety of scales

For instance, the Neftex heatflow map can be used to provide valuable screening for opportunities

Engineering Geology – Wind Farms

- Understanding of sub-seabed geology key



Slide 39

Le et al. (2014)

The successful deployment of wind turbines also requires expert geoscience input.

As an example, in the North Sea, the Quaternary glaciations have left a buried landscape of glacial and fluvial channels, as can be seen in the shallow seismic image and geological map

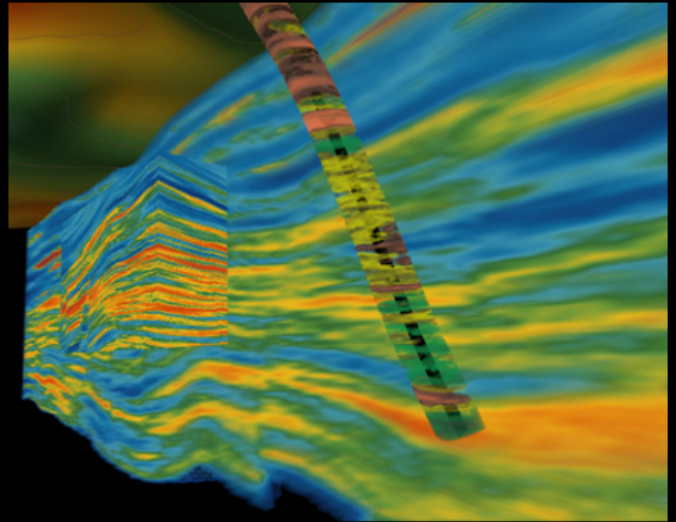
These pose a risk to the foundations of wind turbines

Geoscientists are therefore needed to interpret seismic data to help plan wind turbine placement and foundations

If this isn't done correctly there can be very costly mistakes!

Outline

- Introduction: Geoscience in the 21st Century
- Energy and Society
 - Energy demand
 - The energy mix – the role of hydrocarbons
- Evolving Geoscience Needs
 - Advantaged hydrocarbons
 - Carbon capture and storage
 - Renewables
- Geoscience Research and the Digital Transformation
- Conclusions



Slide 40

Let me begin by giving you an overview of the talk

I'll start with an introduction to set the scene, then look at energy and society.

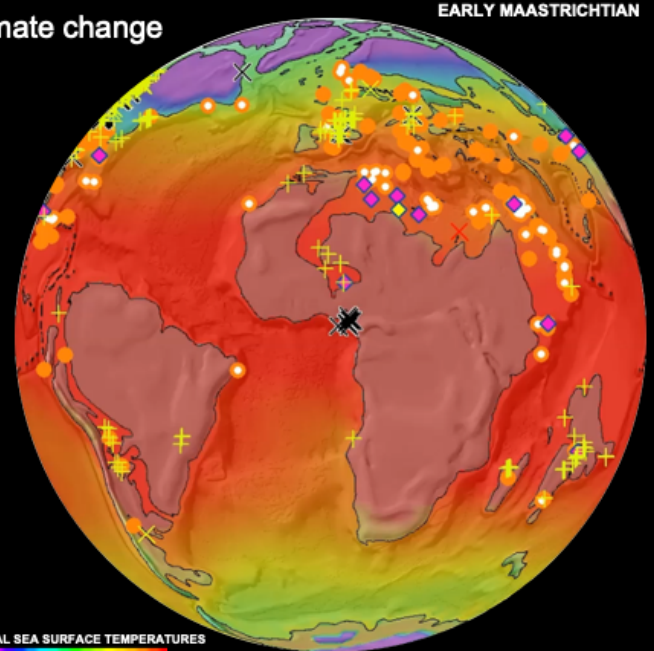
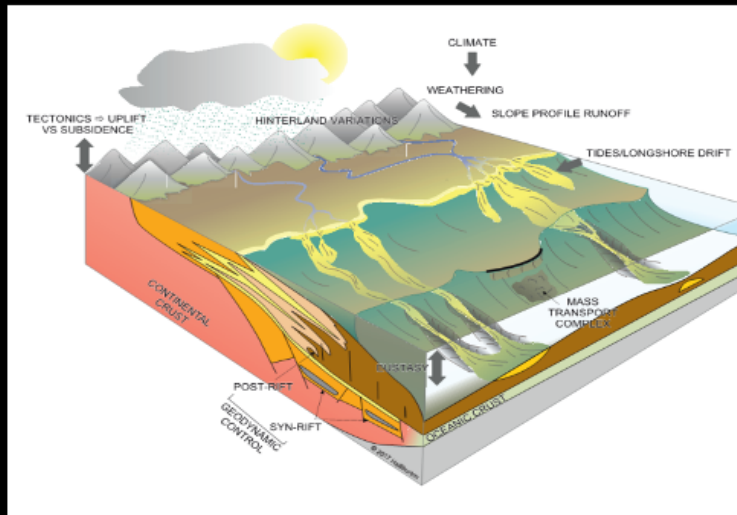
This will lead us into assessing future Geoscience Careers in relation to the energy transition

I'll then assess some aspects of future geoscience research and the digital transformation

Before wrapping up with some conclusions

Geoscience Research – Earth Systems Science

- A holistic approach and relevant to understanding climate change



Slide 49°C 10 20 30 Palaeoclimate model. DecisionSpace® 365
Neflex® Predictions product suite, Halliburton

To put it bluntly, there is still an awful lot we don't know about the Earth system

The fundamental research, undertaken at Universities like Leeds, must therefore continue.

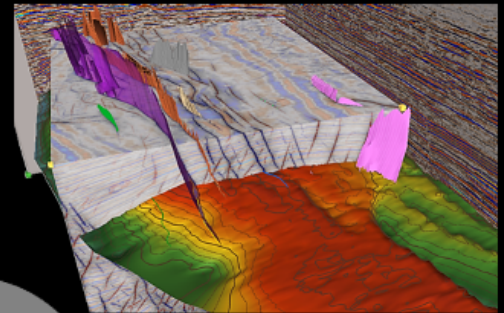
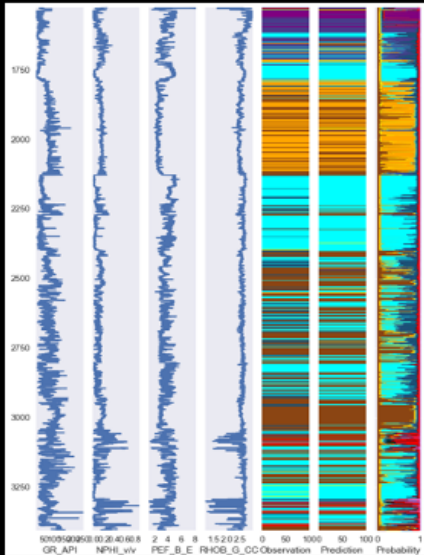
It not only benefits pure scientific curiosity, but is needed to help with all of the industrial challenges I outlined in the previous section.

One aspect of geoscience I have been involved with over the past few years is the development of a holistic Earth systems approach to understand depositional systems and petroleum systems elements

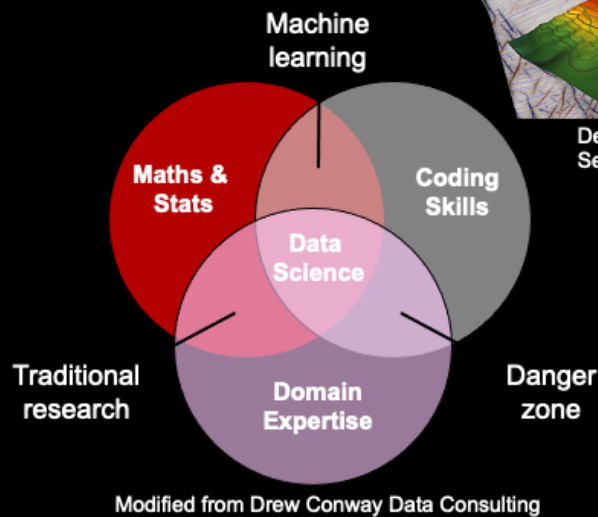
This involves the use of paleoclimate models, as seen on the right, which the university of Leeds help us to create.

Geoscience Research – Digital Transformation

Geoscience input crucial



DecisionSpace® 365
Seismic Engine (Halliburton)



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To support all of this, geoscience needs to further embrace the use technology and AI

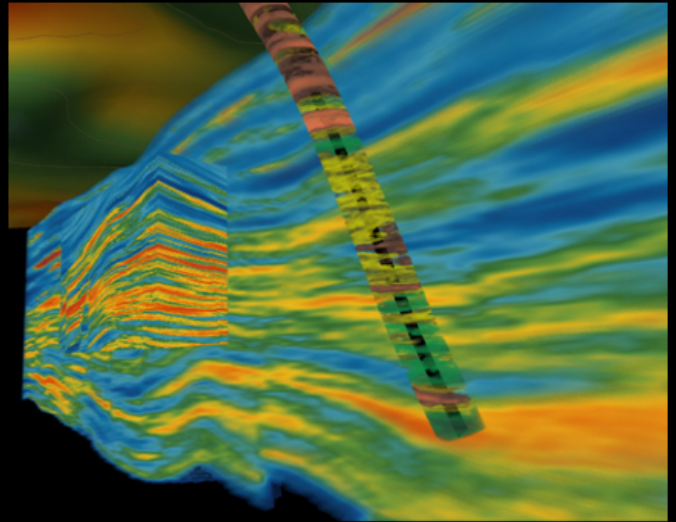
At Halliburton we have multidisciplinary teams that include maths expertise, coding skills and geoscience domain knowledge that work to generate our next generation tools

These tools use techniques like machine learning to conduct geological interpretations automatically

As an example, we now use machines to automatically interpret lithology in wells, as shown in the image on the left, and automatically interpret faults in seismic data, as shown in the top right image

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Slide 43

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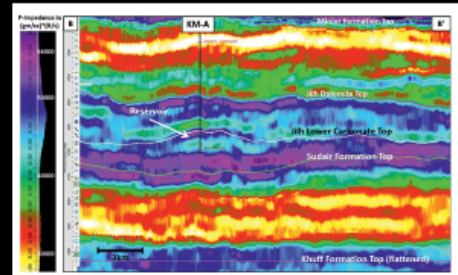
Before wrapping up with some conclusions

Key Take Home Messages

- Geoscientists have a crucial role to play through the energy transition
- Hydrocarbons will continue to be a major part of the energy mix for decades to come
- Needed to sustain the energy demands of a growing, healthier and wealthier global population
- Produce >900 billion barrels and >4,700 Tcf by 2050, including finding significant new resource
- With minimal carbon intensity (“advantaged hydrocarbons”), augmented by CCS
- Other renewable energies require geoscience know-how
- Data science required to allow geoscientists to focus on higher-value tasks



<https://www.pinterest.co.uk/pin/176555247869320740/>



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So at this point I'll give you my take away messages for the talk

Key Take Home Messages

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