May/June 2020

SPE Review London

The official e-magazine of the Society of Petroleum Engineers' London branch

Machine learning and AI: Part one

PLUS:

Oil is the new data: the uneasy relationship between big tech and big oil

* Temperature effects on large-scale CO_2 storage
* Modelling safe gas extraction from stratified lakes
* Gaia talks: Measuring what matters
* School talks: The future of energy
* C-level talks: Leigh-Ann Russell, BP
* Book Review: Make, Think, Imagine

SPE International London Section

BEHIND THE SCENES MEET THE BOARD ONLINE EVENTS

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ABOUT US

The Society of Petroleum Engineers (SPE) is a not-for-profit professional association whose members are engaged in energy resources, development and production. SPE is a non-profit professional society with more than 156,000 members in 154 countries, who participate in 203 sections and 383 student chapters. SPE's membership includes 72,000 student members. SPE is a key resource for technical knowledge related to the oil and gas exploration and production industry and provides services through its global events, publications, events, training courses and online resources at www.spe.org. SPE London section publishes SPE Review London, an online newsletter, 10 times a year, which is digitally sent to its 3000+ members. If you have read this issue and would like to join the SPE and receive your own copy of SPE Review London, as well as many other benefits – or you know a friend or colleague who would like to join – please visit www.spe.org for an application form.

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In this issue

Cover photo by Enrico Nunziat

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Behind the Scenes: SPE Review Editorial Board

Elizaveta Poliakova, Editor in Chief

Elizaveta is a Reservoir Engineer at Trident Energy Management Limited. She has a Master's of Science in Petroleum Engineering from Imperial College London and a Bachelor's in Petroleum Engineering from the University of Leeds.

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A big Thank You! to all the organisations that support the SPE London section

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Letter from the SPE London Chair

Dear SPE London members and colleagues,

Welcome to the June 2020 issue of SPE Review London! We hope you enjoy quite a few new features we are introducing to our publication!

SPE London volunteers have busy recently and since our last Newsletter we organized a very successful outreach programme. On June 5, Alison Isherwood from the SPE London Board gave a virtual presentation to students of the Westminster Academy in London, as part of the Schools visit and Sustainability initiative. The topic was “Evolution or revolution? The Future of energy”. The best indication of how it went was the questions after, the students were engaged and there were some great ones, which give a good indication and that the students are thinking about the right things: What are the barriers to getting carbon capture going and how long will it take? Doesn’t it take a lot of energy and chemicals to make solar panels and aren’t they difficult to dispose of? Additionally, familiar to many SPE members, Energy4me has launched a new website providing at-home learning resources for students.

SPE London invites our members on the June 24 to meet and network in a social setting for discussions in small groups (Zoom). We plan for the small group breakout sessions to be repeated a few times in the hour-long event with different (randomly assigned) groups of 3-5 people. Due to current circumstances, we're all missing out on face-to-face discussions about our industry, including new uncertainties. This aims to replicate the small group chats we all have at in-person events. This event is limited to 50 people and it might be oversubscribed by the time you are reading these lines.

On June 25 at 2.30 pm UK time, SPE Distinguished Lecturer, Lawrence Camilleri, will deliver his talk "Production optimization of conventional and unconventional wells with ESP real time data" as a live online webinar event. This is because Lawrence is unable to visit the London Section due to the pandemic.

During these unprecedented times, SPE is here supporting our members! SPE International is currently offering a 50% discount on your membership renewal for 2020 (individuals who were members in 2019 who have not renewed to date for 2020). This is an increase from the previous 20% discount. Membership is essential to keeping you connected to a global network, with online resources enabling you to stay current and enhance your technical knowledge. To receive this special offer, you must use the Renew Now button, **use this link** or contact service@spe.org.

SPE International is assisting Members in Transition in the following ways. Dues waivers for members who have been furloughed or unemployed due to COVID-19, contact service@spe.org. Enhanced the resources available on Members in Transition pages. Launched a new virtual support community for members to connect during these challenging times. Created a job board where members can post their resume and search available job postings at no cost. Companies can also post available positions and search through resumes.

Even as the global energy mix is in transition, oil and gas will continue to supply more than half the world's energy for decades to come. As part of Energizing Our Lives initiative, SPE International started to share the stories of our members and their companies about all of the ways that what we do improves the lives of the regular people across our planet. Together with "Fueling Progress" blog it is a starting point for increasing understanding of the positive aspects of the oil and gas industry.

From the July 1, we start a new "SPE year" when the new London Board will come into effect. If you wish to join a group of enthusiastic people who shape the activities of energy professionals in London area or just have ideas to contribute, please contact SPE London Board individually, via social media channels or SPELondon@spemail.org.

Thank you for your continued efforts. Stay safe!

Maxim Kotenev

Letter from the Editor

Dear SPE members and colleagues,

Welcome to the third SPE Review London publication of 2020!

In this edition, we would like to introduce a new series on Machine Learning and Artificial Intelligence applied to Oil & Gas. Starting from our June issue, we will be publishing three articles written by Cameron Snow, co-founder at Danomics LLC, discussing how the next technology frontier might impact our Industry. Moreover, we want to thank our readers for the exciting feedback on all series created throughout 2020.

This month's Book Review discusses "Make, Think, Imagine" by John Browne, while "C-Level Talks" features an exclusive interview with Leigh-Ann Russel, incoming Chief Procurement Officer at BP. Please let us know your thoughts on how to make SPE Review London even better!

Since our last publication many events have unfortunately been postponed due to COVID19. However, SPE London and SPE International are still active online! SPE London hosted a Live session named "Gaia Talks N3: Measuring what matters", where a panel discussed how to achieve socio-economic development sustainably. You can find a summary and links to the recorded panel on pages 18 and 19.

I would also like to congratulate our Sustainability & Communication Officer at SPE London, Alison Isherwood, on giving the first talk to secondary school pupils about "The Future of Energy: Revolution or Evolution". The aim of these talks is to improve understanding of the O&G industry and show its scope to students. Hopefully, this will contribute to spark the interest of a new generation of energy enthusiasts!

Finally, I would like to thank our Editorial Team at SPE Review London for their efforts, energy and support!

Take care,
Elizaveta Poliakova

NEWS DIGEST... NEWS DIGEST... NEWS DIGEST

Collaboration on assessing Oil & Gas Digitalisation

At the beginning of June 2020, Oil and Gas UK launched an important research partnering with Technology Leadership Board (TLB), the Oil and Gas Technology Centre (OGTC), and Opportunity North East (ONE) to analyse the scope of digitalisation across the industry.
In collaborative work with Deloitte, the partners are using UKCS Data and Digital Maturity Survey to engage with companies and individuals on several aspects including data analysis, training, digitalisation across organisations and innovation processes.
Link here for full story

Time to challenge – vision for logistics

Peterson Energy Logistics has shared its view on the opportunity of reshaping O&G logistics.
The biggest expenditure across the industry's supply chain is "where each party operates their own vessels, their own bases, manages their own planning teams and their own complex invoicing systems."
The company's vision includes a collaboration of worldwide operators based on the geographical location of their assets to amalgamate bases and resources to provide cargo to offshore locations.
The idea has already been implemented in the UKCS with the beginning of Central and Northern North Sea (CNNS) Pool in 2017 applying and sharing logistics without compromising the service.
On the example of CNNS collaborating with Southern North Sea (SNS), more than 66,000 of CO_2 was saved over the past three years. This, on a global scale, can realise significant environmental benefits and financial savings.
Link here for full story

Industry insights for YPs

The first OGUK webinar took place in April, overviewing strategic and long-term future as well as the direction in which the industry is going.
The webinar gave a "virtual opportunity to network and learn from industry leaders amidst unprecedented times due to a turbulent oil price and the Covid-19 pandemic".
View recorded webinar here
Link here for full story
And here

Oil price – back to growth

Tighter crude supply, as a result of OPEC+ agreement, is helping to recover the oil market damaged by COVID-19.
Brent crude, that experienced a 36% plunge this year, was trading at $42 per barrel.
Amid the production cuts, the EIA chief is predicting crude demand to surpass pre-crisis levels at the current low prices.
Link here for full story
And here

More oil majors expanding renewables portfolio

To achieve its recent announcement of going net-zero emissions in all operations and products, French O&G major, Total, has announced its intention to acquire 51% of of Scotland's biggest offshore windfarm.
Italian major, ENI, has also started its transition to greener energy.
As Claudio Descalzi, Eni CEO, said, "This new structure reflects Eni's pivot to the energy transition; an irreversible path that will make us leaders in decarbonised energy products."
The company is planning a major structural transformation with a plan to create a separate division dedicated to renewable energy.
Like Total and other European O&G majors, ENI is looking to increase investments into green energy alternatives and cut its emissions.
Link here for full story
And here
And here

O&G Commitment to halve emissions within 10 years

The industry is devoting to net-zero by the mid-century, aiming to cut its emissions by two-fold in the next 10 years. The plan is to power platforms with locally generated electricity or powered from the land as well as to monitor emissions in the logistics sector, exploration and onshore terminals.
Deirdre Michie, CEO of Oil & Gas UK, said: "Our industry will play its part by reducing its emissions and using its skills to develop the solutions that will be needed to make a significant contribution to the UK's overall targets."

Link here for full story
And here
And here

Ambassador Lecturer Programme: Postgraduate study, scholarships and SPE Involvement

Promise Ahante, the current President at SPE Imperial, shared his experience as an Imperial College London (ICL) ambassador and Shell's scholar during the Ambassador Lecturer Programme (ALP) organised by SPE Port Harcourt Section.

When we consider the impact of recent global issues, and the impression made on the oil and gas industry, it is all the more important to realise the need for support and guidance to budding energy professionals.

As every cloud has a silver lining, the adaptation and surge of online events now provide an avenue for such conversations that is unlimited by either location or distance, hence promoting more collaboration between sections and chapters of the Society of Petroleum Engineers (SPE), around the world.

On June 1, the SPE President of Imperial College London spoke to nearly 60 Nigerian students and recent graduates during an Ambassador Lecturer Program (ALP) organised by SPE Port Harcourt section.

Promise Ahante, who is currently completing his Masters in Petroleum Engineering program under the sponsorship of Shell Nigeria, shared key lessons gathered from his experience through advancing his studies, gaining a scholarship and being part of the SPE.

Consistent with the theme of the ALP, he communicated why undertaking a postgraduate study better equips graduates with technical and soft skills required to thrive in the industry and provided a guide on how students can identify, prepare for and obtain funding opportunities. He further shared his experience of how beneficial it is for desiring energy professionals to be actively engaged with professional societies such as the SPE and how to actively participate to maximise those benefits.

On the whole, the attendees expressed positive feedback on how insightful the session was and the added value this discussion provided on the back of the already highly regarded ALP platform. This was an additional benefit to connect people to exchange valuable industry and career information.

Machine Learning and AI applications in Oil & Gas

In the first of a three-part series, Cameron Snow (co-founder, Danomics), provides an overview of existing applications of machine learning and AI, and where opportunities are ready to be seized.

The oil and gas industry has long taken pride in its ability to innovate and use cutting edge technologies to bring new pools of oil and gas to market. Embracing new technologies allowed the industry to unlock unconventional plays, explore extreme water depths, and drill high pressure and temperature wells that were previously beyond our reach.

However, the industry has been late to the party with respect to machine learning and artificial intelligence (AI), and is all too often still employing methods that arose during periods with less computing power, sparser data, slower activity and larger staffs. Although this is slowly changing, there are many roadblocks to adoption; most companies don't have the internal resources to perform the work themselves, evaluate use cases, or properly assess vendor solutions, and are unwilling to build out internal resources for uncertain use cases.

Data Analytics vs. Machine Learning vs. AI

Over the past decade, the terms machine learning and AI have become part of every executive's lexicon, and vendors are quick to label their products with the buzzword of the day. We've all seen the ads offering an "Analytics-driven, machine learning-based, AI-enhanced solution." However, many of the would-be buyers of these solutions are hard-pressed to define these terms, so it's important that we do so here.

- Machine learning refers to the application of a suite of techniques towards making predictions of values or classifications, using algorithms from simple regressions to complex neural networks with reinforcement learning.
- AI, although often used synonymously with machine learning, is better defined as combining the predictive power of machine learning with the ability to take an action.

Regardless of what you call the technique applied, the goal should be to reduce the trade-off between time and quality while generating actionable insights.

Upstream Exploration and Development Applications

Within the industry machine learning has gained the most traction in the areas of exploration and development. One example of this is Danomics' automated log repair tool, which employs basic machine learning models to repair curve data in areas affected by borehole washouts. Another is the application of clustering algorithms to distinguish rock types and make facies classifications. But the applications of machine learning are not just limited to well logs. Potential applications include:

- Combining machine learning with traditional autopicking tools to rapidly interpret seismic data and high-grade areas of interest.
- Automating well-log correlations across a basin
- Integrating physical models of reservoir performance with machine learning tools to provide thousands of wells with customized predictions.
- Performing velocity analysis and static corrections in the seismic processing chain.

Even in the age-old field of geological mapping, algorithms could be implemented to generate deeper insights than traditional methods. For example, consider the So*Phi*H map, which is a combination of the oil saturation, porosity, and thickness properties. This map, although powerful, is also non-unique by nature and doesn't allow the user to distinguish which component drives results.

Machine Learning and AI applications in Oil & Gas continued

Machine learning algorithms could help focus interpreters by classifying areas with the highest potential based on correlations derived from analogous plays.

Operations and Production Applications

Although the adoption rates for these technologies may be higher in exploration and development, the size of the prize and potential value add within operations and production is larger and the potential scope significantly wider.

- Drill bit selection could be performed via models trained using historical data given a well's lithology and expected P/T conditions to minimize drilling times or bit trips
- ESP pump failures could be pre-empted by analyzing sensor data streams to minimize downtime and maintenance costs
- Machine-learning algorithms could ingest a combination of seismic, log, and drilling information in real time to predict dangerous pressure kicks.

In the future, one could imagine a field with 100s of wells on a combination of beam pumps and ESPs in which a neural network enhanced by reinforcement learning could be utilized to identify the optimal pumping parameters and control flow from each well to maximize oil production while minimizing water cut, with all the changes enacted automatically.

The AI could also identify wells with potential tubing or casing leaks and pumps that are at risk of failure, send a message to field personnel alerting them to the situation, and simultaneously order replacement parts.

Deploying Algorithms

One key point is that in almost all use cases machine learning is used to augment and enhance what the human interpreter does, not to replace them. The algorithms can't do everything. The goal is to clear your team's plate so that they can focus on the highest value-add activities.

In many cases, it is best to think of AI and machine learning solutions as an army of young, extremely consistent, and tireless interpreters. They can do good work, but they need training and you are going to QC their outputs before making expensive decisions.

The supervision and oversight of deployed models is critical as we move from the office to the field. In exploration work a failed model may result in lost time, project delays, and frustration. However, in the field the consequence of a prematurely deployed model taking actions without proper oversight could be deadly. Therefore, it is critical that we maintain human expertise to oversee operational decision.

Conclusions

Machine learning and AI have the potential to transform our industry, and there are countless opportunities across all parts of the oil and gas spectrum to utilize them for value creation.

However, the industry has not yet been able to realize their potential.

In the following parts to this article I will outline how companies can set the stage to take advantage of the technologies and outline a framework for evaluating vendor solutions.

The second part of this three-part series by Cameron Snow will be in the July/August issue of SPE Review London.

A study of temperature effects in the Bunter Closure 36, a potential large-scale CO_2 storage site in the UK

The effect of temperature variation is discussed with reference to the Bunter Closure 36, a prospect considered for CO_2 storage in the UK. Although temperature is often considered as a secondary effect, it should not be neglected in an accurate CO_2 injection design.

Introduction

When selecting a storage site in deep saline aquifers, economic feasibility requires pressure and temperature conditions such that the CO_2 can be stored at a liquid-like density, to minimise the volume stored, and so maximise capacity, [1]. In many of the prospects studied around the world, the CO_2 is close to its critical point [31° C, 73.8 Bar], where small variations in temperature cause significant changes in density and viscosity. The viscosity impacts the mobility of the CO_2, while the density alters the volume occupied, with consequences on the footprint and the over-pressure during injection.

In general, CO_2 does not enter the aquifer at the initial aquifer temperature. However, the thermal capacity of the aquifer is such that the CO_2 being injected is quickly warmed-up or cooled-down to the ambient temperature. The thermal front generally lags behind the CO_2-brine interface, although its penetration depends on the type of injection. For multi-year prolonged injection, the injection temperature will travel further from the wells, while for intermittent injection the effect is more local. Either way, it's worth observing that the CO_2 at storage conditions has a heat capacity close to that of a liquid, so the effect is greater than that of a gas such as methane. Away from the injection front, the natural geothermal temperature gradient of the aquifer is another cause of temperature variation that impacts the CO_2 properties.

The importance of thermal effects will vary from site to site, depending on the depth, vertical extension, difference between injection and aquifer temperature, and the way the site is operated.

The Bunter Closure 36 prospect

In 2015, the Energy Technology Institute (ETI) selected five potential sites for commercial-scale CO_2 storage in the UK [2]. The Bunter Closure 36 (BC36), located in the Southern North Sea, offshore the east coast of the UK (Fig 1), was one of the prospects chosen due to its ideal dome structure offering a good storage efficiency, and its strategic location near two important CO_2-generating clusters, the river Thames and the Humber.

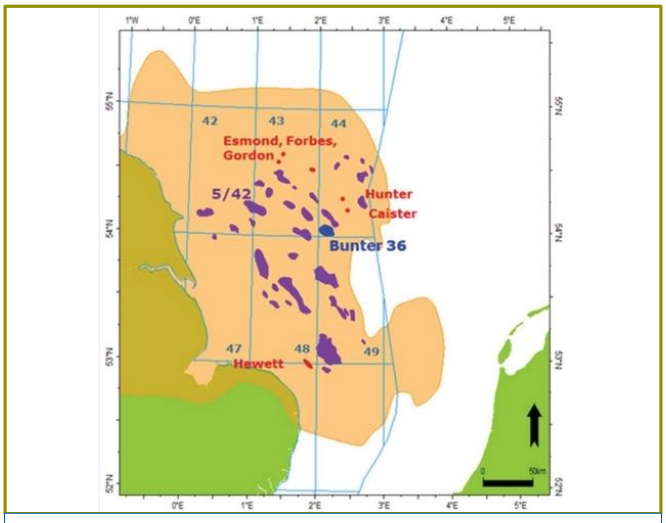

Fig. 1. Location of Bunter Closure 36 prospect.

The development plan elaborated for the site and the computational model used for the initial assessment are publicly available [3], and have been used to set up the model presented in this study.

The target layer has a thickness of about 200 m, with the crest of the dome situated at a depth of 1170 m below sea level.

The number and location of the injector wells has been chosen to maximise the injectivity while minimising the pressure build-up to preserve the integrity of the caprock. The maximum pressure permitted has been fixed to 90% of the fracture pressure, which is computed using a fracture pressure gradient value of 0.168 Bar/m.

A study of temperature effects continued

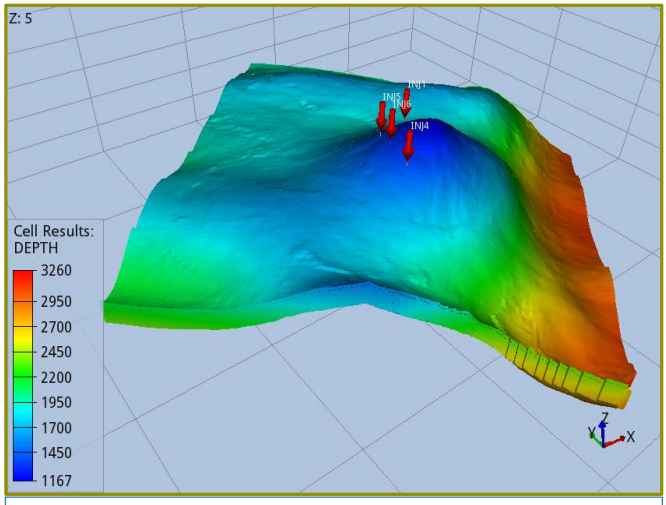

Fig. 2. Target layer of Bunter Closure 36 and location of the 4 injector wells.

The four wells selected are all located in the western side of the dome (Fig. 2), a configuration that favours the brine displacement towards the east, and avoids an excessive pressure build-up, which is the limiting factor of the storage capacity of BC36.

Each well injects1.75 Mt (Mega Tonnes) of CO_2 per year, for 56 years, reaching a total capacity of 392 Mt. The well top hole temperature is estimated to be at 4 C, i.e. the sea bed temperature. Well pipe simulations suggest that CO_2 will enter the aquifer at about 12 C [2], where it encounters an average ambient temperature of 45 C.

The Bunter Closure 36 computational model

The computational model, as downloaded from the ETI website, covers an area of 25 x 25 km, and uses a horizontal discretization of 200 x 200 m. Vertically, the computational grid has a variable discretization that goes from 0.5 to 20 m, with refinement in proximity to the impermeable layers, where the CO_2 is expected to accumulate. The total number of active cells is approximately 600,000.

Permeability, porosity and other static data, as well as relative permeability drainage and imbibition curves are those given in the ETI model. The static data required for thermal modelling is not provided, however the properties needed have been estimated with the following values: the rock density is equal to 2350 kg/m3, the rock heat capacity is taken as 1000 J/(kg-K), and thermal conductivity of the saturated rock is given a value of 1.541 W/(K-m).

The surrounding remainder of the aquifer, which has a volume of 270 km3, is connected to the computational model by means of cell volume multipliers applied along the lateral boundaries.

The simulator used for the study is the CO_2 storage option of PFLOTRAN-OGS [4]. This can model a system with two phases (aqueous and vapour), and two components (CO_2 and water), which can be present in both phases. The partitioning of CO_2 and water in the aqueous and vapour phases is modelled using the correlation of Duan and Sun, [5]. Supercritical CO_2 is characterised using correlations by Span and Wagner [6] and Fenghour et al [7]. The water properties are computed using standard water tables, correcting the density for the presence of dissolved CO_2 and salt [8]. A constant background salt concentration of 4.28 molar is used, which impacts the solubility of CO_2 in brine and brine density. The formulation accounts for molecular diffusion in the aqueous phase, using a diffusion coefficient of 4x10-9 m2/s, as suggested by Tamimi [9].

Three modelling options are compared to assess the temperature effects:
1. Isothermal, using an average temperature of 45 C.
2. A vertical temperature distribution obtained by imposing T = 37.5 C at the crest of the dome (depth of 1167 m) and a thermal gradient of 30 C/km, which remains constant in time.
3. A full thermal option, where the initial temperature is the same of option 2, but heat conduction and convection are also modelled. Cell volume multipliers are applied to the top and bottom layers so that their heat capacity is increased, and their temperatures remain fixed to the initial values given by the geothermal gradient over the 1000 years simulated. These layers, with nearly-zero permeability, confine the aquifer and model the thermal inertia of the over- and under-burden.

Option 2 accounts for the vertical variation of the temperature in the fluid flow calculations. Option 3 can also model the cooling-down due to the injection.

A study of temperature effects continued

The computational model simulates the 56-year injection, starting from 2027, and a post-injection phase until 3027, 1000 years from the start of injection.

Results

Three simulations were carried out, one for each temperature modelling option selected. Each run was processed on an Amazon Web Service computational node powered by a 3.0 GHz Intel Xeon Platinum processor with 36 cores. The simulations using options 1 and 2, took approximately 55 minutes, while for the thermal modelling option 3 the computational time was 70 minutes.

Figures 3 and 4 show the shape of the CO_2 footprint and distribution along a cross section at the end of the injection period, and 1000 years after the injection started. An intra-shale divides the target layer in two sub-layers, which are both completed by the injector wells. The size of the footprint is shown at the top of the deeper sub-layer, as this is affected by a wider CO_2 spread.

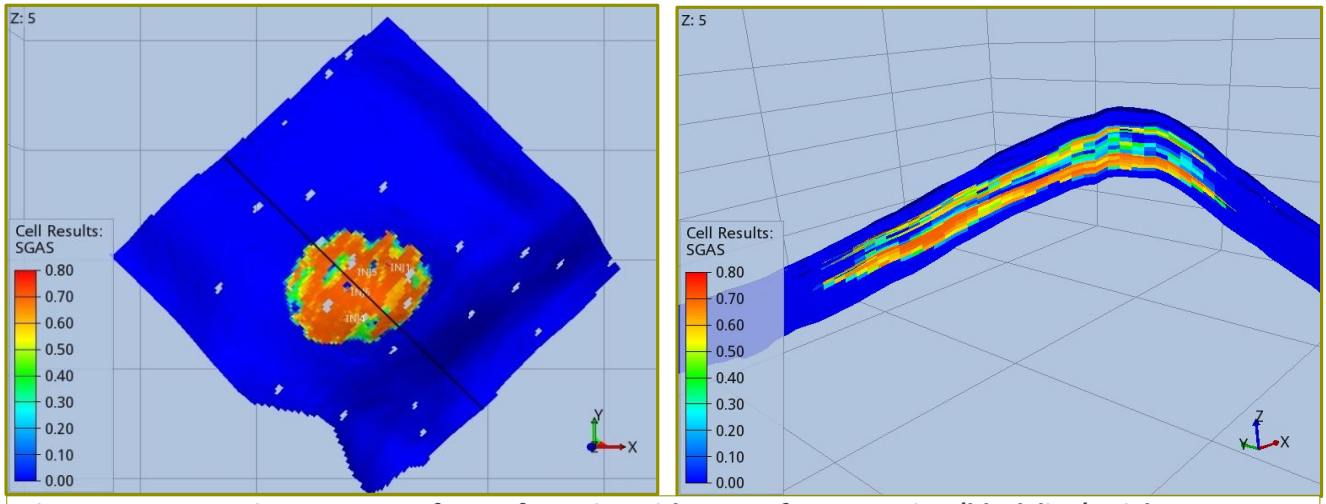

Fig. 3. CO_2 contour in Jan 2083. Left: CO_2 footprint with trace of cross section (black line); Right: gas saturation contour along the cross section marked in the left figure.

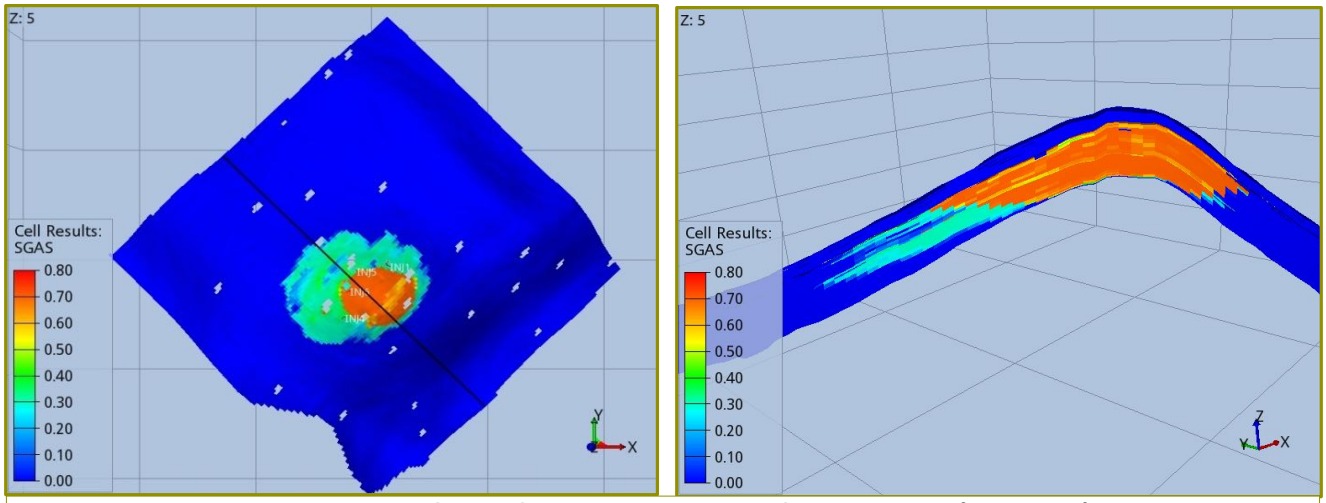

Fig. 4. CO_2 contour in Jan 3027. Left: CO_2 footprint with trace of cross section (black line); Right: gas saturation contour along the cross section marked in the left figure.

The CO_2 migrates upwards until it finds the two impermeable seals present in the target layers. When the injection stops, migration continues towards the crest of the dome, with part of the CO_2 being trapped in the pores of the rock, as shown by the blue trail in Fig. 4. One thousand years after the injection started, 75% of the CO_2 mass is structurally trapped as free gas, 22% is residually trapped, and 5% is dissolved in brine.

A study of temperature effects continued

When the full thermal model is run (option 3), the CO_2 entering the aquifer cools down the immediate surroundings of the wells, and the regions swept continuously by the CO_2 stream during the 56 years of injection, Fig 5 and 6.

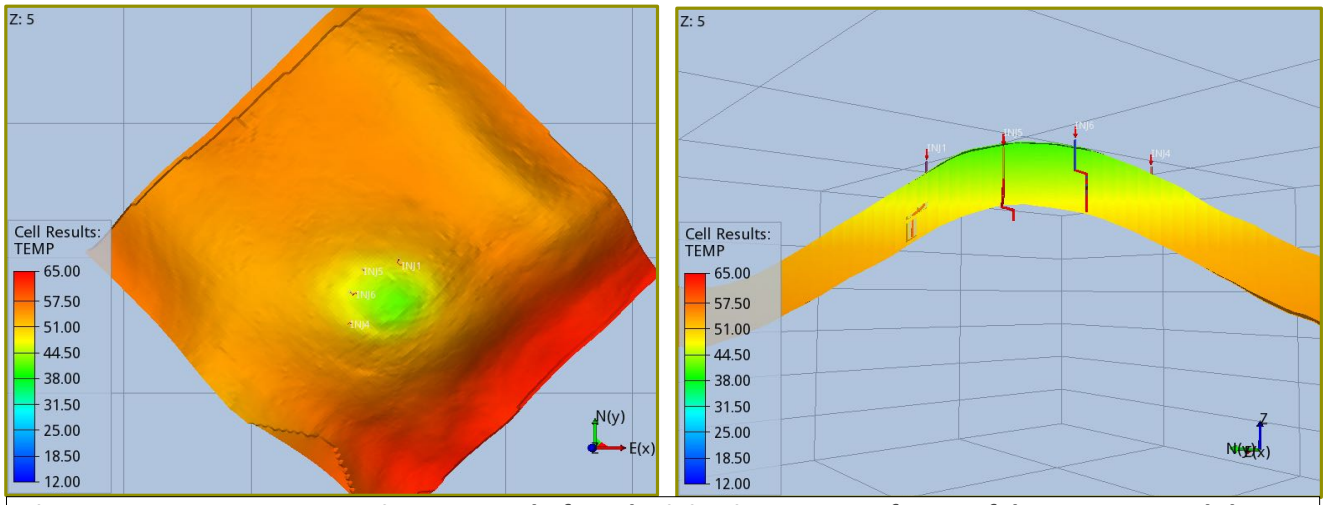

Fig. 5. Temperature contours in Jan 2027, before the injection starts. Left: top of deeper target sub-layer; Right: NE cross section between the injector wells.

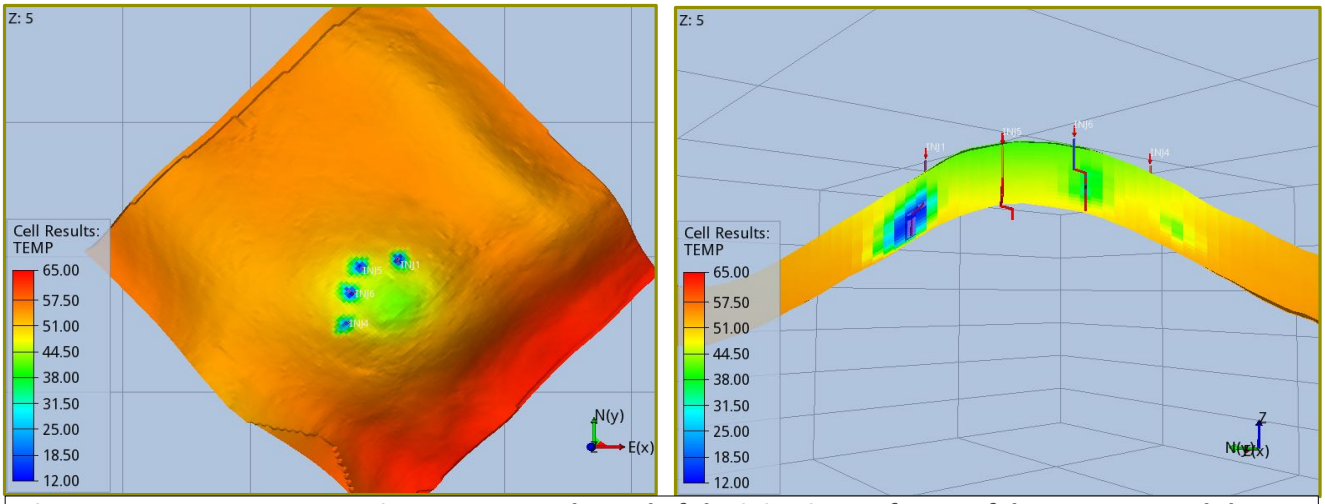

Fig. 6. Temperature contours in Jan 2083, at the end of the injection. Left: top of deeper target sub-layer; Right: NE cross section between the injector wells.

The modelling options 1, 2 and 3 predict different pore volumes occupied by the CO_2 at the end of the injection. The smallest value is predicted by the full thermal option 3, as the cooler region reached by the temperature front increases the density of the CO_2. While this effect has a minor effect on the CO_2 footprint, it affects significantly the pressure build-up due to the injection, which is the design parameter limiting the storage capacity of the BC36 prospect. Monitoring the pressure below the primary caprock, above one of the injectors, where the risk of fracturing the rock is higher, the thermal run (option 3) predicts an over-pressure ~15% smaller than the one computed by isothermal model (option 1), Fig 7. Very similar values are found for locations above all the other injectors.

When accounting for the time-constant vertical distribution of the temperature, option 2, the pressure initially follows the thermal run (option 3). However, it eventually diverges as the temperature front propagates away from the wells. Once the injection has stopped, the pressure decreases in all cases at slightly different rate, and the region cooled down by the injection gradually recovers the initial temperature due to

A study of temperature effects continued

the heat conduction from the warmer surroundings.

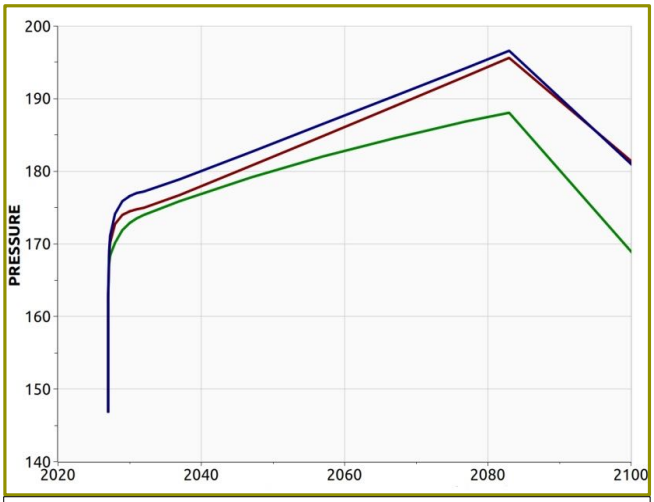

Fig. 7. Pressure vs time in a cell above the injector 1 in the layer just below the primary caprock. Blue: modelling option 1; Red: modelling option 2; Green: modelling option 3.

Conclusion

The Bunter Closure 36 prospect is an excellent candidate for large-scale CO2 storage in the UK, due to its dome structure that provides a four-closure confinement and good storage efficiency.

The pressure build-up during injection is a limiting factor for the storage capacity, as this must remain below the fracture pressure to preserve the integrity of the caprock.

Since the temperature has a non-negligible effect on the maximum pressure reached during the injection, accurate thermal modelling can help improve the design of the injection strategy.

OpenGoSim develops and supports reservoir engineering modules based upon the PFLOTRAN parallel open-source simulation code. These modules focus on advanced modelling of CO_2 injection processes, including thermal effects. The use of cloud technology enables powerful parallel computing resources to be accessed, even from a laptop.

Paolo Orsini is the founder and MD of OpenGoSim. He has been working on CO_2 modelling since 2013, when he also got involved in PFLOTRAN development. After an M.Sc. in mechanical engineering, he acquired a PhD in numerical analysis applied to groundwater. Before OpenGoSim, he worked as consultant in groundwater and CO_2 storage projects.

References

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The future of energy: School talks

Alison Isherwood, Sustainability & Communication Officer with SPE London, discusses her role in resurrecting a schools engagement programme.

I have been a reservoir engineer in the oil and gas industry for 23 years, starting my career with Shell in Aberdeen, before moving to smaller independents and most recently becoming a self-employed consultant. I have lived overseas and worked on assets all over the world and have had the pleasure of working with amazing engineers, geologists and commercial specialists along the way. It has been a fascinating and fulfilling career path, but the last few years have been more difficult and I talk to many old colleagues who feel the same way. It is not only the difficult financial downturns we have endured of late, but also many oil and gas workers have started to question their purpose and motivation due to negative press about our industry. I believe the way to regain our purpose is to whole heartedly embrace the energy transition process, become part of the solution, at the same time as trying to ensure a wider understanding within our communities of why oil and gas has been vitally important to our past and still has an important role to play in our future.

I took on the role of Sustainability & Communication Officer with SPE London late last year as I was excited about the prospect of resurrecting a schools engagement program and believe this is the perfect way to start improving the understanding of our industry in the wider community and hopefully to motivate school students to consider a career in energy in the future.

As a committee, we decided to develop a new talk to give at schools, titled “The Future of Energy: Revolution or Evolution?”. This talk is aimed at secondary school pupils and is designed to stimulate them to think more deeply about the challenges involved in the Energy Transition and reaching UK’s “Net Zero 2050” ambition. The overall message is it needs to be a smoother “evolutionary” process rather than an overnight revolution and an effective way to play their part in this important process would be to join the energy industry (rather than protest against it). It acknowledges global warming, the role activists such as Greta Thunberg have played in bringing attention to it and the necessary growth of renewable energy. It makes clear the wider definition of “Sustainability” as defined by the UN Sustainability goals, which include social and economic development factors as well as environmental issues. It challenges them to consider how we balance these different factors. It discusses how “Oil and Gas” companies are becoming “Energy” companies and the practical complications involved in transitioning a world built around hydrocarbon energy and products to a greener future. Finally, we highlight the skills sets required to fill traditional as well as emerging energy jobs, and talk about carbon capture and storage, hydrogen, big data and electrification.

Our first presentation was a virtual talk to Westminster Academy on 5 June. The presentation appeared to be well received by the students and there were some excellent questions asked, from the environmental impact of making solar panels, to the barriers to carbon capture projects moving forward to the role of nuclear fusion in the energy transition. This showed that the students were thinking deeply about the challenges of the energy transition which was fantastic to see.

Now the talk has been developed and trialled the committee is keen to roll this out to more schools, potentially taking advantage of the development of virtual schooling during lockdown to enable us to reach a wider audience. We are planning to develop links with other STEM education institutes to this purpose but would also be very interested to hear from SPE members who may have links to particular schools who may be interested in the talk or would like to be part of the volunteer team of presenters who deliver the talks. The presentation pack is available on the SPE London website.

Modelling safe gas extraction from stratified lakes: Case study Lake Kivu, Rwanda

Daniel Branson (M/LWD Field Engineer, Schlumberger) was awarded the prize for best MSc Petroleum Engineering thesis at Imperial College in 2019. His background in geology and aqueous system modelling led him to pursue a project in new energies with the application of petroleum engineering concepts to lacustrine gas systems.

Since the appraisal of Lake Kivu which showed the lake contained 60-65 km3 of methane and 300 km3 of carbon dioxide dissolved in its deep waters (Schmid et al., 2005), the commercial extraction of this methane resource has presented a significant challenge to engineers. The continued supply of these gases by microbes and volcanic springs (Pashe et al., 2011) into Lake Kivu gradually decreases the stability of the fragile density gradients holding the gas in place within the lake water.

The analogous weakening of density-stratification in gas-rich lakes was evidenced by the catastrophic degassing of the “killer lakes” Monoun (1984) and Nyos (1986) in Cameroon, claiming a combined 1738 lives (Sigurdsson et al., 1987, Kling et al., 1987, Sigvaldason, 1989). To ensure the safety of the two-million inhabitants of the shores of Lake Kivu, Daniel modelled different scenarios of commercial gas extraction to prevent a catastrophic degassing event.

To date, the impacts of gas extraction on the stratification stability and ecological integrity of Lake Kivu are only poorly understood. To address this, a one-dimensional simulation model was constructed to capture the diffusive, advective and reactive processes governing the distribution of gases and nutrients within the lake. The impacts of different production strategies were assessed using key performance indicators to make management recommendations to the current concession operator, GASMETH.

While the extraction of gas from the lake must occur from the deep waters of the “resource zone” where methane concentrations presently reach up to 20 mol m-3, the re-injection of gas-depleted water after surface separation was found to pose a significant challenge.

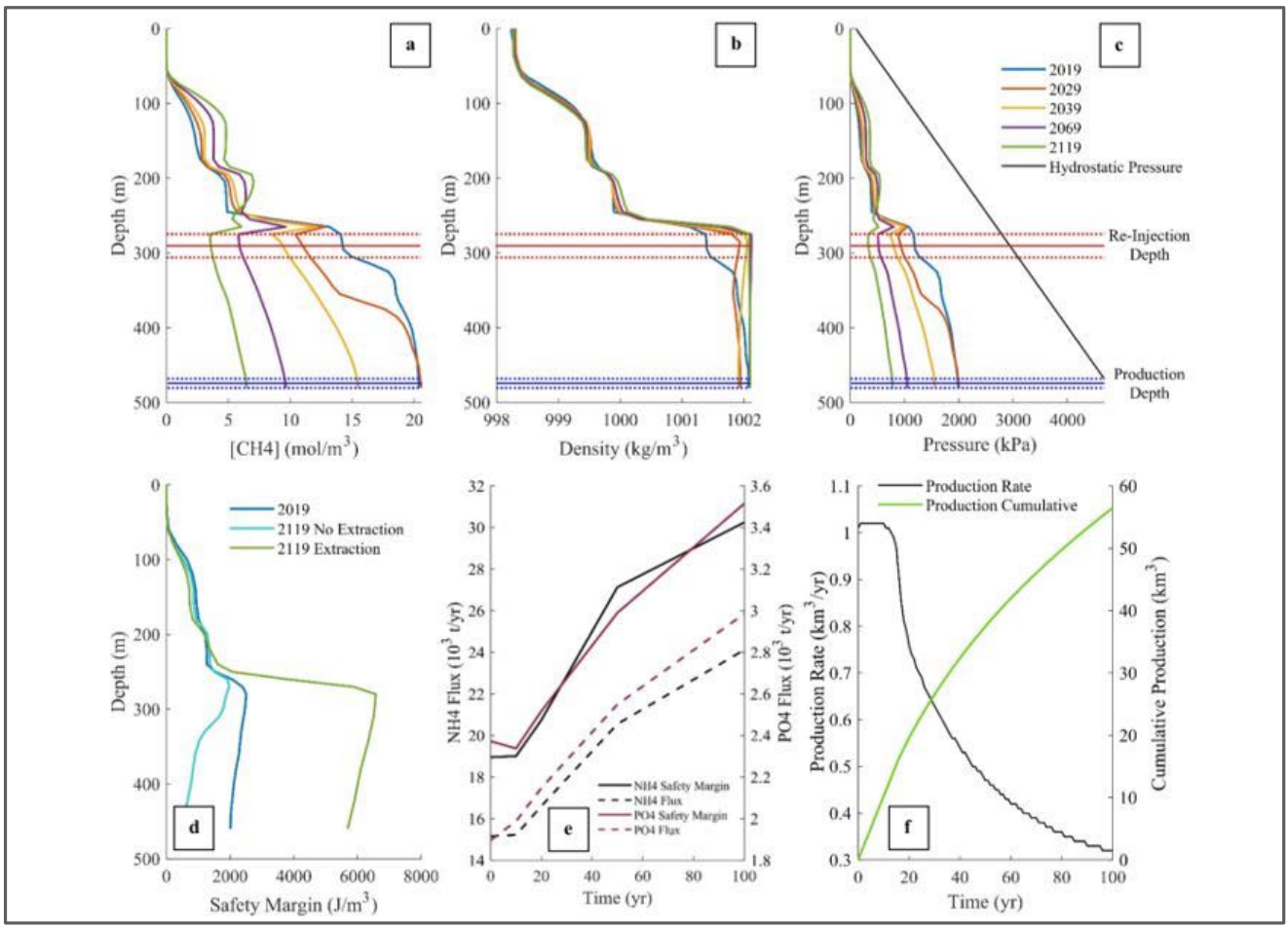
The lake was divided into an upper “biozone”, an “intermediate zone” and deep “potential resource zone” and deepest “resource zone” based on the presence of fragile density gradients controlling the distribution of dissolved gases and nutrients. The re-injection of depleted water into the lowermost resource zone was found to be the only safe option of water disposal, as it ensured the lake stratification was preserved and a gas release was prevented.

The water production rate of 6 × 105 m3 d-1 required to produce an exsolved methane volume of 2.3 × 10-4 km3 d-1 desired by GASMETH was proven feasible with the PETEX well performance tool, PROSPER ®, using gas lift. Over a 100-year production lifetime, the lake model constructed predicted 12.7 km3 of methane extraction, increasing the energy production capacity of the bordering Rwanda by 37.7 MW. However, this production was found insufficient to exceed the rate of new methane formation within the lake and the concentration of solution gases continued to increase.

This conclusion may provide an incentive for more operators to produce gas from Lake Kivu to avert the risk of gas saturation while transforming the bordering nation of Rwanda into a net energy exporter.

See next page for diagrams and caption.

Modelling safe gas extraction from stratified lakes continued



The extraction strategy of producing gas-rich water from the lowermost “resource zone”, where CH4 concentrations are highest, was shown to effectively reduce the dissolved CH4 molarity across the vertical lake profile (a).

The density gradient responsible for preventing a catastrophic degassing (b) was kept intact over a simulated production period of 100 years.

With sufficient gas production, solution gas pressure (c) can be maintained below hydrostatic pressure, increasing the amount of energy needed to cause a degassing event from any given depth (improved “safety margin”, d).

The nutrient fluxes to surface were minimized by the placement depths of producer- and injection syphons, preventing toxic algal blooms detrimental to the local fishing industry (e).

The resulting early break-through of re-injected depleted water at the producing syphon is predicted to cause a sharp drop in production rate (f).

This must be accepted to preserve the ecological integrity of Lake Kivu and to prevent artificially triggering a gas eruption from its waters.

Gaia talk: "Measuring what matters"

The SPE Live Gaia Talk on May 26th – both for the SPE members and for many guests from outside the SPE – addressed sustainability in the oil and gas industry using the lens of "Measuring what Matters", focusing on the metrics that should monitor the sustainability performance of the oil and gas sector companies.

Moderator Dr Tatiana Mitrova supplied this report. She says: "I was delighted to moderate this great opportunity to engage with SPE members and guests."

Of course, there is a big role for the governments to play – for example, with carbon pricing. But the responsibility of the industry itself is also huge. Oil and gas has been held to account for its sustainability performance for quite some time, but the problem is that our current sustainability measurement efforts are largely carried out to satisfy external stakeholders and even then, very imperfectly which is to the detriment of the public, policymakers, investors and the industry itself. Some flagship initiatives have emerged but all would acknowledge that there is still a long way to go before businesses themselves are proactively developing and maturing the metrics they need in order to improve their sustainability performance.

Management guru Peter Drucker is often quoted as saying that "you can't manage what you can't measure." Drucker meant that you can't know whether or not you are successful unless success is defined and tracked. It is 100% applicable to the oil and gas industry: we have enormous amount of data, we love data, we know about data and how to mature metrics to the point that they can underpin complex decisions. We know how to work with it, and whilst there are numerous frameworks including our own industry frameworks to help us meet the needs of investors and activists, these same metrics are not yet generating the data that can meet the needs of operations, R&D and commercial decision-makers running our businesses and in whose hands the sustainability performance of any business ultimate lies. The challenge of fully integrating the SDGs, the full range of sustainability factors concerning any given business is great. Efforts to account for the total cost of doing business, accounting for our externalities, are progressing. We need some universal metrics, which provide objectivity, which can be comparable and, most importantly, which are fit for decision.

This panel discussion looked at how to measure and improve sustainability performance, its contributions to the UN sustainable development goals and in particular how to engage the internal stakeholders - the business decision-makers in business administration, operations, R&D and commercial roles - so that they and their business can better enable development that is truly sustainable.

Four guest speakers of the panel work at the cutting edge and have shown us some of the way there.

Pavan Sukhdev

Pavan Sukhdev, CEO and Founder of the GIST Advisory and also President, World Wildlife Fund gave a great presentation on progress on the integrated P&L, most notably Natural, Human, Social, and Financial capital. He showed us the roadmap to accounting for externalities, and lamented the unintended consequences of many of the ratings and rankings methodologies.

The second panelist was **Antoine Halff**, co-founder of Kayrros, a technology-focused earth observation analytics firm, and Senior Scholar at Columbia University Center on Global Energy Policy. He has demonstrated the industry's ability to manage its own methane emissions, and showed that the technology is available today to detect, measure and source major GHG emissions from O&G operations and other assets anywhere around the globe. Modern algorithms can extract realtime, accurate, precise measurements and actionable signals from data provided by existing satellites such as Sentinel 5P. He stressed that the O&G industry - companies

Gaia Talk: "Measuring what matters" continued

Antoine Halff

Poppy Kalesi

Vanessa Miler-Fels

across the value chain - must provide independent third-party verification of its environmental performance. Beyond validation, the capacity to detect, measure and trace emissions can help industry actually reduce its footprint.

The third speaker was **Poppy Kalesi**, one of the architects of the Gaia program, and Global Energy Director for the Environmental Defense Fund leading their Energy Program in Europe with a focus on delivering ambitious EU policies that will contribute to deep reductions in global oil and gas methane emissions by 2025. She stressed how important transparency and auditing are to establishing the right conditions for business to integrate particular sustainability factors. She argued that increased transparency enabled by technology is intensifying demands for disclosure.

But not all data is equal. In the area of methane emissions, investors and regulator pressure is now shifting to demand for verifiable data. Moreover, verifiable data will be the key differentiator between companies in two respects: market performance and license to operate, including, increasingly market access. This means that two of the industry's main customers – governments and investors – will increasingly be asking our commercial colleagues to provide assurances of our companies' ESG performance with the same diligence and transparency as they do for financial data. And our commercial colleagues will be coming to us for this information.

This new normal will require increased collaboration across disciplines and business areas at a scale never experienced before because it will be financially material. Best practice exchange is crucial but voluntary action is no longer enough. Corporate commitments and activities on methane will be tracked and evaluated based on how aligned with the ESG they are as well as on transparency and credibility. What this means to the community of Petroleum Engineers is that safe and efficient operations will no longer be enough they will also have to be done with the lowest environmental impact and this will have to be systematically documented and independently verified.

The fourth speaker was **Vanessa Miler-Fels**, Director of Energy Innovation and Impact with Microsoft, based out of Washington. She gave us a sense of how digitization and artificial intelligence can benefit man's understanding of nature, demonstrating amazing examples of such technologies and how - through partnerships and open source sharing - such technologies are being deployed with an agility consistent with the urgency of the biodiversity challenges.

Vivid discussion and Q&A session followed the talks, proving there is great interest in this topic across the industry. Winds are changing, and in order to improve our sustainability performance we all need to work together – engagement of all stakeholders is crucial for success.

Links to the on-demand version of the broadcast:

Linkedin (scroll down the page)

YouTube

Vimeo

Oil is the new data: The uneasy relationship between big tech and big oil

Justin Reynolds, Editorial Board member, discusses the economic storm generated by the Covid-19 outbreak and how the OPEC price war has obscured another significant development for the oil and gas sector this year.

The economic storm generated by the Covid-19 outbreak and the OPEC price war has obscured another significant development for the oil and gas sector this year.

In May, Google announced it will become the first major tech company to stop building custom AI and machine learning tools tailored for oil and gas extraction.

The statement, which followed well publicised protests by Google's own employees, is one of the most visible indications yet of the friction being generated by the abrasive - but potentially lucrative - relationship between big tech and big oil.

Oil on campus

There has been a tentative convergence of interests over the past few years between the world's largest providers of cloud services - Amazon, Google and Microsoft - and the oil majors. Microsoft and Google have opened offices in Alberta, and Amazon in Houston, and several oil corporations have a presence in Silicon Valley. Microsoft has joined with Schlumberger and Baker Hughes to open an AI Center of Excellence focused on accelerating the oil and gas sector's digital transformation.

Last year Microsoft and Amazon headlined CERAWeek, the industry's premier annual conference, and Darryl Willis, former President and General Manager of BP, became Energy Industry Vice President at Microsoft, having previously served as Vice President of Oil, Gas, and Energy at Google Cloud.

For the oil majors, the data storage and analysis capacity opened by the cloud offers transformative potential comparable to horizontal drilling and hydraulic fracking. And for the tech giants there is the prospect of accessing the IT spend of some of the world's largest corporations: six oil majors still rank among the world's 10 largest companies in terms of revenue.

BloombergNEF predicts exploration and production spending on cloud computing and advanced analytics will increase from $2.5 billion to $15.7 billion over the next decade, and Accenture estimates advanced analytics and modelling could generate as much as $425 billion in value for the oil and gas sector by 2025.

Amazon Web Services, Google Cloud and Microsoft Azure offer the computing firepower necessary to store and analyse the colossal but often disorganised data sets accumulated by oil companies that for many years has been archived on sprawling digital networks, or recorded on yellowing paper in vast filing systems.

Machine learning (ML), a sub-field of the larger field of AI, uses algorithms customised for the task at hand to identify patterns in raw data, and present them as models to guide decision-making. ML can be used to estimate missing or incomplete data by training algorithms on known data sets and applying the resulting models to new data.

Oil is the new data continued

The enveloping cloud

Cloud technology is being used to facilitate every element of exploration and production operations. The 3D models produced by crunching the data gathered from seismic surveys facilitates more precise targeting of wells in oil-bearing regions. Subsurface data can improve reservoir flows by indicating optimal well depth and distribution, and the most efficient fracturing techniques. Operations can be automated by analysing the data produced by sensors, drones and satellites that monitor pipeline flow and detect leaks.

Wellheads, rigs and processing plants traditionally overseen by teams of skilled staff can increasingly be run remotely from control rooms by a few operators. And the cloud has the power to monitor these increasingly sophisticated digital systems against cyber attacks. The Shamoon viruses that hit Saudi Aramco in 2012 and 2016 erased data on at least 30,000 of its corporate PCs.

All of these technologies are already in use at several of the world's major exploration and production locations. Amazon, Google and Microsoft are all working with companies seeking to improve recovery rates - currently around 8 to 10% - in the Permian Basin. ExxonMobil and its subsidiary XTO are employing Microsoft's iAzure, Machine Learning and other technologies to improve the efficiency of their operations. And Microsoft and Google are working with Schlumberger to develop cloud-based software for clients including Chevron.

Aker BP and Baker Hughes GE are working with Google and Norwegian firm Cognite to develop a cloud platform to facilitate gas turbine and other operations on the Norwegian Continental Shelf.

Microsoft and Google have both opened offices in Alberta to provide AI services for expediting Tar Sands exploration and production. Microsoft is working with Suncor and Plains Midstream Canada to harness big data, predictive analytics and machine learning that will connect oil and gas producers with refiners and customers throughout Canada and the United States. Data mining and ML is also being used at other locations, including the Atlantic, the Arctic and the Gulf of Mexico.

Rising pressures

The partnerships forged between the oil and tech majors has attracted increasing notice - and controversy. Amazon, Google and Microsoft have presented themselves as pioneers of environmentally-sensitive business practices. All three have set out ambitious plans to go carbon-neutral, and indeed to source all of their power purely from renewables. Their eye-catching initiatives have included Microsoft's experimentation with locating data centres under the sea to reduce the cost of cooling systems, and Google's becoming the first IT company to establish a framework for assessing AI applications according to their social benefit.

But their failure to broaden their targets to include emissions generated by the services they sell to the oil and gas industry has provoked an increasingly sharp backlash from their own workforce. Earlier this year more than 350 Amazon employees put their names to a Medium post calling on the company to drop its cloud-computing contracts with clients in the oil and gas industry, obliging Jeff Bezos himself to respond. Last year an anonymous Microsoft engineer wrote a much read article in Logic Magazine providing insights into the company's work to develop AI solutions for Chevron's Tengiz oil field in Kazakhstan.

Oil is the new data continued

In May, a report by Greenpeace turned up the heat further. 'Oil in the Cloud: How Tech Companies are Helping Big Oil Profit from Climate Destruction' studied contracts between Google, Amazon, and Microsoft and major oil firms, and argued that tech companies must disassociate themselves from big oil to ensure that known fossil fuel reserves - roughly five times larger than the 1.5°C carbon budget allows - should stay in the ground.

The protests and the report have prompted the tech giants to reframe their relationship with the energy sector and other controversial clients. In the spring of 2020, Amazon and Microsoft changed the language on their public-facing websites to offer 'energy' rather than 'oil and gas' services. Google has abandoned at least two major initiatives, including plans to work with the US military on cloud computing and to re-enter the Chinese market with a Beijing-friendly search engine. And just a few weeks ago Google made its announcement that it 'will not build custom AI/ML algorithms to facilitate upstream extraction in the oil and gas industry'.

A new cloud?

Despite the pressures placed on their current cloud providers it seems inevitable that the oil and gas sector's embrace of data storage and analysis technologies will continue. The industry has established the Open Group Open Subsurface Data Universe (OSDU) Forum, so far including Shell, Chevron, Schlumberger, ExxonMobil, Total, BP, ConocoPhillips and Devon Energy, that aims to build an open data platform for production and exploration - as the ODSU website puts it: 'a standard data platform for the oil and gas industry, which will reduce silos and put data at the centre of the subsurface community'.

Amazon, Google and Microsoft are currently members. But given the scrutiny to which they are subject it remains to be seen what long term role they will be able to continue to play in the Forum, and indeed the oil and gas sector's ongoing digitalisation. Perhaps the ODSU points the way to the industry's development of its own cloud network, a formidable infrastructural challenge that, together, the oil majors have the financial power to fund.

In pursuit of a culture of care, a demand for equality and purpose in life.

Leigh-Ann Russell is currently Chief Procurement officer and Head of Supply Chain Management for BPs global businesses.
Her previous roles at BP include: Head of Procurement and Supply Chain; ManagementVP Global Wells Technical and Business Functions: Vice President Asia Pacific and New Ventures and Global Wells Performance; and Drilling and Completions Manager.
She will take over as Chief Procurement Officer for BP from July 1, 2020.

Who is Leigh-Ann Russell? Tell us about yourself.
I am a single parent of a teenage daughter residing in London with our two rescue dogs. I grew up on a council estate in what was at the time the small fishing village of Aberdeen, Scotland and became a big oilfield city. My father's advice to me growing up was "Work really hard and care for your family". He was my role model and I certainly have tried to live by that mantra.
In my free time I enjoy doing running, sailing and yoga; during this lockdown period I took up a 40 day yoga challenge which has been hugely beneficial for me. Reading is also one of my biggest passions. A book I read recently that had a big influence on me was "Let my people go surfing" which tells the story of Patagonia and how they revolutionised their supply chain, making it more sustainable. It also talks to a powerful work-life harmony.
Rescue dogs are hard work but a big part of our family. Whoever said money can't buy happiness never paid a pet adoption fee.

Walk us through your career. How did you become a Head of Procurement and Supply Chain Management??
I got my first job straight from school, working at a prestigious bank. Then I got my 'A' level results which were surprisingly (at least to me) good. I decided I wanted to go to university, and study engineering. At first, this was met with some resistance from my family. I would have been the first in my family to go to university; eventually I won them over.
I graduated with a degree in mechanical engineering and joined a company that soon was acquired by Schlumberger. I entered their graduate training program working in a number of technical roles including offshore. I then moved onto a Shell Technology Ventures company where I managed a team of engineers marketing drilling technology and subsequently Helix RDS, as Senior Production Technologist.
I joined BP in 2006 as a Completion Engineer and was then promoted to Well Engineering Team Leader and then Operations and Engineering Manager. I worked the full spectrum of engineering jobs at the time from completion engineer to drilling engineer and operations.
In 2013, I was named Vice President for our Wells Division's Technical Functions which I did for five years, leading a staff of 700 across Engineering, Operations, Process Safety and Strategy. One outstanding achievement for me was leading the modernisation and transformation agenda for the business, implementing new digital technology and world's first automation to deliver a step change in safety performance.
In 2018, I was asked to lead Supply Chain for our Upstream Business. Our Supply Chain Function procures and delivers all our company's goods and services in a safe, ethical and reliable manner. This role has been a fantastic learning experience for me, stepping out of mainstream engineering after two decades and into a very commercial role. However, my technical expertise is highly useful as we are buying products and services that supply a high-hazard industry.
I will take over as Chief Procurement Officer for BP from July 1, 2020.

Throughout your career, you moved across different sectors of O&G. How did you find your transitions from the global marketing role, to production technologist to head of Procurement? To oppose, what do you think about linear career progression?
I think the question of having diverse experiences as opposed to a linear progression is one that many people agonise over. A piece of advice I received early in my career was not to worry about your next role, but simply to deliver great performance in your current role, and that great performance is what will unlock the door of opportunity. And you tend to perform well at something you have a passion for.
I think it is key to ensure that you are doing something you love, or at least in service of getting

In pursuit of a culture of care... continued

yourself to something you love. But also develop a very recognisable career in your discipline.
I have moved roles, but also have a solid base leading to engineering manager.
I think it is also important to move outside your comfort zone at times, to take on new challenges, solve new problems and find new sources of value. Whether that advice takes you into diverse roles or a linear progression with deep technical expertise is really down to the individual.

Prior to joining BP, you worked with Schlumberger and WellDynamics - how do you feel this experience prepared you for working with an operator?
What these experiences certainly helped with was understanding deeply the points of view and drivers for our supply chain. It certainly helped me to see our suppliers as equal partners who have a lot to bring to the table as we drive to safely solve complex business and engineering problems. It also further cemented my passion for fostering diversity, specifically diversity of thought, and ensuring every voice in the room is heard.

There are a lot of discussions going on about countries nationalising their economies, production, and supply chains – how do you see it affecting companies like BP?
In BP we have seen our supply chains be much more resilient than expected. We have been able to achieve minimal supply chain disruptions throughout the COVID crisis. We are exploring establishing ESG (Environmental, Social and Corporate Governance) criteria and programs for the energy supply chain to reflect our expanded sustainability ambition at BP (BP aims to be a net zero company by 2050 or sooner). This would also dovetail well with changing government priorities post-COVID / economic recession. Utilising this criterion to inform supplier selection we certainly would seek to partner even more with governments to 'build back better'. It would benefit governments, the private sector and the environment to have more resilient supply chains that at the same time reduce waste and inefficiencies.

What positive and/or negative changes might our industry see as a result of the current economic challenges?
This crisis has been described as one of the worst seen for the industry, with the fall in price of oil and gas being coupled with economic recession. Before the crisis, much of the service sector was already in a difficult financial position. The traditional oil and gas global supply chain was heavily exposed financially due to increased debt and reduced margins with a range of outcomes by sector. Capital intensive sectors face bankruptcy or restructuring and potential inability to raise future capital. Service based sectors may have to consolidate further leading to decreased competition and/or potential diversification. There is a risk of reductions in investment in Research and Development by service companies and potential difficulties with attracting talent. That being said, there certainly is the opportunity to increase the use of digital and automation in a drive for efficiency and reduced waste. This could see expanded relationships between operators and larger tech or multi-sector companies. We are very keen to partner with our suppliers to remove waste from our combined ecosystem to benefit the whole sector. The current crisis has also shone a spotlight on the possibilities of remote working and collaboration. This could provide the impetus for continued demand for digital services and skills, further creating the need for deeper partnerships with technology and digital providers.

From your experience, what are the important points to focus on and what are the noises to ignore during a crisis such as our current one? (Especially for people starting out in their careers or perhaps just a few years in)

One basic example is that many companies, including ours, are in the process of reimagining how and where we work. This crisis certainly has also emphasized how interdependent we are. Many have drawn a parallel between the COVID crisis and the challenge the world faces on climate change and getting to Net Zero. The world needs to get to Net Zero, and for all of us, contributing to figuring out how we get there is certainly going to be of value in any and all industries going forward.
But, overwhelmingly, I think it has emphasised the need for a culture of care, for a demand for equality and purpose in life. I believe at BP we embody all of these values. And the world wants and needs cheap clean energy. What could be a better career than to be part of the solution for providing energy to improve people's lives in a Net Zero world.

Make, Think, Imagine: Engineering the Future of Civilisation

Editorial Board member Justin Reynolds reviews John Browne's most recent book, published by Bloomsbury.

Many histories have been written viewing civilisation through the lens of art, literature, design or science. Not many, however, acknowledge the importance of engineering for its development.

Former BP chief executive turned writer John Browne tries to put that right in his latest book "Make, Think, Imagine: Engineering the Future of Civilisation", an extended essay considering engineering's cultural, economic and political significance.

The book is at least as personal as his 2014 memoir. For Browne, who started at BP as a graduate engineer, and has gone on to serve as President of the Royal Academy of Engineering and Chair of the Crick Institute, engineering creates the very conditions for art, science and commerce. It builds the tools that artists, architects, designers and scientists use to turn ideas into reality.

Like the artist, the good engineer has a strong aesthetic sense, compelled by simplicity, beauty, efficiency and logic. Browne writes that the 'impact that engineered structures have on us is influenced by the aesthetic response they provoke; for any designed object, how you feel is part of its function.' Appropriately the book was written from his home overlooking Venice's Grand Canal, one of the world's great engineering projects, a sublime blend of beauty and technique.

He describes engineering as 'a head with two sets of eyes: one looks to the fruits of discovery, while the other looks to the demands of commerce and customers.' It is this concern for practical application, he suggests, that accounts for the field's unfavourable comparison with the 'pure' disciplines of art and science. A natural aesthete, the young Browne's concern to 'do something practical that humanity wanted' led him to choose engineering as his career.

The watchmaker and the gunsmith

The book offers a broad overview of engineering's foundational importance for history's great civilisations. The Mesopotamians built their cities by baking bitumen, and the Mayans with hydraulic cement. Ancient China its built power on the invention of the stirrup, paper, the compass and gunpowder. The Venetian Republic was founded on its engineers' ability to build a great city on a lagoon, defended by a formidable navy. The epic engineering projects of the Victorians drove the Industrial Revolution, and mid-20th century computing breakthroughs like the EDSAC mainframe and the Intel 4004 microprocessor, established the framework for our digital age.

A few key themes emerge. Browne emphasises how fundamental engineering's insistence on standardisation has been for technological and economic progress. He illuminates this defining distinction between engineering and craftsmanship by drawing an intriguing comparison between two 18th century innovators, the Swiss watchmaker Abraham-Louis Breguet and the French gunsmith Honoré Blanc.

Make, Think, Imagine... continued

Breguet created mesmerising 'worlds of gears, springs, wheels and ratchets', crafting each element by hand. He made watches for Napoleon and Marie Antoinette, the latter taking more than 20 years to design.

His contemporary Blanc, meanwhile, was able to produce thousands of muskets at short notice by designing a set of essential components which could be snapped together by anyone. Breaking with the convention that each gun should be handcrafted, Blanc showed how exact copies could be quickly assembled through the connection of interchangeable parts, and in doing so sketched the blueprint for mass production. Seemingly unremarkable innovations such as the standardisation of screw sizes were also of enormous significance for the development of the giant assembly lines that culminated in the rollout of the Ford Model T.

Venice, Italy from above.

Browne offers today's rapidly expanding space exploration industry as a compelling 21st century example of the power of standardisation. SpaceX and Blue Origin are just the best known of the many private firms for which access to space has been opened by the repurposing of existing machines. Even small companies can now construct micro-satellites made from the same off-the-shelf components used in consumer electronic devices.

Browne is also keen to stress engineering's often overlooked contribution to healthcare. There are famous examples like Joseph Bazelgette's design of London's sewer system in response to the 'Great Stink' of 1858 that forced the evacuation of Parliament. Less noted is engineering's role in the design and manufacture of medical equipment, and even the medicines themselves. Browne visits the laboratories of Robert Langer, often called 'the Edison of Medicine', to discuss drug delivery nanotechnologies such as polymers that release chemicals in slow, controlled fashion, through tiny microchip-driven devices that release their payloads by remote control.

Fear of the 'black box'

Though written from the heart the book bears the imprint of Browne's years as a pragmatic chief executive. The tone is hopeful, though not utopian. Browne recognises the progress engineering makes possible is gradual, often erratic, alternately propelled forward by emotion, and restrained by fear and vested interests.

Honoré Blanc's musket production techniques were regarded with suspicion in his native France because of their threat to traditional craftsmanship. It was Thomas Jefferson, during his time as US Ambassador to France, who recognised their potential, inviting Blanc to America to produces tens of thousands of guns for the defence of the new state. And one of the great icons of 20th century modernity, the Japanese bullet train, was not a product of a systematic plan to develop the country's transport infrastructure, but rather a patriotic desire to showcase Japan's post-war rebirth in time for the 1964 Tokyo Olympics.

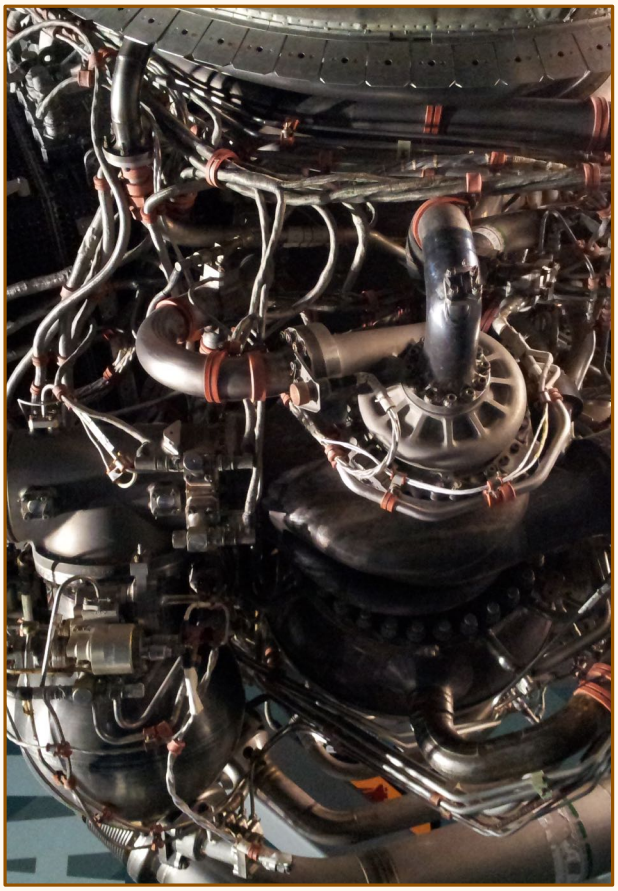
Browne is sympathetic regarding the anxieties that accompany technological change. It is entirely understandable that there should be scepticism about 'black-box' technologies we don't understand. Innovation is a double-edged sword, with light and dark sides. The Haber-Bosch process, for example, made cheap fertilisers possible, but also poisonous gases. The Manhattan Project facilitated the discovery of the double helix structure of the DNA molecule, and the atom bomb. Today, drones promise to transform logistics, but enable assassinations. Facial recognition assists law enforcement, and allow mass surveillance. Browne is sceptical about the "misguided" Silicon Valley mantra "move fast and break things". Existing

Make, Think, Imagine... continued

technologies often just work, and their "disruption" should be scrutinised.

The long energy transition

But ultimately he believes "unintended consequences and intended abuses can almost always be counteracted or prevented." Browne's cautiously optimistic philosophy is epitomised by his discussion of his own industry. He was, famously, among the first oil executives to concede the sector had to acknowledge its contribution to carbon build up. BP's renewable energy division was established under his leadership. He has subsequently invested in the renewables sector - the book discusses solar photovoltaics, developments in battery research for use in aircraft, and hydrogen-based engines for cars. He has even visited the Vatican to discuss climate breakdown with Pope Francis.



But Browne is unrepentant about his long career in the industry, and continuing involvement with gas companies. **Interviewed** about the book, he told The Guardian: "I entered the energy industry to solve problems rather than to create them - it is a decision that I have never once regretted or felt ashamed of, because I believe the industry can, and will, be a part of the solution to its own problems." For Browne, carbon-capture and market mechanisms must be critical elements in what he believes will have to be a long energy transition.

Into the future, cautiously

Browne is, in many ways, the ideal author for this book, combining a keen aesthetic sense with the realism of of the boardroom executive. It is that pragmatic strain that colours the book, for all its controlled passion, with a somewhat technocratic tone. Browne's attitude epitomises the rational liberal belief in cautious, incremental progress. With its calm insistence that we are living "healthier, wealthier and longer lives" his book recalls another recent liberal manifesto, Steven Pinker's "Enlightenment Now".

Browne's businesslike concern with engineering's usefulness means he doesn't pay much attention to the field's utopian dimension. Throughout history, programmes for new technologies and gleaming new infrastructures have often been accompanied by visions of new societies. Consider, for example, the great engineering works envisaged by the French revolutionaries Georges-Eugène Haussmanand Le Corbusier to reconstruct Paris, or the soaring visions of the Soviet constructivists, or even the high-minded hopes of the post-war planners who designed Britain's New Towns. Engineering is often charged with hopes for radical social change, the reconstruction of physical infrastructures motivated by designs for political reconstruction. It's an aspect of engineering history that doesn't fall within Browne's measured vision.

The book is also rather Eurocentric. It pays insufficient attention to China and South Korea, where many of today's most radical engineering projects are taking place, as the new sci-fi skylines rising in response to rapid economic growth testify.

However, all-in-all "Make, Think, Imagine" is an absorbing and much-needed attempt to assert the cultural importance of engineering by a vastly knowledgeable writer able to draw on a lifetime's experience overseeing and sponsoring some of the world's most complex engineering challenges.

What's happening in 2020?

Let's explore London - inside and out!

Best London attractions

Buckingham Palace
Majestic!

The Houses of Parliament
Check it out

The Churchill War Rooms
Stepping into history

The National Gallery
Picture yourself here!

Best parks outside London

Richmond Park
Walk it out!

Battersea Park
Down by the river

Crystal Palace
Walk with views

Epping Forest
Green spaces

London theatres - online

National Theatre
All about the play

Southwark Playhouse
Shows and video

Hampstead Theatre
Main stage

The Globe
Midsummer dreaming

Keep fit and active

Yoga with Adriene
Art of waking up

Fitness Blender
Work it!

Go for Gold
Stronger, fitter

Dancing
Your own beat

Meet the SPE London Board

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