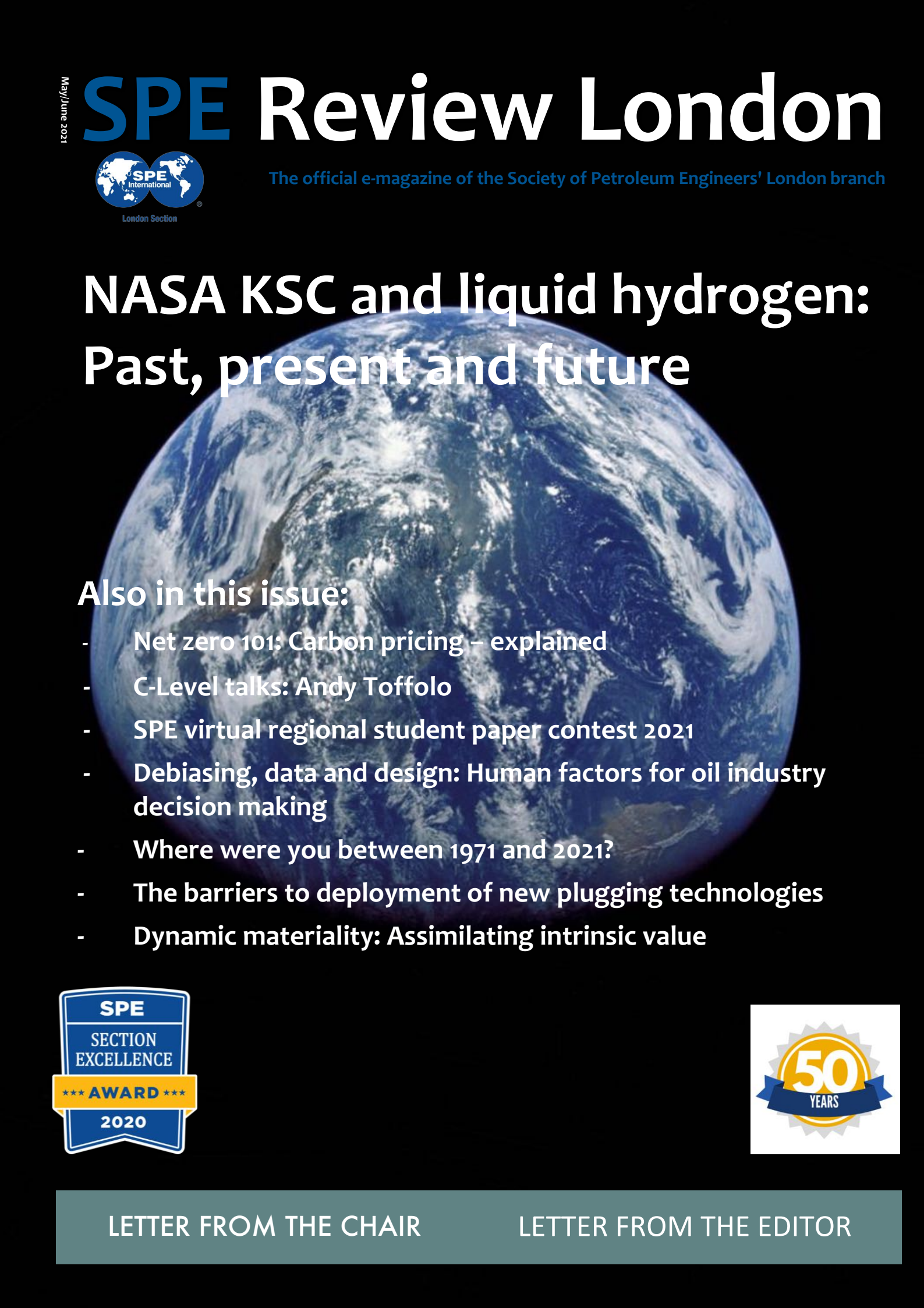
May/June 2021

SPE Review London

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

NASA KSC and liquid hydrogen: Past, present and future



Also in this issue:

- Net zero 101: Carbon pricing – explained
- C-Level talks: Andy Toffolo
- SPE virtual regional student paper contest 2021
- Debiasing, data and design: Human factors for oil industry decision making
- Where were you between 1971 and 2021?
- The barriers to deployment of new plugging technologies
- Dynamic materiality: Assimilating intrinsic value

SPE SECTION EXCELLENCE *** AWARD *** 2020

50 YEARS

LETTER FROM THE CHAIR LETTER FROM THE EDITOR

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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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SPE SECTION EXCELLENCE *** AWARD *** 2020

In this issue

View of Earth photographed by Apollo 15 on voyage to the Moon. July 1971.

Photo credit: NASA

Behind the Scenes: SPE Review Editorial Board

Elizaveta Poliakova, Editor in Chief

Elizaveta is a Reservoir Engineer at Trident Energy. She has an M.Sc in Petroleum Engineering from Imperial College London and a B.S. in Petroleum Engineering from the University of Leeds. Elizaveta has been with SPE for more than five years. She was the President of SPE Imperial College Chapter and the President of SPE Leeds Chapter. Previously, she was also on the committee of SPE YP.

Josh Beinke

Graduated from University of Adelaide in 2008 with a Petroleum Engineering degree. After several years with Chevron moved to Europe in 2016, now working as an Exploitation Engineer with Vermilion Energy.

Ffion Llwyd-Jones

Business editor and writer. Extensive experience in content writing and editing (digital and print). International experience in technology, health, and the environment.

Mark Beleski

Experienced engineer, with deep understanding of industry practices, trends and challenges. Energy Loss Adjuster with AqualisBraemar, in London.

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,

This is the last letter that I will write as your Section Chair as my tenure completes at the end of June. It's been a pleasure and challenge to serve the society and I don't think that anyone can say that last year hasn't been exceptional.

We are already halfway through 2021 and I hope that you are all remaining safe and well. The Covid19 pandemic continues to affect our daily lives, but in a less invasive way and I hope that you are enjoying the loosening of restrictions in a responsible manner.

In my role as Chair, I have been supported by a team of committed volunteers that have demonstrated great enthusiasm to make the SPE London section a valuable resource to membership.

Specifically, I would like to draw attention to individual board members for their particular contributions this year. Many of you know Tim Lines, a long-serving SPE member and the driving force behind the high-quality monthly evening talks. Tim is also pushing the development of the digital science engineering and analysis (DSEA) program in which I know he has a special interest. Tim's contribution is significant and the section would be poorer without him.

There are several recent committee leads that have enhanced the section's profile during the 12 months. Alison Isherwood has shown great leadership in developing the Net Zero and Sustainability (NZ&S) committee. Alison and her team have created a unique and distinctive program which continues to evolve. The move to a completely virtual offering to membership has proven to be a success that has supported both Tim's and Alison's content. Adam Zalewski has developed into a capable 'Zoom Master' that has ensured our virtual content has been delivered efficiently and without incident.

Although the year has challenged the delivery of technical and non-technical content directly to membership and beyond, the long-standing section digital publication, the 'SPE Review London', has grown in content both in depth and breadth. The editorial team lead by Elizaveta Poliakova have been responsible for making the Review such a success and above all a great read.

The board has seen other changes and I have welcomed Mehdi Alem to the membership lead and Promise Ahante to the communications lead. Both these young members offer great promise to support the section in their respective areas and I look forward to seeing their development.

Our student liaison officer has left the role and we are seeking a replacement volunteer. Maria Centeno has worked tirelessly to support our student chapters during the difficult times of 2020 and 2021. The section is committed to support those universities that offer SPE student chapters. I believe that despite the changing times the SPE offer valuable benefits to student chapters and I encourage all classes of engineering, science and technology to consider joining.

Shwan Dizayee and his team at the YP's continue to offer a great resource to the section's young engineers. Mark Beleski, after several year coordinating the communications committee, is looking to support the section in a broader role, however, he remains committed to the section.

The section continues to have a strong financial position with a significantly strong balance sheet. Thanks to Vincent Penasse and the support of our long-standing accountant Lucy Hebb.

The past year has thrown up both challenges and opportunities and I believe that the section has made some visible and not so visible achievements. The successful adoption of technology supporting the delivery of our range of event programs has been an essential requirement and it is one that I see being a consistent feature of future event programs. The well-recognised establishment of the NZ&S committee has added a new dimension to the sections' offering to membership and one that continues to evolve both in terms of content but also reach across the European region. The NZ&S committee put on an inaugural and very successful Industry Connect Day with the SmallPiece Trust which introduced A level students to the changing world of energy.

Letter from the SPE London Chair... continued

The section has two award winners that are associated with both the delivery of the virtual event program and the Net Zero & Sustainability committee. Well done Adam Zalewski and Alison Isherwood respectively we hope to celebrate your success later in 2021.

Looking forward to the forthcoming SPE year, I can see that there will be a slow and measured return to physical events. This will be driven by membership preferences, and venue safety protocols, however I believe that there will be support for this move.

It is unlikely that Imperial College, a key venue supporter, will be open to external events for some time and section is looking for cost effective alternatives. The monthly evening lectures will continue as will the evolving Net Zero & Sustainability program. The sections' well-respected annual 'Introduction to E&P' event is already being planned through the support of AqualisBraema and led by Adam Borushek. To reflect the changing world, you can anticipate contributions on emerging topics such as Carbon Capture and Storage, Fugitive gas emissions and additional carbon abatement technologies. Although the section was unable to provide its annual 'Women in Energy' event due to the impact of CV19 I am encouraged that a 2022 event is planned. It's a pleasure to have Isabel Asenjo back as WiE (now Diversity and Inclusion) lead of this event.

On the D&I topic, I would like to recognise that the board are promoting a strong, diverse and inclusive culture. Please check out your board members to see this for yourselves.

The section's commitment to students and pre university scholars will remain and I see a great opportunity for the section to work with universities and the Centre for Masters Training in Energy Research (CMT) to prepare students for the new world of energy. The section will be continuing its engineering scholarship support, providing that there are scholars of sufficient calibre, and working with the Smallpeice Trust to offer another Industry connect day. The section is keen to reinvigorate its schools' programme and I would encourage those interested to contact the section, here **https://www.spe-london.org**

Membership may have seen recent SPE International mail shots covering the proposed amalgamation of SPE and AAPG. At this point in time the discussions between the SPE and AAPG are at an initial level. Nevertheless, the SPE is under significant financial pressure and so too is the AAPG. It seems inevitable to me that a stronger relationship with other complementary technical institutions will be needed. My personal opinion is that the amalgamation will go ahead. The board of the section will do its utmost to ensure the membership is kept informed of developments.

Members may have seen two recent communications regarding membership and volunteering. The membership numbers are a concern, however during the coming year you can expect to see more emphasis on promoting the considerable benefits of membership and as an existing member I encourage you to promote membership. Volunteering is a great way to improve and expand your professional network and to develop communication skills. The section is always keen to expand its volunteer network. A recent Linkedin post looking for support to the communications team would be a great way for members to develop their volunteering skills.

As we move into another SPE year I would like to thank our annual sponsors for sticking with us, especially OPC who have continually supported the section. I hope that our existing sponsors will continue to value the relationship with the section. If you believe your business would benefit from sponsoring or supporting the SPE London Section please contact me at **Oleumventures@icloud.com**

Finally, I'd like to introduce you to the forthcoming Chair of Section and their Chair Elect. Adam Zalewski will be taking on the role of Chair of Section from July 1st 2021 and will be supported by Elizaveta Poliakova as Chair Elect. Please join me in congratulating both Adam and Elizaveta and offering your support to them to ensure they succeed in their respective roles.

I will continue to support the section as Sponsorship Lead and will also be working with Adam and Elizaveta to ensure the section remains relevant to its membership.

Adrian Southworth, SPE London Chair

Letter from the Editor

Dear SPE members and colleagues,

Welcome to our third edition of SPE London Review in 2021. Although the complete ease of restrictions across the UK has been postponed, we hope that you are enjoying reduced restrictions responsibly. I also hope that you managed to make the most from the sunny weather in England before the rainy week.

This month completes the 50th anniversary of our chapter and we have collated a photo collage from some of our previous events - you can see it on page **22**.

In this publication, the winners of the SPE Regional Student Paper contest, held online in May, share their experiences on page **10**. On page **8**, you find the C-Level Talk with Andy Toffolo, Vice President Operations & Country Manager at bp. In addition, on page **12** you will find an article about 'Debiasing, Data and design: Human factors for oil industry decision making' written by Matthew Welsh. Also, Adam M. Swanger has shared an article with us about 'Nasa Kennedy Space Center (KSC) and liquid hydrogen: past, present and future' that you can find on page **19**.

We are continuing publishing the Net Zero 101 series and on page **16**, you can find our second publication explaining carbon pricing. Please refer to page **29** for the fifth article from the London Section's Net Zero Committee by Adrian Gregory about 'Dynamic materiality: Assimilating intrinsic value'. On page **26**, Brian Willis has shared his thoughts and findings of 'The Barriers to Deployment of New Plugging Technologies'.

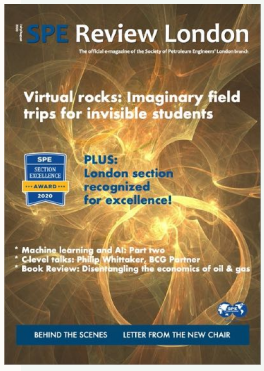
This month concludes another SPE year, and please refer to Adrian's letter for the committee updates. I am also pleased to share that in the upcoming year I will be supporting our new Chair, Adam Zalewski, as Chair Elect.

I would like to thank the Editorial team for their ideas and constant support.

I hope you will enjoy reading this publication.

Stay safe and take care,
Elizaveta Poliakova

Click here to access past issues of the SPE Review London!



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

Spain banned new O&G exploration

Spain has passed the Climate change and energy transition law joining the list of the European countries banning new oil and gas exploration.

The law also prohibits the sale of petrol and diesel vehicles by 2040 and makes it illegal to produce fossil fuels from 2043.

The bill also aims to ramp up the share of the country's renewable energy generation to 70% by 2030.

Read more

Orcadian aims to raise £5 million via London IPO

Orcadian, previously known as Pharis Energy, whose key asset is the Pilot oil field in the UK intends to raise £5 million during the initial public offering.

Steve Brown, CEO, shared that the company is looking to be listed on the Alternative Investment Market (AIM) by the end of June.

Read more

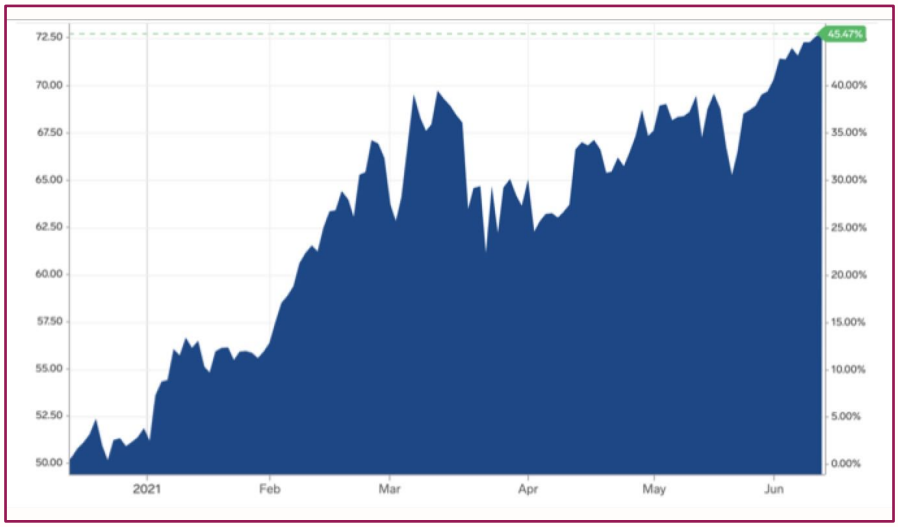
IOG reached a milestone after Blythe and Southwark unmanned platforms installed

Independent Oil and Gas shared an installation completion of the Blythe and Southwark platforms in the southern North Sea.

Andrew Hockey, CEO, said: "These facilities are integral to our infrastructure-led hub strategy and form a pivotal link between our co-owned and operated offshore pipeline network and our onshore Thames Reception Facilities at Bacton Terminal.

"With forecast average power demand as low as 33kW they are also an important part of our low-carbon operating philosophy."

Read more



IEA projects oil demand reaching pre-pandemic levels in 2022

International Energy Agency predicted world oil consumption recovering to pre-pandemic 100 million barrels of oil per day in late 2022. The IEA has not predicted the demand peak but is foreseeing a plateau in 2030s.

Read more

Oil (Brent): Image credit

Technical competence and strong leadership

Andy Toffolo is bp's Vice President Operations and Country Manager in Algeria, overseeing all activities across the value chain for bp in the country, where bp has been present since the 1930s and is one of the country's largest international investors.

Prior to this role, Andy was the President and GM of the Joint Venture. He has a Bachelor of Engineering from Heriot Watt University.

Who is Andy Toffolo? Tell us about yourself.

I was born in Venice, Italy, and grew up in a family of Venetian glass makers going back four generations. My parents emigrated to England when I was two years old, so I was lucky to grow up bilingual and with a heightened appreciation of differing cultures and attitudes. I spent my early teens working in the family business and was immersed in a strong work ethic, in common with many other families who are required to make their own luck in life.

I prefer playing sports to watching them, and participate enthusiastically in most things, including judo and rugby in my younger days, even joining the territorial army for a challenge, though this is not strictly a sport. These days, I prefer lower impact pastimes and I am currently enjoying learning a new language. I discovered motorcycles in my early thirties and have been intoxicated by them ever since. They provide endless opportunities for tinkering and create a wonderful source of experiences to share with friends. In some ways, motorcycling has become an integral part of my psychological wellbeing regime.

Most importantly, I am a proud dad to two wonderful daughters, both of whom are currently entering the world of full-time employment and pursuing their own life and career goals.

How did you become VP for Operations & Country Manager at bp? Walk us through your career.

I was recruited from university into a graduate engineering program with a large multinational operator and spent the first six years of my career gaining as much experience as possible in a variety of assignments in petrochemical plants, project offices and design teams.

The programme included structured technical and managerial development over the first four years of my career, which in my case ensured a thorough grounding in process safety and risk, technical, equipment knowledge and leadership principles. The latter included foundation training in learning, teamwork and work management, all aimed at developing transferable competencies for the future.

As I worked towards chartered status, I greatly benefitted from being mentored by some outstanding individuals who were genuinely interested in my personal and technical development and who were able to provide sage advice when needed.

My early philosophy was to try and move horizontally across the organisation as much as possible to maximise future career opportunities. I realised that a purely technical career path was not for me so, over the next few years, I took responsibility for my own development, which led me to move companies several times in order to gain the experience I felt I needed. I simply chose roles based on what I enjoyed doing and which would add new dimensions to my core skills. In this way I was able to develop a track record of delivery in each role while moving from engineering and design to maintenance then major turnarounds, projects and on to operations.

I found that this multi-functional experience allowed me to work well across boundaries and my apparent adaptability made me a natural candidate for troubleshooting and opened the door to new opportunities as one role led to another. Over time, I continued to seek roles based around my core competencies, which also provided a development dimension. The rest of my career developed accordingly, and I was able to move between the private and public sector, and from the petrochemicals sector into nuclear, and then upstream oil and gas, with each new role building on the previous one.

Prior to joining bp, you worked in petrochemical and nuclear energy industries. How different were these experiences?

As a mechanical engineer, I found the transition between industries to be quite manageable. I was

⇨

Technical competence and leadership continued

told in my early career that equipment doesn't know which industry it is in, it only has to perform to a certain design criterion. I followed this sage advice and made time to improve my knowledge of different industries as I went along. Starting with safety and integrity then moving onto other standards over time, I volunteered for as much training as was available and was able to quickly demystify much of the jargon and abbreviations which often accompany individual industries. In parallel, I took care to nurture relationships with experienced colleagues, asking a lot of questions and seeking advice without guilt or any sense of inadequacy. Looking back this appetite for variety and continuous learning over the past 25 years has allowed me to successfully reinvent myself in the employment market when times were tough.

You have transitioned from leading a local organisation to a joint venture to international operations. What are the major differences in leading different types of businesses?

In my experience, the major difference in leading a joint venture business is the need to focus equally on business performance and external stakeholders; often peer companies or national governments. Being tuned into their needs and working through the inevitable differences that can occur is often extremely challenging.

For international joint ventures there is also the added dimension of language, cultural and business diversity which makes inclusivity, cultural awareness and empathy important leadership skills; just as important in fact as formal business qualifications or deep technical competence.

How was your volunteering experience in Malaysia? What did you learn?

I went to Malaysia as a volunteer on a Raleigh International expedition spending my 21st birthday in 300 square kms of rainforest, near the village of Tambunan in Sabah. In practical terms, I learned how to build an oven and use it to cook for 25 people. I learned how to plant pineapples, how to build a sturdy shelter to sleep in and how to navigate through the jungle without getting lost.

More importantly, I also improved my ability to establish relationships and work in a team of complete strangers from different national, social and educational backgrounds; even when things went wrong. I learned a lot about my own strengths and weaknesses and the satisfaction of putting something back into society. It allowed me time, away from my normal world, to appreciate how lucky I was. As I reflect on the experience it also highlights the importance of creating space for personal development whether be inside or outside of the work environment.

What is the one piece of advice that you would give to petroleum engineering graduates and young professionals?

It really depends on your career aspirations. I can easily see petroleum engineering graduates developing their careers via either leadership or technical routes.

In terms of careers advice, I believe organisations initially look for the following basics:
- a track record of delivery
- strong technical competence in your field of experience
- leadership, influencing, change management skills

However, in my experience, the latter is the differentiator between very good candidates who may be equally competent in delivering the core job.

If you can show that you routinely identified a problem you can influence, analysed what was going on, designed a solution in conjunction with others, gained commitment to make a change, implemented your plans, adjusting for complexities and finally made a measurable long-lasting difference to performance, then this is the gold standard because you will be adding value to the organisation in every role you move into. In your career, seek out opportunities, in every role, to make a difference and collect a string of examples where you have done this. This behaviour will stand you in good stead now and in the future.

You could start by exploring improvement opportunities with your department leader and then volunteering to work on this. Any role or company that allows you headroom to do this will be great for your career and make you a valuable commodity to that organisation, and with this will come rewards.

There are many examples where things can be improved, and I have every confidence that with an inquisitive mind you will be successful in the future.

SPE virtual regional student paper contest 2021

On Wednesday 5 May, SPE's student paper contest (European region) took a place for the Bachelor, Master and Ph.D categories. Eight participants from the Master's category represented top European universities including: Imperial College London, IFP School, NTNU, Coventry University, International Hellenic University and Heriot Watt University.

The students discussed a set of interesting topics and suggested some advanced modern solutions by incorporating AI and machine-learning technologies to tackle the oil and gas industry's day to day problems. Most importantly, climate change and carbon capture and storage were not missing from the scene.

Ibrahim Mabrouk from Heriot Watt University (first-place winner), **Raghd Gadrbouh** from Imperial College London (second-place winner), and **Elissavet Emmanouilidou** from International Hellenic University (third-place winner) shared their experience of the competition and talked about their research projects.

Certificate of Participation

The Society of Petroleum Engineers (SPE) awards to

Ibrahim Mabrouk
Heriot-Watt University

presented as a contestant in the Master's Division of the
2021 SPE Europe
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Ibrahim Mabrouk

I am a graduate Petroleum Engineer from Heriot Watt University and this is my second time representing my university in the SPE student paper contest. My research this year focuses on the Petrophysical Evaluation of Heterogeneous Reservoirs through using machine-learning techniques that help minimize the data required to understand the field.

Integrated Reservoir Modelling (IRM) is usually performed by the operating company to find the optimum scenarios to develop their hydrocarbon fields and the first step of the IRM is the Petrophysical Evaluation. The heterogeneous reservoirs proved to be more challenging as they require more extensive data acquisition programs, which usually include several cores and advanced well logs.

The workflow introduced in my research is based on creating correlations between core data and advanced well logs from one side, and the conventional well logs from another side using neural network analysis. By using this workflow, a comprehensive field Petrophysical evaluation was performed using only conventional well logs. Based on the result of the research, developing the field using horizontal wells rather than vertical wells was tested and proved successful.

Raghd Gadrbouh

This was my first time participating in the SPE student paper contest and it was such a pleasure to represent my university, Imperial College London. Although the competition was virtual and we missed the chance to travel, meet each other and the judges, I was fascinated by the all the contestants' work and I really enjoyed the Q&A session with the judges.

My research 'Quantification of CO_2 Storage Efficiency with Aquifer Pumping', which was part of a student placement with Shell, Norway, aimed to quantify the additional storage efficiency that can be achieved with brine production by deriving dimensionless results that

SPE virtual regional student paper contest 2021... continued


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Raghd Ahmed Gadrbouh
Imperial College
presented as a contestant in the Master's Division of the
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can help screening candidate aquifers for CO_2 storage projects with aquifer pumping. Although numerous studies focused on quantifying CO_2 storage efficiency with aquifer pumping by understanding the effect of different aquifer parameters on CO_2 storage efficiency at breakthrough time, these studies were carried out for specific fields and results cannot be scaled and applied to different projects.

The novel aspect of my research is estimating CO_2 storage efficiency with aquifer pumping by investigating the effect of aquifer parameters together with different storage strategies and creating scalable results that can be applied to any project. The dimensionless groups in my work helped propose changes in some operational strategies. These included changes in injection rates, well placements and water extraction options. The results were very promising and would enhance CO_2 storage efficiency ten times more than the expected storage efficiency with no brine offtake.

Elissavet Emmanouilidou

I am an M.Sc student in Oil and Gas Technology at the International Hellenic University in Kavala. My bachelor degree is in Chemistry from the Aristotle University of Thessaloniki.

My paper title is: 'Investigation of Petroleum Hydrocarbon Fingerprints of Water and Sediment Samples of the Nestos River Estuary in Northern Greece', which is part of my MSc thesis. I participated in the competition with the encouragement and support of my thesis advisors Prof. Sofia Mitkidou and Prof. Nikolaos Kokkinos. I managed to win third place and I feel really grateful.


Certificate of Participation

The Society of Petroleum Engineers (SPE) certifies that
Elissavet Emmanouilidou
International Hellenic University
presented as a contestant in the Master's Division of the
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Nestos River is one of the biggest rivers in Greece and comprises the natural border between Macedonia and Thrace. As it empties into the Aegean Sea, Nestos forms its delta, which is considered to be a miracle of nature accommodating a variety of habitats, flora and fauna species and protected by RAMSAR Convention. Oil fingerprinting by GC-MS analysis of petroleum hydrocarbons in water and sediment samples at the surrounding area of the river provides a powerful tool to investigate their potential source and correlation with the oil and gas industry that has operated in Kavala for more than 40 years.

Significant differences were identified in chromatographs of steranes and hopanes biomarkers at m/z 191 and 217 respectively, as well as in pristane-to-phytane ratio (Pr/Ph) between crude oil and petroleum products indicating different depositional environments. In the case of spiked sediment samples there were also clear differentiations in dibenzothiophenes distribution patterns and specifically in methyl-dibenzothiophenes at m/z 198 and dimethyl-dibenzothiophenes at m/z 212 between crude oil sample and petroleum products. Analysis of total ion chromatographs (TIC) for water and sediment samples clearly revealed that no organic pollution was identified for Nestos River area, suggesting that there was no impact from human activities.

I would like to highlight that even if this year the competition took place virtually due to Covid-19, everything was organized properly, and the experience was unique and unforgettable. All judges, contestants and coordinators of this event worked hard in order to provide the best outcome. Of course, I would prefer a live event, but even in that way I felt the 'beat' of the competition and I'm honoured to be part of it.

Debiasing, data and design: Human factors for oil industry decision making

Dr Matthew Welsh has a PhD in psychology and works as a Senior Research Fellow in the Australian School of Petroleum and Energy Resources at the University of Adelaide. Currently, he is employed on an Australian Research Council funded Linkage Grant, with partner organisation support from Santos and Woodside, examining predictors of decision-making ability. He has written more than 50 journal and conference papers and is the author of 2018's Bias in Science and Communication: A Field Guide from IoP Press. He is a current (2020-21) SPE Distinguished Lecturer, speaking on how cognitive science can help to improve oil-industry decisions.

Decision making

Decision making is central to the oil industry because it is how we turn information into action – whether deciding where to drill a well, who to hire, which investments to make or what prospects to develop. All are dependent on our ability to make judgements, compare alternatives and work towards the most beneficial options. It is also, however, often the weakest link in the value chain. One reason for this is that too few people are trained in decision making. We would never hire an engineer without an engineering qualification but do not apply the same standard to decision making. Instead, we assume good decision making comes naturally or that on-the-job feedback is sufficient to train us in its use.

This assumption is at odds with evidence showing human decision making is systematically biased and that many decision-making environments are ill-suited to learning. Renowned researchers Kahneman and Klein (2009) laid out the requirements for learning good decision making from feedback in an environment. Key among these are: validity, that is, how stable the relationships between cues and outcomes are; and, how quickly and unequivocally feedback informs you whether your predictions or actions were successful.

While there are areas within the industry where these conditions hold, none of the key decisions listed above are among them. Taking a wildcat drilling decision, for example, there are multiple predictors of oil presence but these are all imperfect – explaining the long-term average chance of success being below 0.3 (Westwood Energy, 2019). That is, the validity of the environment is low. Similarly, feedback is slow, with years potentially passing between a decision and an initial outcome (oil vs dry) becoming known. Even then, feedback may not be unequivocal as hydrocarbon volumes may remain uncertain for years to come. All of this argues against petroleum personnel learning good decision making on the job.

Debiasing and decision making

Long-term industry results support this conclusion. Ed Merrow, in the early 2000s described a "cult of mediocrity" in oil industry outcomes, with most developments failing to meet the performance benchmarks on which they were greenlit. Recent industry outcomes show similarly poor performance. Norwegian Petroleum Directorates data shows predicted production rates falling outside estimated P10-P90 ranges more than 50% of the time (Bratvold, Mohus, Petutschnig, & Bickel, 2020). That is, despite advances in computing power, modelling, management and drilling technologies, industry decisions show a similar degree of overconfidence – the mismatch between predicted and observed accuracy - to that demonstrated more than forty years ago (Capen, 1976).

This is the case despite increasing conversation within the industry (and management more widely) around this and other cognitive biases known to affect industry decisions - anchoring, framing, outcome, hindsight and confirmation biases to name a few. It seems clear that awareness, while necessary for people to recognise the occurrence of biases, is not sufficient to reduce bias (Welsh & Begg, 2016).

This is due to a combination of several effects – of which three seem key. The first is that awareness of a bias does not always make clear how to avoid it (Welsh, Begg, & Bratvold, 2006). For example, knowing your

Debiasing, data and design... continued

ranges are overconfident may prompt you to widen them but knowing that your estimates are anchored by numbers you have recently seen will prompt you to… do what, exactly? Not look at numbers?

The second relates to our preference for deterministic over probabilistic information. When asking for (or giving) an estimate, we have a strong bias towards precise estimates as these are the most informative about what the person believes the 'true' answer is (Yaniv & Foster, 1997). This works against us in cases where we really do want probabilistic estimates or forecasts.

The third is perhaps the hardest to overcome: the fact that many cognitive biases are not problems with cognitive function but the outcome of normal cognitive functioning. Thus, attempts to avoid biases require people to work against deeply ingrained, even subconscious processes. For example, hindsight bias refers to people's tendency to update their memories with their current knowledge, leading them to think that they 'knew it all along' or that outcomes were easily predictable. This occurs because it is inefficient for a brain trying to learn to survive with limited processing/storage to maintain multiple explanations of the same event. Once you know how an event turned out and why, keeping accurate recollections of your theories about how it might have turned out is superfluous (Welsh, 2020).

This feature of memory then causes additional bias because you remember being correct more often than you have been. So, when it comes time to predict how often you will be right in the future, you will overestimate. That is, normal memory function causes hindsight bias, causing overconfidence (Welsh, 2020).

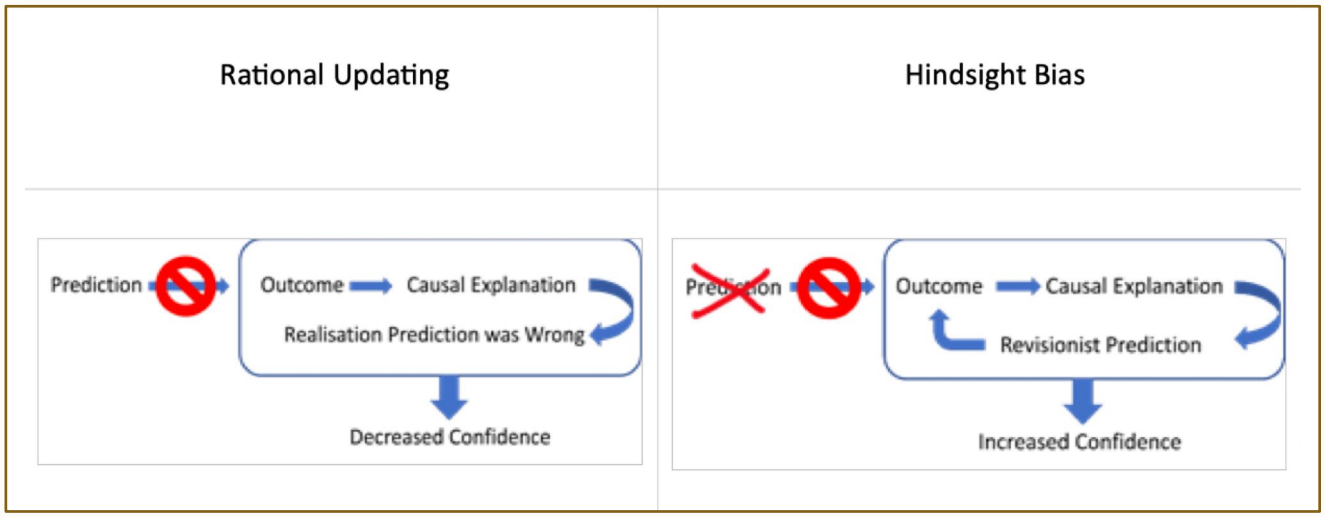

Figure 1: Rational updating of confidence after incorrect prediction vs effect of hindsight bias.

All of this suggests that, in the absence of deliberate, informed interventions that demonstrate alternative strategies and offer support for human cognition, decision makers will continue being subject to a range of cognitive biases and oil industry performance will continue to lag behind expectations.

Data and decision making

Of course, a common reaction to poor decision outcomes is to blame a lack of information and then argue that future decisions need more or more precise data. This, however, is a fundamental misunderstanding of decision making. Excellent decisions can be made under uncertainty or with partial data and additional data is only useful if it would change the decision you make.

As a simple example, consider the following (page 11) series of four images, in which each step to the right reflects four-fold greater data resolution. The decision you need to make is: should I continue walking in this direction?

Debiasing, data and design... continued

Figure 2: Increasing data/resolution images for decision: "Should I continue walking in this direction?"

Most people, on seeing the first image may not have any idea what it is and need to increase the resolution – i.e., collect more data. By the third image, though, it is clear the image shows a tiger and additional time and effort to further improve the resolution is wasted as the decision should already have been made: do NOT walk towards the tiger!

This key aspect of technical work is often forgotten. The goal of data collection, analysis and alternative development is to assist in making better decisions. If your goal is to produce the best technical work possible or the most complete data, you will keep working on improving that resolution well beyond when a decision should be made.

This tendency, which we might call 'faith in data' seems to be increasing as the world moves towards 'Big Data' and 'AI' systems. People talk about decisions being "data-driven" and assume this means decision making will automatically improve. Conversely, the move to data-driven processes can create situations where decision makers are reliant on the data a system has been designed to give rather than the data they might actually want/need. Similarly, models can be based on parameters and assumptions they do not know or understand. This relates to a current hot topic in Human Factors research – trust in autonomous systems (see, e.g., Chen & Barnes, 2014). As systems become more complex and autonomous, people's ability to understand them is decreased and, without careful training and design, this can result in worse performance as people may distrust the outputs of these 'black boxes'.

Design and decision making

Most engineers are familiar with the concept of Human Factors – taking into account how people will interact with the engineered environment. At its simplest, we consider physical requirements – don't design a single-operator device that requires three hands to use. We then move to thinking about perceptual requirements – make sure auditory warning signals are at a frequency and amplitude that most users can hear (and test your users on this). We often forget, however, that the same approach needs to be applied to decision making. Understanding how and why people make decisions is central to the ability to make good decisions. Analytic tools allow rational calculation of the value of options and information but this is not enough. As even a cursory examination of the world reveals, decisions are rarely based entirely on numerical or statistical evidence. To make good decisions, we need to understand how and why we make our decisions, how our customers and competitors do, and what assumptions developers or data analysts might subconsciously build into their systems and analyses. Further, we need to build decision processes with this knowledge that enable us to use the abilities we have while offering support for our limitations.

That is, we need to expand our understanding of Human Factors from the physical and perceptual into the realm of judgement, communication and decision making. By understanding human cognitive abilities and limitations we can design processes that improve judgements and decisions - as demonstrated by the MOLE process for reducing overconfidence in estimated ranges (Welsh & Begg, 2018).

Without this, attempts to debias our decisions and close the gap between our expectations and performance are likely to fail as they ignore the underlying cause of bias – these cognitive, human factors.

Debiasing, data and design... continued

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Australian School of Petroleum and Energy Resources (ASPER)

Founded in 2003 from the merger of the School of Petroleum Engineering and Management and the National Centre for Petroleum Geology and Geophysics, ASPER is Australia's top ranked school for Petroleum Engineering and Geoscience.

Located within the University of Adelaide's Engineering, Computing and Mathematical Sciences Faculty, it has additional areas of expertise in carbon sequestration and geological hydrogen storage. Its programmes further include a management stream incorporating petroleum economics, decision making and risk analysis.

Net zero 101: Carbon pricing, explained

The implementation of a carbon price is a fundamental step in our effort to achieve the 1.5oC and well-below 2oC twin climate goals set in the 2015 Paris Agreement — ratified by 189 countries. This piece explores why a carbon price is needed, what it is, and how it can be established in the effort to mitigate greenhouse gas emissions.

Why is this being discussed?

Before delving into what carbon pricing means, it is necessary to understand why it is needed. This starts with the price we pay to consume goods and services – from the clothes we wear to the petrol we use to power our cars.

The price of a good or service represents how scarce that product is, which is measured by the total cost of having one more unit of it. This takes into account not only production and distribution costs, but also the external effects ('externalities') that that good or service may impose on others, be they positive or negative. In economic terms, when the price paid by the consumer does not reflect the real, total cost, a market failure arises.

However, the price of goods and services we consume today mostly do not take into account negative externalities such as the impact of carbon emitted during their production and distribution that exceeds the carbon cycle. This results in climate change and is creating costs and risks for future generations – the ones who will suffer the largest impact, particularly in developing countries.

Figure 1: The youth's strong adhesion to the Fridays for Future climate strikes across the world stems from this perception that young individuals will be the ones to disproportionally bear the consequences of climate change (Source: Personal archive).

This creates a challenge where those generating emissions are not paying for their social and environmental intangible impacts. In this regard, Sir Nicholas Stern, in the release of The Stern Review, famously stated: "Climate change is the greatest and widest-ranging market failure ever seen."

Indeed, mitigating carbon emissions is more of an ethical decision rather than an economic one. So how can this be changed?

The importance of carbon pricing

When there is a market failure, a government can implement policies to help mitigate it. In the case of climate change, the policymaker will ideally implement the solution that generates the largest reduction in carbon emissions at the lowest cost to society.

This is where carbon pricing comes into the scene. The application of a cost to carbon emissions allows for the cost of climate change to be borne not only by future generations, but rather shared throughout generations so that we pay at least partially for how much we consume.

How can a carbon price be implemented?

The most straightforward approach to establishing a carbon price is through a carbon tax.

Net zero 101: Carbon pricing, explained... continued

The tax seeks to 'correct' the price of polluting (although this is not a straightforward calculation), making those emitting carbon pay for something closer to the real, total cost of polluting. Thus, the polluter is nudged to reduce output to meet the emissions target while the government receives tax income, which can be utilised to help finance climate change solutions.

In this realm, prominent economists Martin S. Feldstein, Ted Halstead and N. Gregory Mankiw made a 'Conservative case' for a carbon tax in the United States as an option that would prove itself valuable for whatever party is governing the country, reducing carbon emissions, limiting regulatory intrusion, and promoting economic growth.

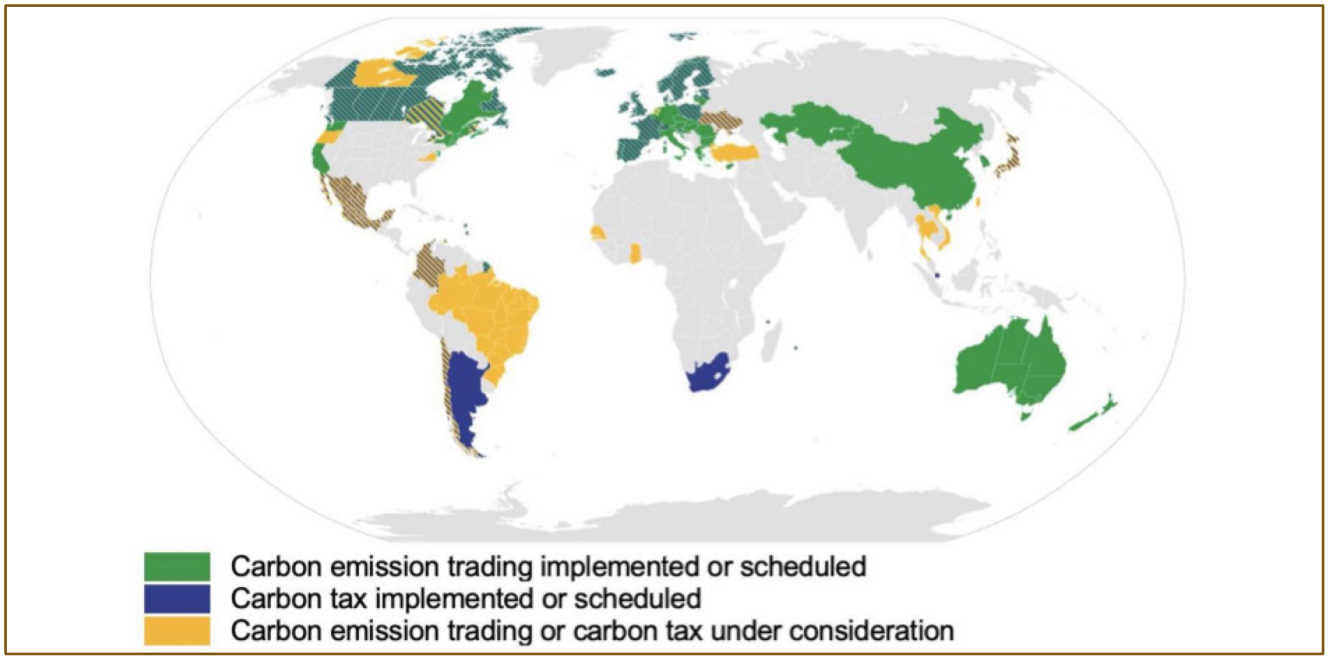

Figure 2: Carbon emission trading and carbon tax around the world (Source: Wikimedia Commons. Data as of 2019)

A second approach is the establishment of carbon markets. There are two forms of establishing them, one enforced by a local or regional authority – which will be further explored in this piece – and another that is voluntary, often known as carbon offsetting schemes, where a country/company trades verified emission reduction units to offset a certain tonnage of CO2 equivalent emitted elsewhere.

The first model is known as a cap-and-trade scheme, where the regulator sets a limit (cap) on pollution and creates enough allowances – normally, each one of them represents 1 tonne of CO2 equivalent – among the participating players to meet this cap. After the permits are allocated by the regulator, they can be bought and sold among the players throughout the year as long as they have enough permits by the end of the set period to give back to the regulator.

Within this logic, a player who faces lower costs to abate emissions is expected to make the necessary investments (e.g. technology) to reduce them, whereas a second player for which this would be more costly will decide to purchase allowances from others. The goal of this system is to encourage the abatement of emissions at the lowest cost.

Regional efforts such as the Regional Greenhouse Gas Initiative in the United States and the European Union's Emissions Trading Scheme (EU ETS) are examples of how carbon markets can work successfully. Article 6 of the Paris Agreement envisages it at global scale in order to help reach its targets, something that will be once again discussed at the Conference of the Parties (COP), next to take place in Glasgow in November 2021.

The EU ETS – implemented in 2005 – was the first international emissions trading scheme. It encompasses

Net zero 101: Carbon pricing, explained... continued

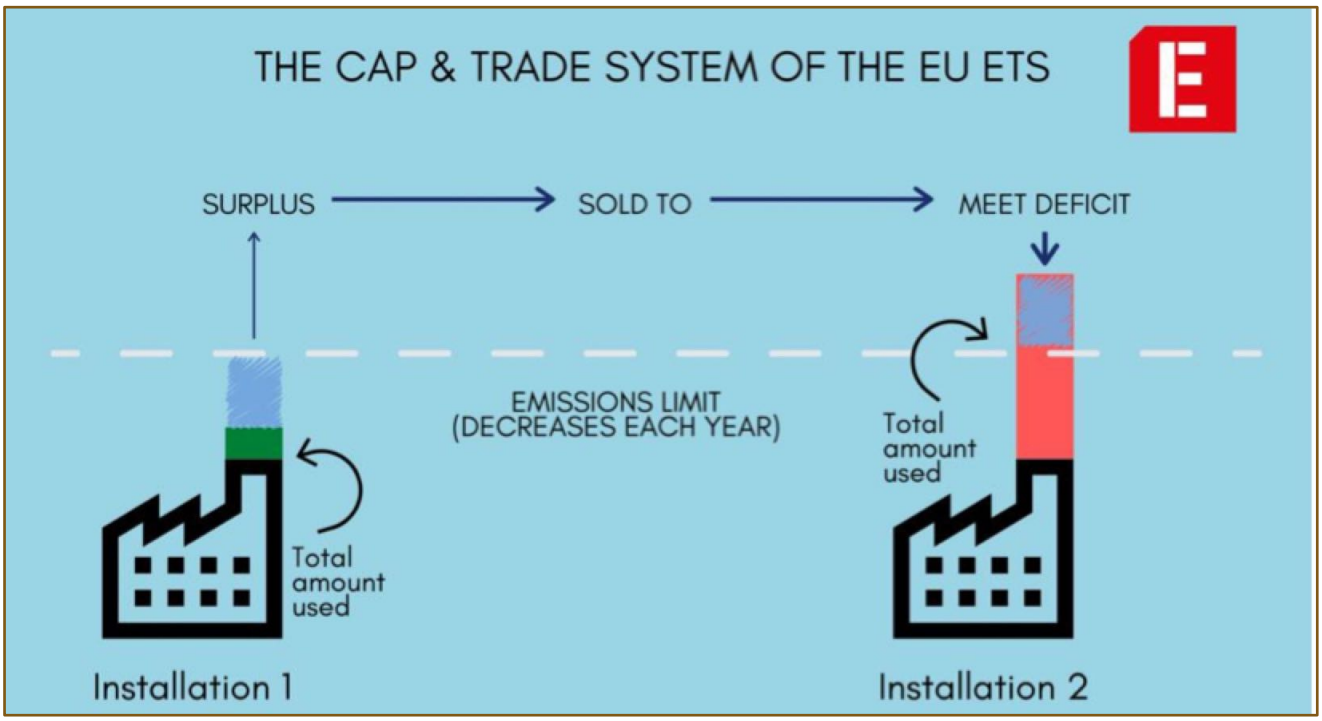

Figure 3: Simplified explanation of how a cap-and-trade scheme functions (Source: Investigate Europe)

40% of the bloc's greenhouse gas emissions and has 11,000 heavy energy-using installations from the industrial and power sectors, as well as airlines, as players. While it is hard to disentangle the causal impacts of the EU ETS from the process of reducing emissions which was already underway in Europe, it contributed to a robust negative impact on emissions of 35% between 2005 and 2019 compared to a business-as-usual scenario.

Thus, there are different approaches countries can take to implement a carbon price in their effort to mitigate emissions in a cost-effective manner. This is important as the successful implementation of these mechanisms shares the costs of climate change across generations and is key to achieving our climate targets from a free-market perspective.

NASA Kennedy Space Center (KSC) and liquid hydrogen: Past, present and future

Adam M. Swanger is a senior research engineer with the Cryogenics Test Laboratory at NASA Kennedy Space Center for energy efficient technology development and materials research. He holds an MSc in Mechanical Engineering (Thermo-Fluids) from the University of Central Florida, and a Bachelor of Aerospace Engineering from Ohio State University. He has worked in the field of cryogenics for more than ten years, with a focus on providing practical solutions to low-temperature problems in both active and passive thermal systems. (Learn more about Adam's work at the end of this article.)

As I sat down at my desk at NASA Kennedy Space Center (KSC) in Florida to begin preparing this article I was interrupted by the distinct sound of supersonic gas exiting a converging-diverging nozzle nearby – the low rumble of thunder in the distance, steadily increasing to a crescendo that shook the third-floor windows and ceiling tiles of the office building before trailing off again. Standing at the window watching the Space X Falcon 9 rocket hurdle into the cloudless, blue April sky, two thoughts came to mind: One: The frequency of launches must have grown substantially over the past few years since I totally forgot this one was happening, and Two: The raw power produced by mixing large quantities of liquid oxygen and fuel together in an rocket engine never gets old! The fuel in this case was not liquid hydrogen but kerosene. However, the results are the same ... thrust and pageantry!

NASA's history with liquid hydrogen (LH2) as a rocket fuel goes back to the infancy of space flight and standing-up of the Agency in the late 1950's. By the mid-1960's, KSC had become the owner and operator of the largest LH2 storage and transfer systems in the world – a fact that still remains today – in support of the Apollo moon program and massive Saturn V rocket. Twin 3,200 m3 LH2 vessels were constructed, one at each launch pad, to supply the second and third stages of Saturn V. Identical in design and construction, these vessels were double-walled spheres that employed bulk-fill perlite insulation under vacuum to achieve boiloff losses of roughly 0.03% per day, or equivalent to about a 370-watt heat load. LH2 was pressure-fed from the sphere to the launch pad surface roughly 300 m away, and over 100 m vertically up the launch tower through vacuum-jacketed piping to the vehicle propellant tanks. Boiloff losses were piped away from the vehicle and/or tank and safely flared-off – in a burn pond in the early days, and then a stack in more recent times. This general configuration was utilised throughout the Apollo program (1961 - 1972) and was carried over into the Space Shuttle era (1972-2011), where it supported another 135 missions. During the Shuttle program, and indeed to this day, no large hydrogen liquefiers existed in Florida, so waves of tanker trucks transported LH2 from production facilities in Louisiana or Alabama to replenish the tanks.

In the subsequent years since the Space Shuttle retired, NASA has been designing and building a new heavy lift launch vehicle called the Space Launch System (SLS). The on-board quantity of liquid hydrogen for SLS is about 20% higher than for the Space Shuttle which, when combined with the intrinsic losses associated with cryo loading/draining, analysis revealed that the legacy tank could not support the required number of consecutive launch attempts. Various options were explored to address this issue, ultimately resulting in the design and construction of a new LH2 sphere to supplement the original. Located adject to the existing tank, this new vessel is roughly 50% larger at 4,700 m3 usable volume and is of the same general construction.

Where it does make a substantial departure from the old design, however, is in the inclusion of two new technologies pioneered by the Cryogenics Test Laboratory at KSC: Glass Bubble bulk-fill insulation as a replacement for traditional perlite, and an Integrated Refrigeration and Storage (IRAS) heat exchanger[1] for future controlled storage capability.

Bubbles are Better!

As their name implies, glass bubbles are just that: hollow spheres made from borosilicate glass. The 3M corporation K1-type product, which has been the primary focus of R&D efforts for LH2 tank insulation, has a

NASA Kennedy Space Center (KSC)... continued

bulk density of 125 kg/m3, and individual bubbles have average diameter of 65µ and are filled with a partial vacuum of SO2. R&D for the use of glass bubbles – a.k.a. glass microspheres, glass beads, and microballoons – bulk-fill material as part of a cryogenic tank insulation system began in the early 1970s[2]. Beginning in the 1990s, the Cryogenics Test Laboratory embarked on multiple R&D efforts to thoroughly characterise the thermal and mechanical performance of K1 glass bubbles for LH2 storage tanks, ultimately culminating in a larger scale test where a 190 m3 perlite-insulated vessel located at NASA Stennis Space Center in Mississippi was retrofitted with glass bubbles in 2008.

Various goals were achieved through this test campaign, including insulation loading processes, vacuum pump-down characteristics, thermal cycling effects, and long duration boiloff performance. In 2015, after collecting roughly six years' worth of data, the LH2 boiloff reduction versus the original perlite insulation was found to be 46%[3].

As a direct result of NASA's R&D efforts with glass bubbles the insulation was included in the specification of the new 4,700 m3 LH2 sphere currently being constructed. Filling of the annular space with an estimated 1.3 quadrillion individual bubbles is schedule to take place in August 2021, followed by tank commissioning in early 2022.

Gaining Control

Fundamentally, Integrated Refrigeration and Storage is about control. Or, perhaps more appropriately, it provides a means of gaining control over a situation that had previously called the shots – namely, the necessary venting of hazardous and precious hydrogen to balance out the heat absorbed throughout the LH2 supply chain. Since Sir James Dewar first liquefied hydrogen in 1898, safely dealing with flammable vent gas caused by continuous and unavoidable heat ingress through the storage vessel has been of utmost importance. And as large scale LH2 systems began to emerge in the 1950s the issue became even more imperative; so much so that it effectively shaped large parts of what we now consider traditional LH2 storage and transfer system designs and operations. Additionally, there can be significant economic impacts associated with venting boiloff losses. During the Space Shuttle program NASA lost almost 50% of the LH2 purchased due to combined heat leak[4]. Depending on the cost of LH2 at a given location and time, which historically can vary significantly, these losses may constitute meaningful financial impacts.

IRAS provides a means of reducing and/or eliminating LH2 losses – which also indirectly reduces risk and increases operational safety by eliminating the need to purposely vent hydrogen – by removing heat directly from the bulk fluid inside the storage vessel via an internal heat exchanger connected to an external cryogenic refrigeration system. Just as the invention of the 'artificial ice machine', or home refrigerator, liberated us from the use of consumable ice blocks by simply plugging into a wall outlet, IRAS can liberate us from the heretofore unavoidable tax paid to the universe in the form of boiloff gas to access all the benefits LH2 has to offer.

The Cryogenics Test Laboratory began IRAS research efforts in the early 2000s, culminating in the design construction, and testing in 2016 of the Ground Operations Demonstration Unit for Liquid Hydrogen (GODU-LH2)[5] – a custom-built 125 m3 horizontal-cylindrical LH2 IRAS storage tank coupled to an 880 W at 20 K Brayton cycle helium refrigerator. GODU-LH2 successfully demonstrated the five primary advanced capabilities afforded by IRAS:

1. Zero-loss tank chill-down from ambient temperature
2. Zero-loss LH2 tanker offloads
3. Long duration zero-boiloff of LH2
4. In-situ hydrogen liquefaction
5. Densification of LH2 down to the triple point.

Post-test economic analysis of zero boiloff testing revealed that for every dollar spent on electricity to power the GODU-LH2 system, roughly 7 dollars' worth of LH2 was saved (based on $0.06/kWh electricity cost and $5.20/kg LH2 cost); a fact that played an important role in infusing the technology into the new launch pad sphere.

NASA Kennedy Space Center (KSC)... continued

Setting the Benchmark

With the inclusion of glass bubbles and future controlled storage via IRAS the new LH2 sphere currently being constructed at KSC has the potential set a new standard for large scale liquid hydrogen storage and operations. **And as the technical community tackles a host of new challenges brought on by mega-scale LH2 initiatives—land and sea–based tanks pushing 200,000 m3 capacity—driven by a collective global momentum aimed at addressing climate change, advanced designs and methodologies that increase efficiency and make LH2 a more viable contender in the energy market will prove to be invaluable.**

Adam M. Swanger has played an integral role in projects for NASA, the Department of Energy, the National Institute for Occupational Safety and Health, and many commercial and industrial partners. He has authored or co-authored more than twenty publications in the areas of integrated refrigeration systems, thermal insulation systems, and cryogenic materials testing methodologies. His current research activities include solid-state thermo-fluid storage, next-generation cryogenic propellant storage and densification, and high-performance insulation systems for both terrestrial and in-space applications. He has received numerous NASA awards for his research and technology development efforts, including the Space Flight Awareness Trailblazer Award and silver achievement medal. He is also a lifetime member of the Cryogenic Society of America, and regularly contributes to international conferences such as the Cryogenic Engineering Conference and Space Cryogenics Workshop, and publications such as Cold Facts and Gasworld magazines. Adam lives in Orlando, Florida with his wife Vanessa, two-year-old son Rory, and their Australian Shepard Zoe. He is a lifelong car enthusiast, both vintage and modern, and enjoys golf, travelling, and watching college football.

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Apollo-era LH2 sphere middle upper


New LH2 sphere under construction


GODU-LH2 system


SLS core stage under test

All images: National Aeronautics and Space Administration (NASA)

SPE London section: It's our 50th!!

SPE London section: It's our 50th anniversary!! continued

Do you remember what happened 50 years ago in 1971? Here are just four significant events.

NASA's Apollo 14 mission to the Moon launches.
The mission crew included Commander Alan B. Shepard Jr., Lunar Module Pilot Edgar D. Mitchell and Command Module Pilot Stuart A. Roosa. It was 31 January 1972.

The photo shows crew members training for an extra vehicular activity. Image credit: NASA/KSC

Spring

In Sicily, Mount Etna erupts.
On 5 April, 1971, the top of the volcano broke in several different parts. Just 10 days later, more fractures opened, resulting in more lava. In early May, more vents opened. Activity went on until 12 June, although no towns were destroyed.,

Image credit: LE GUERN from the book Etna (1977)

Summer

The nation of Qatar becomes independent from the UK.
In early September, the United States recognized the State of Qatar, which had declared independence on 3 September. Qatar was previously a protectorate under Great Britain.

The photo shows modern-day Qatar.
Image credit: www.visitqatar.qa

Autumn

Walt Disney World opens.
In October, the Walt Disney World Resort officially opened. The resort included Disney's Contemporary Resort, the Magic Kingdom Park, Disney's Fort Wilderness Resort and Campground, and Disney's Polynesian Resort

Image credit: Disney Parks

Winter

Now, we need your help!

We're planning a 50th Anniversary Special issue. But we need your help! We're asking for photographs or perhaps short 100-word stories from your adventures during those 50 years. Where were you in the years between 1971 and the present? If you have a memorable story and/or photo, please share – such as:

Exhilarated by working on your first field site?

Celebrating a special family moment?

Perhaps doing a career day at a school?

Please send your digital/scanned photos and/or short stories to our Editor, at:
elizaveta.l.poliakova@gmail.com

SPE London section: It's our 50th anniversary!! continued

SPE London section: It's our 50th anniversary!! continued

The barriers to deployment of new plugging technologies

The North Sea is facing one of its greatest challenges; how to decommission thousands of wells safely, effectively and for the lowest possible cost.

This pursuit is not one only of the operators, who have endured a collapse of demand and historically low oil prices, but also the government and regulators, with a priority to 'improve decommissioning efficiency'.

This article is written by Brian Willis, Senior Engineer at Astrimar.

All wells will eventually be required to be plugged and abandoned (P&A'ed). Typically for a production well, this will be after it is uneconomical to continue to produce from. Following cessation of production (CoP), the wells may be suspended while preparations are made for the P&A. To minimize risk and liability, the well should be plugged and abandoned timeously, however this sometimes is not feasible.

The UK North Sea is rapidly approaching a life-cycle phase where decommissioning will be the major activity, referred to as the 'Decade of Decommissioning'. Well decommissioning is not a cheap activity; each well can cost between approximately £3 to £7 million (OGA UKCS Decommissioning Benchmarking Report 2020) depending on whether it is a platform or subsea well, and this expenditure gives no financial return to the operator. It is however absolutely necessary to ensure that these wells do not pose a long-term threat to the environment or the livelihood of communities who depend on the oceans.

The cost to the industry (and the taxpayer) is estimated to be £27 Billion in the next decade, alongside the erosion of jobs offshore as the platforms continue to shut down. The hope is that the workforce and supply chain can pivot to supporting the 'new' industry of decommissioning and other emerging offshore industries like offshore wind. In 2017, the Oil & Gas Authority (OGA) challenged the industry, to reduce decommissioning costs by 35%. While large steps have been taken so far in achieving this (17% reduction in P&A costs by 2020), this has not resulted from step changes in technology or processes; there has simply been greater cost certainty.

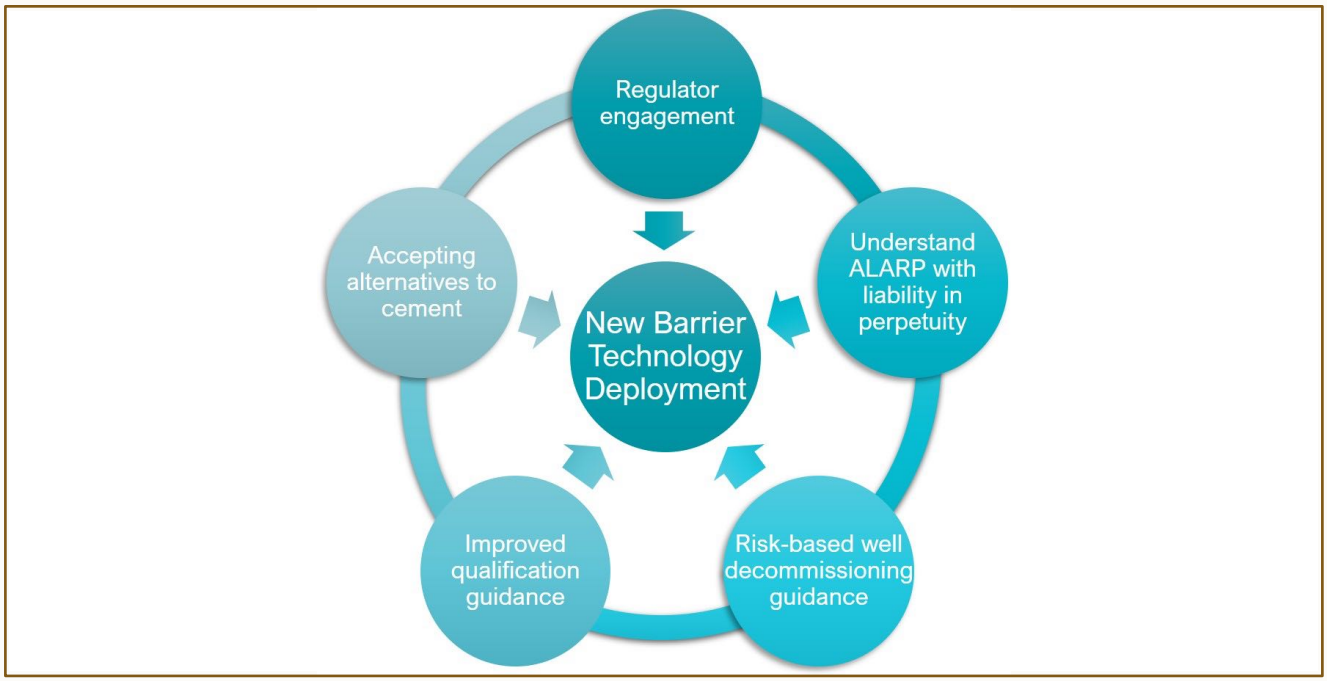
'Technology, processes and guidance' is one of the four priority areas in the Decommissioning Strategy publish by the OGA in May this year. New plugging technologies, especially rig-less through tubing technology, are seen key to delivering a step change in costs and efficiency. There are currently many new plugging technologies at various stages of development, however 'appropriate regulatory processes and clear guidance underpin' their acceptance and deployment. The challenges these technologies face, and how best acceptance be supported, are discussed further below . Urgency is required – the Decade of Decommissioning is already here. Each year that passes without achieving these improved efficiencies is a year of potential cost reductions lost.

The challenges facing new well barrier technologies are numerous:

1: Good practice essentially assumes a cement barrier of 100 ft or more
2: There are no industry standards for testing new barriers
3: Current guidance is unclear in relation to the qualification of new barriers
4: There is no guidance or accepted good practice on risk assessment for well plugging and abandonment
5: There is uncertainty around regulations and application of the "ALARP" principle and
6: Liability remains in perpetuity

This list is not exhaustive and technology developers are further challenged by the development costs and necessary funding as well as the limited opportunities for field trials.

The barriers to deployment of new plugging technologies... continued



Cement has been used in well construction and abandonment in the oil & gas industry for over 100 years. This wealth of historical experience in both the deployment and performance of the cement as a barrier has ensured its continued use and this is unlikely to change. The aim of plugging and abandonment is to essentially re-instate the sealing formations which were drilled through and to prevent the unplanned flow of fluids from the reservoir (or other shallower zones of flow potential).

Cement, however, has material properties (e.g. shrinkage) and deployment challenges (e.g. channeling) which make it a less than ideal permanent barrier. To mitigate against these, typically a few hundred feet of cement is placed such that there will be at least 100ft of good cement. For new plugging technologies, such as metal alloy plugs, the cost of setting a 100ft plug would be prohibitive; however the performance of these new materials indicate that plugs of this size will also be unnecessary. Ultimately though, to displace cement as the de facto barrier material, any new barrier will need to deliver a step-change in barrier performance and cost reduction.

Current decommissioning guidelines, for the most part, assume that cement will be used for the permanent well barrier. Although intended as guidance, the guidelines are often treated in a prescriptive manner. The guidelines specify a minimum length of barrier which should be placed as opposed to defining a barrier performance requirement, such as an acceptable leak rate, with no real recognition of the material properties. The more favorable material properties of novel barrier technologies will facilitate a substantial reduction in barrier length, potentially an order of magnitude, however the predisposition to simply setting a longer barrier makes the case for the use of new barriers inherently challenging. Current guidance does allow for alternative options, cement or otherwise, provided they can be demonstrated to be acceptable – and the UK regulation goal setting regime can support this.

Any new plugging technology should go through a technology qualification process to demonstrate that it will meet the performance requirements and have the required durability. Best practice technology qualification processes used by industry today are derived from practices developed by NASA to support their space program. Application of these processes often requires specialist expertise, especially when the plug is intended to be permanent barrier. The OGUK (Oil & Gas UK) has guidance on the qualification of materials for abandonment (Issue 2), and while this is regularly referenced both locally and internationally, plug developers have struggled to successfully apply it and often found prescribed tests unnecessary or not applicable for their technology. The guidance is, however, currently being updated, and a particular emphasis is being made on

The barriers to deployment of new plugging technologies... continued

describing the expected qualification process for a novel well barrier. Key to this process is the failure mode assessment, and rather than the guidance prescribing tests to be performed, the identified failure modes and mechanisms of a barriers systems, and their associated risks, are intended to drive the test program. The hope is that this results in tests and analyses which are fit for purpose, and ultimately deliver new barrier technologies with demonstrable acceptable risks.

During the recent decommissioning focused conferences hosted by the SPE and Decom North Sea, 'risk-based' approaches to well decommissioning was one of the key topics discussed. There has been a concerted effort from the industry, supply chain and the regulator, to improve decommissioning and be more efficient, while still ensuring the health, safety and environmental risks are kept as low as possible. Any divergence from current good practice, should be supported by a thorough risk assessment, however the extent to what should be included is not clear. Furthermore, the risk assessments should rather inform the decision-making process, as opposed to being seen as a requirements after P&A design decisions have been made. To this end, what is needed is a risk-based decision-making framework and associated guidance for well owners and service companies to support the decision-making process when developing the abandonment programme.

UK regulations on the abandonment of wells are goal setting, and not prescriptive. This therefore permits the acceptance of alternative abandonment designs and barrier materials, which depart from current industry good practice for permanent well abandonment provided the risks are demonstrated to be acceptable. The regulations state that, so far as is reasonably practical, that the risk of a leak to from the reservoir should be zero. This essentially means that an abandonment design that differs from current good practice (which is assumed to be ALARP), requires the demonstration of being ALARP, essentially implying that any further action to reduce the risk will be disproportionately costly compared to the potential risk reduction gained. The ALARP principal has historically been applied for the assessment of health and safety risks and its application to well decommissioning still requires guidance.

Furthermore, UK regulations also imply that the liabilities for a well remain in perpetuity. Therefore, should an integrity issue arise for an abandoned well at a future date, there may be a liability for the previous well owner to address this. Fortunately, in the decades since wells have been abandoned in the UKNS, there have been no such incidents yet, and therefore no precedent set for how the regulator may respond in such an event.

In the unlikely event that any remedial action is needed, it is likely to be assessed using the ALARP principal, with a particular focus on safety during any proposed intervention and remedial operations. There should be no doubt that it is in the interest of all stakeholders for any change in guidance to maintain the current level of abandonment barrier integrity whilst enabling use of more cost-effective technologies.

A robust risk-based decision making framework is needed to support the latest available technological innovations and solutions to enable this to be achieved while still ensuring that industry good practice represents the lowest risk and cost options. Such a framework, along with good practice guidance, is not currently available, however a number of industry organizations are considering it to various extents. The current landscape facing plugging technologies developers is therefore fraught with difficulties, and in particular a lack of clear and appropriate guidance and alignment between all stakeholders.

It is therefore essential that, as the UK North Sea works towards achieving the decommissioning goals set out by the OGA, and aims to establish itself as world leaders in decommissioning, that the appropriate mechanisms are put in place to drive technology innovation and deployment to enable better, more efficient and cost effective solutions to mammoth task ahead. This, as indicated by the OGA, is underpinned by 'appropriate regulatory processes and clear guidance', which will support both technology innovation and good practice.

The need for this is immediate and the opportunities are great if an environment is created which encourages operators to support and deploy technologies within an appropriate risk managed framework.

Dynamic materiality: Assimilating intrinsic value

Welcome to the London Sections' Net Zero Committee section of the SPE Review London where we will present and discuss a range of topics associated with Energy Transition and Net Zero. We hope these articles will be informative and help readers understand some of the significant changes in the oil and gas industry.

This is the fifth in a series of articles for the SPE Review covering Sustainability, brought to you by Adrian Gregory who is a subsurface and wells engineering consultant. Adrian is excited to be part of and contributing to the new London SPE Net Zero Committee and will be writing future briefing articles broadly focusing on sustainability strategy, frameworks, principles, delivery and performance.

This article will be covering integrated thinking about 'value', Enterprise Value and more specifically on the 'power engine' & 'stock' of Sustainability Value – building on the outcomes from some thirty years of Environmental Stewardship and Ecosystem integrated thinking. 'With & Marked', 'Material Circularity' and 'Stewardship' will be covered – with the Tragedy of Horizon needing 'front-end' loading if climate Physical Risk and Transition Risk are to be abated.

For those readers who want a 22-second outtake:
"*Intrinsic Value is the kinetic and potential energy, the total energy behind the power house of Business Sustainability. Intrinsic Value is accessed, assimilated, assembled and activated or actioned now or tomorrow through future generations - the 'intrinsic' umbrella that covers Sustainable Commerce. Current day 'Non-Use' stock, not currently traded in the market place, still needs to be valued to understand 'Total Value' and the business worth and value to Society. Materiality of firms' change over time, particularly 'with' natural resource companies which can have significant associated circular, dynamic materiality cycles – through replenishment of production of reserves, requiring new resource discovery and regeneration going forward. 'With', the bedrock 'Resource & Relationships', is core to delivering a better future – performance & progression 'marked' by Societal Scrutiny. Over time, more and more Sustainability concerns are becoming relevant to current Enterprise Value – affecting valuations today thereby amplifying dynamic materiality.*"

The last article on Business Sustainability highlighted the 'primacies of the enterprise', **Value Creation** and now due to producing at Environmental Limits, the need for a **Social Oriented Business Purpose**, operating or at least 'marked' by **Societal Scrutiny**. For Business Sustainability, the **Sustainability Value (SV)** is simply the other part of ecological integrated thinking's **Total Value (TV)**; SV is the additional value not currently valued in 'The Market' after enterprise current market value, **Enterprise Value (EV)**, has been evaluated, assessed based on 'The Market's' current assumptions of boundary limits and conditions. So **Total Value** for Business Sustainability is made up of the sum of Enterprise Value & Sustainability Value.

Technical Sustainability perspective pillar opportunity (Figure 1, Article 3) is predominantly derived through Business Sustainability, commerce technical enterprise, so the main focus of this article will be on this Technical Pillar. Total Value means Technical Sustainability has to be DNA core of the Total Value 'Umbrella' of the whole enterprise – not just a subset of Safety & Environmental technical activities as in some corporations and institutions; **Sustainability, Stewardship and Succession**.

The 'Principles of Sustainability' is about 'valuing everything', not just the price (worth) of everything. The 'value of enterprise', **Enterprise Value** is the measure of value 'In-Use'[1] of the associated economical contributions performed in 'The Market' – valued as the current (enterprise) market value as part of the enterprise's **Intrinsic Value**. Other enterprise associated 'stock' which is not currently in 'The Market' will have a 'Non-Use' value with associated **Existence Value** and **Future Value** – for use to contribute tomorrow or even over the next or future generations. Both Enterprise Value and Sustainability Value contribute to the **Total Value** – the 'Total Intrinsic Value', the sum of **Governance Value (GaV)** & **Governess Value (GeV)**.

Dynamic materiality: Assimilating intrinsic value... continued

Sustainability Value, exercised through Business Sustainability, is why Sustainability as a business practice is much more relevant to **Prosperity** than Sustainable Development. IOR proved this in the mid-1990s with massive contribution to Planet Oil, built from Existence Value – nearly thirty years ago now.

Governance Value is the **Full Value** of the enterprise – taking into account the full value potential of assets-of-value (**Real Assets**) which the enterprise has in its portfolio as well as its strategic future opportunities to become in-use, in 'The Market'. So why is this Governance Value? Governance is the organisational benefit of the enterprise being worth or valued more than just the sum of its parts – its full collective benefit. Governance is the 'task' concerned with setting goals, the direction to be taken to achieve these goals; its roles and responsibilities of functionaries; what an organisation must do and what it should become in the future; the 'concern' of governance ensuring compliance with the rules and regulations and making necessary changes in 'command & control' policies to avoid conflicts inside and outside the organisational 'production' boundary. Typically in Business Sustainability three main area of governance exist: Project, business & corporate.

What the reference article[1] on **Value** did not stress, probably not important enough then some 140 years ago, was there is 'value-in-use' plus **value-of-use** – embedded in all **Real Assets**. Real Assets deliver excess economic rent and are impactful to own. Most projects have a 'singularity' theme, the best however, have embedded 'portfolio of projects' which typically means these Real Assets go on to become **Legacy Assets**. In 1990, this became very evident at Wytch Farm Oil Field when the Frome Clay was discovered with commercial reserves. Value-of-Use1+. Having contributed to the acidisation job, bp found the initial post acidisation well testing rates to be excellent! Who would have thought ancient oyster beds would be so productive a hydrocarbon reservoir – turned out very few before hindsight. Then six months later we introduced Extended Reach Drilling ('ERD') technology through ARCO California's technical knowhow; resulting in the Island Bill being abandoned and the offshore reserves drained from an existing onshore well-site. Value-of-Use2+. Wytch Farm just kept on giving more and more **Value Creation** ('**portfolio of projects**') becoming a **Legacy Asset** and is still producing well some 30 years later.

Value-of-use was immortalised in the film Apollo 13, 1995. No one should be allowed into governance without having watched this film! All the main governance, management and worker characters had their bit parts in this classic film. The (project) director's immortal words: "People, not what it was designed to do – what can it do!"; classic square peg – round hole syndrome; etc, etc. NASA's organisational most important achievement – getting their astronauts home, alive. 'But we thought the project was just to go to the moon'.

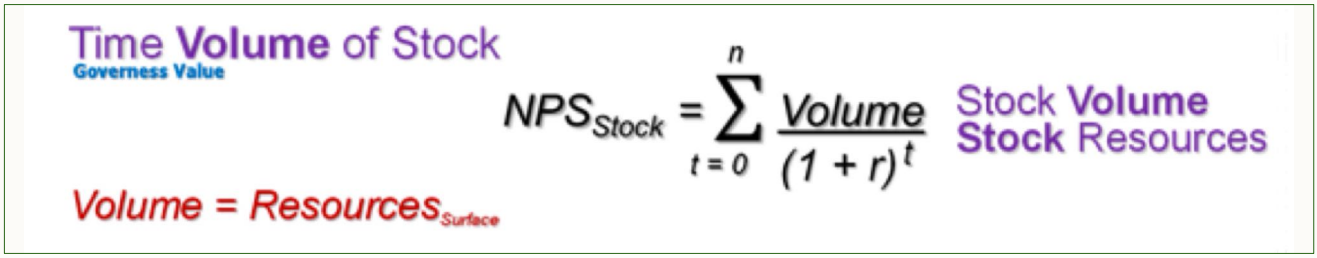
Edwin Dolan classical book TANSTAAFL[2] nicely discusses how 'everything of value' has a cost. There is an **opportunity** cost – the idea that whatever you chose to do has a cost that is measured in terms of the other things (or activities) you could have done instead with the same time, energy and resources; work done. Societal License to Operate (SL2O) is best when the local communities and society-at-large have empathy or at least endure such operations, ensuring better choices and Environmental Limits are taken into account – resulting in at least an informed decision making processes, to get through stakeholder and **Societal Scrutiny**; and Political Governance.

Sustainability Value has two core parts. The 'full on' power house engine of Value Creation of 'all things' valued in 'The Market' – primacy 201. PLUS, all **Governess Value** (sum of **Existence Value (ExV)** & **Future Value (FeV)**) 'with' due regard for all of 'The Commons' & 'Global Cover' driving Custodianship & Guardianship practices; 'marked' by Societal Scrutiny through 'Standards of Performance' based on SLO (Stakeholder or Social), or SL2O modus operandi; primacy 301, Social Oriented Business Purpose. The four **Core Practices of Sustainability** ('Sustainability Practices') being the means to achieve **True Sustainability**; 'the well' that keeps on giving – through natural & technical succession & 'spark' of entrepreneurialism (Goddess Gaia & Goddess Nigella!); Sustainability as reported in annual Sustainability Reports. The current **Enterprise Value** covers primacy 101; **Corporate Finance** as reported in annual Financial Reports. If your employer has not totally embraced Sustainability, you may find that is why it's **Worth** (to Consumers Customers Clients) or **Value** is on decline.

Dynamic materiality: Assimilating intrinsic value... continued

Political Sustainability & Financial Sustainability, the other perspective pillar opportunities (Figure 1, Article 3), are simply the Total (Intrinsic) Value of these Institutions based on 'The Market's' in-use & value-of-use valuation; and non-use 'stock' value – not valued in 'The Market'. These will be considered in separate articles.

'Non-Use' **stock value**, a massive part of **Governess Value**, has emerged in 2021 thanks primarily to the excellent Partha Dasgupta Report[3]. How this report will be taken forward is currently under the governance of the UK Bank of England. Putting a 'price' on Nature & Biodiversity will then result in better or at least more informed decisions. But, we have been doing this for Speculative Resources since the conception of IOR back in 1992(4). For **Governance Value**, for valuations we use the 'time value of money', Present Value ('PV') or Net Present Value ('NPV') equation; discounting the benefits & costs by a discount factor which is typically set at 10% as exampled by the UK Oil & Gas Authority (OGA). For **Governess Value**, for **Stock**[4] valuations particularly in screening & scoping studies, the 'time value of stock' ('NPS'); **Equation 1** is used. Enterprise will also carry out their internal NPV valuation, so by dividing the resultant NPV by NPS – the resulting **Guide Price** (Social Price) is an excellent guide to be used for Societal Scrutiny as long as the Full Costs have been used in the NPV valuation. Guide Price for **Prospective Resource & Speculative Resource** projects of about $10/BOE clearly shows based on 'Full Costing' that associated projects benefit society as well as enterprise. Positive 'Guide Prices' fully support moving subsurface projects (**The Hidden Commons**) through the Stage Gate Process, from **Contingent Resource to Reserves-Under-Development**. Using NPS for IOR project appraisal means different IOR Techniques can be compared, with different Guide Prices helping with resource allocation & management. With **Value**, particularly assimilating Intrinsic Value, 'Capital' results; **Capitals Stock**. This Capitals Stock can then be used to engineer & build ('E&B') a better future, guided by the science. Enterprise Value &



Equation 1: Net Present Stock (NPS)

Sustainability Value assimilation requires working with **Governess Value** as well as **Governance Value**, as discussed in previous Articles in this Sustainability Series, to maximise E&B. To achieve the 'primacies of enterprise' therefore needs 'with' (Resource & Relationships) to be firmly integrated into the thinking of the classical enterprise 'Why-What-How' framework; baring in-mind that Society will be 'marking' the 'papers' (ie Annual & Strategic Corporate Reports). **Technical Sustainability** framework is **Why-What-How-With-Marked**.

Understanding the Governess Value – Existence Value & Future Value, means associated surface **Resources** and **Capitals Stock** need full assessment and should be reported in some manner in annual corporate Sustainability Reporting. Annual Financial Reporting is about Governance Value and (Corporate) Financial Performance; annual Sustainability Reporting should be about Governess Value, Sustainability Performance: Impacts and Effects – built around **Dynamic Materiality**. Relationships with **Stakeholders** and formalised **Partnerships** are key to Sustainability being considered overarching – capstones and keystones, to the governance and governess activities of full **Stewardship** (Business-Technical-Resource-Product). Whereas IOR was built on R&5Ds; Business Sustainability is built on **V&5Cs** (Value & Capitals, Connections, Cooperation, Collaboration, and Co-organisation). Capitals Stock is the topic of the next Article; Valuing Everything.

Before we think about Technical Sustainability: Value Creation, Value evaluation and assessments; we need to address Sustainable Value notion-ality – for transparency and clarity. **Sustainable Value** of a commercial enterprise basically is how long can the EV be continued being positive for; sustained before the enterprise is 'not viable' commercially? It is therefore actually a 'question' that needs answering! **Sustainable Development** or **Sustainable Commerce** have the exact same issues. That is the same question. SV, i.e. the

Dynamic materiality: Assimilating intrinsic value... continued

value of Sustainability, is simply the second term in the TV equation (= EV + SV). So when does an enterprise become 'not viable'? At that point in time, 'The Market' will evaluate any **Governance Value (GaV)** as zero, but most likely negative. The only SV left is therefore just **Governess Value (GeV)**, its **Residual Value**, its remaining Inherent Value. More often than not, this residual value gets exploited by new owners; hopefully with better & more stewardship applied.

Sustainable Value? therefore is a question needs answering. As does Sustainable Development? & Sustainable Commerce? Like S**ustainability Strategy**, that question is answered best by answering other questions; set in a defined context (boundary conditions). The relevant questions around Sustainable Value, Exploration, Development, Production, Commerce being all around: Relevance, Ownership, Morals, Ethics, Equity, Justice, Realignment of and Redistribution of Opportunities & Wealth, Capitals Stock; a thick soup of often bubbling Triple Bottom Line (TBL) 'magma'.

For an enterprise having, or deemed to have Sustainable Value, **Stewardship** (First Core Practice of Sustainability) of those assets; being Good Stewards now and going forward is paramount. In fact, if a firm can be deemed **Best Steward** by 'Society at large', this is the best reputational 'Brand Value' that the company can have. To be awarded 'Best Steward', society must recognise it cannot perform these activities and actually it is in their best interest that that enterprise does. That enterprise therefore has tremendous **Brand Loyalty** as was proved by Cadbury's in 2010. 'Society-at-large' – consumers, did not want "their" chocolate to taste different. Quite Right! It became a national issue when US-based Kraft took-over the original company. So the "Sustainable Value?" question has to be answered and can have considerable elements of individual or collective Values effecting its Value; Values of Value(s)[5].

The value of Sustainability is simply, but not simple, an intrinsic part of evaluating the **Total Value** of the enterprise's Intrinsic Value. Ethics, morals, personal ideology, 'doing good' can be put back into the Business & Societal 'magma soup' debating being sustainable – an ancient, ongoing matter between business and society. Sustainability is an evaluation, assessment based around **Materiality (Value, Impact and Effects)**, **Priorities** and **Action (Mitigation) Plan(s)**. Technical Sustainability is about Doing Right, Doing the Right Things, and Doing Things Right; Why-What-How-With-Marked by Societal Scrutiny and enacting the four core **Sustainability Practices**. **Due Diligence** governance audits and **Technical Competence** mastery audits are already on the horizon.

So how should society 'mark' commerce & enterprise? Society looks to **Total Value** and the **Environs Capitals**, to be discussed more in the next Article. Societal Scrutiny introduces the concept of **Citizen Power** over the establishment, particularly over Political Governance. Markets actually function effectively, efficiently based on how we organize institutions – market outcomes from collective actors. The concept of the **Capitalist Society** being made up of Citizen Investors[3] is new – very similar to 'The (Capitalist) Market' having Market Investors. Market Investors are driven by **Market Price**; Citizen Investors are driven by **Social Price**. Market Investors invest if they assess Enterprise Value will move more towards its associated full (market) value (Governance Value). The current Market Price (Enterprise Value) being their guide. So too can Citizen Investors 'invest' based on Total Value, and the associated current **Social Value**. The current **Social Price** being their guide.

Clearly, when the **Social Cost** paid by society (and its citizens) is greater than the Market Price paid by commerce, Societal Scrutiny currently kicks-in. For Biodiversity there are two good examples of this, clubbing seal pups to death and killing whales in International Waters. Both activities, based on Societal Scrutiny were abandoned. For Natural Resources, the UK Bowland Shale exploitation activities also came to a halt; local community and society-at-large Societal Scrutiny driving that agenda. Like having a Social Oriented Business Purpose, to some this is all very embryonic. The next generation, however, will decide whether 'wider choices' need to be made with current humanity having the best of times; and current nature & biodiversity having the worst of times[3].

Dynamic materiality: Assimilating intrinsic value... continued

Natural Capital again will be discussed more in the next Article, but, **Natural Ecosystem Services** (clean air, fresh water, fertile soil, food, stable climate or disease control, etc) & **Natural Resources** (timber, oil & gas, coal, minerals & metals, etc.) have important current 'Flow(s)' – therefore Value element. **Nature Capital** has these two subset 'Stocks' – *Nature Stock & Natural Resource Stock*. Most Nature Stock is however regenerative & mobile on an annual basis; bit like Nature Accounts – like Financial Accounts. Natural **Total Stock** for oil & gas being currently renewed by making more discoveries or proving commerciality through appraisal (New Resources – Speculative Resource [Linkedin 2017]) or improving recovery (IOR) in producing fields (screening & scoping studies [SPE Review May 2007]).

Firstly as Lovelock[6] wrote, waste products are returned to the natural environment which nature has to clean up; currently beyond its capacity (environmental) limits. Commerce is actually embedded in and dependent on nature, even though from the 'factory area' or 'production boundary' this is hard to see. But secondly, the wealth from Natural Capital during the Industrial Revolution has been expensed through new 'flows' to create other **Environs Capitals**; assimilating **Intrinsic Value** which are not regenerative; hence eroding more Value when viewed from the 'total system' perspective; particularly complex biodiversity & habitat loss for resource gain. The **Anthropocene** being so called because humanity has changed the surface geodiversity so much – society has noticed. So a new type of **Portfolio Analysis of Assets** has been suggested to help guide 'Full Value' (Governance Value) and 'Total Value' (Governance Value & Governess Value); improving guides like Market Price and Social Price.

Intrinsic Value is the value that resides within the product, asset or resource which is more than just a 'quality' or 'feature' as it is valued, independent from market circumstances. Value[1] based on utility has to satisfy a desire or serve a purpose. This intrinsic value is the key attribute/characteristic that determines whether value analysis needs to be assessed or evaluated based on 'use value', 'value-of-use' or 'non-use value'. In Sustainability, it is important to ascertain whether that use value or value-of-use is captured organisationally hence needing associated governance & management; or existing non-use with opportunities for capture and even appropriation in the future - potentially passing on to the next or future generations. This latter non-use case indicates a perception of benefit from the knowledge that these assets, resources and opportunities exist or are being passed onto descendants; such as a rain-forest or coral sea. To value based on the 'cost-of-loss' of such natural assets is clearly a poor indication of Total Values.

Governess Value has two main distinctions based around a product, asset or resource 'stock' – their 'current' and 'future' status. **Existence Value** is very much current stock, ie value from simply knowing that these products, assets or the resource (e.g. natural resource; biodiversity or ecosystem services) exist today which add to at least a general well-being; and **Bequest Value**, **Option Value** and **Altruistic Value** are much more about *future stock*. The former existence stock is more unusual and can be deemed controversial when related to a particular resource such as an environmental (e.g. Antarctica, the Grand Canyon, endangered biodiversity, species or landscapes) asset that currently exists. The latter indicates a perception of benefit from the knowledge that these assets, resources and opportunities are being exploited or passed onto descendants or others in the *future*, but currently are not discovered.

Non-use Governess Value is very subjective with often very little recourse to efficient marketplace valuation – often resulting in use of **auction-style process** valuation instead. The motive for an auction is to call for the highest price for a product, asset or resource. It is said to be successful when achieving the highest price but this process is often far from ideal in practice. There are three main non-use values: Bequest Value, Option Value and Altruistic Values. **Bequest Value** is value placed on an individual willingness to pay for maintaining or preserving an asset or resource that is not in-use now, but could be available for future use. **Option Value** is the value placed on individual willingness to pay for maintaining an asset or resource even if there is little likelihood of that individual actually ever using it, because of uncertainty about future supply (i.e. the continued existence of that asset or resource) and potential future demand (ie the possibility that asset or resource may someday be used). **Altruistic Value** is the value placed on usually individual willingness to pay for maintaining an asset or resource that is not used by that individual, so that others may make use of it

Dynamic materiality: Assimilating intrinsic value... continued

instead. Its value arises from others' use of the associated stock. This value has been conceptualised as part of a personal guiding principle that motivates some, usually high net worth, individuals to make a meaningful contribution to the wellbeing of others or of society as a whole.

Governess Value is an extremely important part of valuing a resource especially from the Sustainability point of view because it contain the notion of preserving the freedom of choice for the next and future generations. Each non-use value element has a varying level of concreteness ('tangibility').

How can we more purposely conduct social oriented business to 'make' (build) the future rather than 'take' the future from the next and future generations? Existence Value and Future Value such as Bequest Value of natural resources needs valuing; in combination with 'full' costings of systems, processes and practices such that exploitation (wells) or extraction (mines) is not at the expense of others. The concept of **Guide Pricing** is the best solution sitting on the fence currently. We need to also consider the flow of Wealth: **Six Capitals** Stock Model too, the topic of the next article.

The **Full (Market) Value** from achieving Sustainability through accessing and assimilating associated I**ntrinsic Value**,'organisational Total Value', is why **Sustainability Practices** should sit above all enterprise activities, actions and non-actions. Enterprise Value is the current measure of 'use value' – the measure of the associated economical contributions performed, valued because of the enterprise's current intrinsic value. Value-of-Use embedded projects in **Real Assets** need to be fully exercised and not lost through enterprise notions of 'singularity' of project deliverability. Other 'stocks' having a 'non-use' value can contribute to tomorrow; even next or future generations. **Sustainability Value**, benefiting through enduring Intrinsic Value now and in the future, is built around primarily exercising 'real assets' Existence Value; and additionally Future Value, both 'use' and 'non-use'. All these values need valuations to understand the 'Total Value' or total worth to enterprise & society. Just because some current enterprise stock is not in 'The Market' but can outlive the current owners, does not mean that 'stock' has no societal value or worth. Some natural ecosystem services which have a 'use' value, but, because of the **Tragedy of the Commons** are undervalued leading to ongoing habitat and biodiversity loss, require now **Planetary Boundaries** and their **Frontiers** to be protected – even effectively separated from our **Urban World** and the *Natural World*, through future **Guardianship** practice.

Subsurface Exploration is about Future Value. Pure Exploration companies still have Enterprise Value. They have an Opportunity Value "have to be in it, to win it". As long as the enterprise can fund the exploration; a function of how good they market their 'concept product' – their drill ready exploration prospect (**Prospective Resource)**. The bedrock of Future Value depends on the assumption of **opportunity** and its associated risk (ie Expected Monetary Value (EMV) theory) plus a lot of serendipity in classical 'wildcat' prospects, in particular. The value-of-use from real 'exploration acreage' assets shows very clearly that **Portfolio Exploration Prospects** will still be monetarized in Guyana, Eastern Mediterranean and Middle East, with or without full costing or Guide Pricing.

Humanity always over estimates the upside and underestimates the downside – that's life; back to Tragedy of the Horizon plus Tragedy of Outcomes[7] as mentioned in previous Articles. 'Tragedy of Exploration' and 'Tragedy of Appraisal' of tight rock resource plays, is that there are four possible outcomes – No Flow, Low Flow, Economic Flow and Commercial Flow(7). Only the later adds to full Enterprise Value. Economic Flow can result in the asset being stuck in the **Contingent Resource** category for years and years – such as Jackdaw UHPHT & Puffin HPHT fields in the UKCS. A **Contingent Resource** means that governance costs can be significant, creating large sunk costs, even a billion dollars or more for some assets. Governess resources such as Speculative, Prospective & Speculative Prospective can be parked or worked as needed - awaiting the Goddess Nigella to add that 'spark' for them to emerge from the 'cauldron' adding to new Enterprise Value, moving from Governess Value to Governance Value.
Annual Financial Reporting is well understood and drilled – built around global 'Standards of Financial Accounting' and protocols; and national Corporate Governance 'codes of conduit'. Annual Financial Reporting

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is built around the Enterprise Value creation activities and the created or captured values in the form of financial wealth creation. Creating value and created value is the 'cross' companies must bear as they make their way up the 'hill' towards 'redemption' through wealth stock assimilation – needing collective Human Capital to carry that 'cross' along the chosen pathway. For natural resource companies, **Reserves and Contingent Resources** are well documented in strategic reports giving access to valuations supporting **Enterprise (Governance) Value**.

Annual Sustainability Reporting covering 'materiality of activities' and 'Environmental Social Governance' metrics and performance are still evolving - particularly needing a global 'Standards of Financial Sustainability' to provide clear, binding, procedures on past, current and forward Sustainability data, assessment, response (through action plans) & disclosure. Current Sustainability Reporting seems to only concentrate on past performance data through the 'eyes' of Corporate Governance, and, surprisingly not current and forward data – particularly related to next and future generations, through the additional 'eyes' of Governess.

Governess Value reporting of Existence Value (ie Speculative Resource) or Future Value (ie Prospective Resource and Speculative Prospective Resource) seems absent by comparison in Sustainability Reporting [Figure 1, Figure 2]. Why? Is not the next and future generations not a core principle of Sustainability? Why is current Sustainability Reporting not reporting **Value** as much as **Impacts & Effects**; just **Performance** based on monitoring 'elements' deemed 'material'. Should not there be more specific insights and expectations of company's **Speculative Prospective Resources** (plays & leads), **Prospective Resources** (drill ready prospects) & **Speculative Resources** (discovered resource, undergoing delineation or economic evaluation) – an important part of the annual 'stock-take' where existent and future value reside -- the long term intrinsic value of hydrocarbon provinces; the resource for future enterprise and value creation, capture and appropriation?

"Embedding Sustainability throughout the organisation" has been another prominent perspective considered to be of key importance for integrating Sustainability into business. Authors who assume this perspective, argue that simple bolt-on Sustainability will not suffice to effectively manage the Sustainability risks and opportunities for a company. Yet Sustainability is intrinsic to Governance & Value Creation – organisationally. Business will need to embed Sustainability throughout the organisation, including strategies and operations, governance and management processes, organisational structures and culture, as well as auditing and reporting systems.

Natural Resource Wells & Mining companies [Figure 2] have material 'circularity', **Circular Materiality Cycles**; **Dynamic Materiality** where Sustainability concerns increasingly impinge on enterprise current and future activities, and value – even longer term relevance. Discovered resources are developed and produced. Reserves produced have to be replaced – renewed, material circularity, leading to more exploration and appraisal, hence Circular Materiality Cycles endure without Environmental Limits or loss of Resource Relevance. Resource companies Sustainability Reporting should cover Circular Materiality Cycles and Dynamic Materiality of their resource; the Total Intrinsic Value of the Resource which the enterprise is trying to access, assimilate, assemble and activate or action now and in the future; and transparent clear reporting of historical, current and forward Environmental Social Governance data.

Environmental & ecology thinking - sucession & stewardship

The core strength of our **Urban World** is its diversity – adapted to local landscapes and climates. The same is true for the **Natural World** and the Living Commons but they do not fall comfortably under the Corporate Social Responsibility ('CSR') 'highway' – not being part of our society, our stakeholders or having rights as part of our development operations. The Living Commons used to represent some 62% of the planet in 1960, now only some 35% in 2020 according to Sir Richard Attenborough[8].

What is certain is that good practice CSR does effect the bottom line positively. However, due to **Succession**, additional themes and activities are not required as **Visible Hands** in the marketplace are now active; some

Dynamic materiality: Assimilating intrinsic value... continued

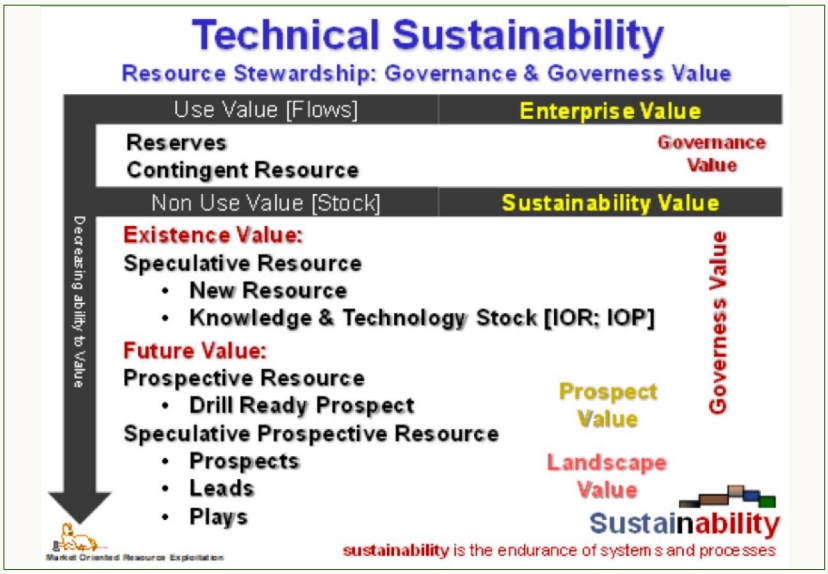

Figure 1

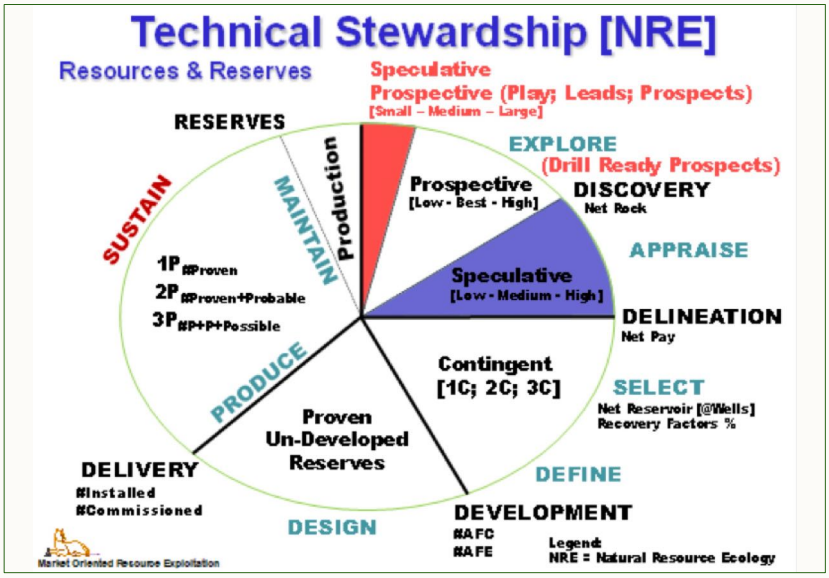

Figure 2

proactively. This context to some means that competitive advantage, not just comparative advantage can be gained by embracing this additionality – typically linked with economic externalities. **Capitalist Society** can get involved through philanthropy or simply paying taxes, but, issues like Net Zero are about decarbonisation of all industries, agriculture and energy provision. Relevant, responsible investments and governmental policies dictates how fast Net Zero is achieved; and its Net Pace. Supply of new products will deliver new demand through new behaviours. Because the 'Invisible Hands' are not delivering these new products fast enough, 'Visible Hands' are now appearing everywhere which means a 'just transition' honouring Social Responsibilities, may not be a 'smooth transition' for some suppliers and more niche markets without transferable competencies & skills.

One way to look at CSR and its bit part today in the role of 'business-in-society' is to consider it as highlighting the organisational activities consciously responsible for its actions, non-action effects and their impact of these on its stakeholders. Now through certain industrial sectors required to satisfy SLO, more is now needed if a smooth transition and continued access to Social Capital is core to their activities commercially functioning. It is important to remember CSR roots started in the 1950s, its Sustainability is proven by its bit part relevance still today. Simply respecting natural environments through **Environmental Stewardship** satisfying the wishes to stakeholders is one core area where SL2O differs by an ever enlarging space. Caring for, even not harming, the Living Commons and protecting Planetary Boundaries are spaces now being filled by **Custodianship** and ultimately **Guardianship** – through the succession of Citizenship. **Custodianship** is introducing 'no harm' & 'no trace' work practices linked more too environmental or societal footprints, rather than environmental stewardship of enterprise 'individual' footprint. At scale, environmental & societal footprints require companies to collaborate and build new partnerships to insure collective action; delivering caring and responsible co-benefits.

Stewardship of natural resources has always been present but sidelined through the age of exploitation. Stewardship too is front and center today – for resources, products; technical & business. Soon Nature, Habitat & Biodiversity Stewardship will be present once an acceptable means to value their non-use stock.

Dynamic materiality: Assimilating intrinsic value... continued

Responsible Business Models have not delivered fast enough; the **Visible Hands** are ensuring the pace is picked up as issues of resiliency are being added. The slower the pace of relevant, responsible investments – the larger the Manufactured Capital stranded resources and ultimately stranded assets will be. The new frameworks we adopt for being a responsible business, in each business sector, have now moved beyond philanthropy and simply paying taxes, to be an integral part of the core business strategy & models, and Sustainability Practices – requiring integrated thinking, enacted through TBL.

Socially responsible company's encompasses the economic, legal, ethical and discretionary expectations that society has of organisations working in their communities – at a given point of time; widening the boundaries of corporate responsibilities. This requires companies to implement fair wage policies, uphold human rights, fair trade and ethical issues; produce safe products and cooperate in the network of companies and communities. These impinge on aspects of Human Capital too. Responsible companies and governments will have a strong role in repairing environmental damage caused by any irresponsible use of their natural resources; that is also good for businesses – limitations, balance – not a trade-off between the TBL dimensions. 'Valuing Everything': **Financial Capital**, **Manufactured Capital**, **Social Capital**, **Human Capital** and **Natural Capital**; everything having a positive dividend contribution to the TBL. If that is achieved, companies will also benefit from **Reputational (Brand) Capital**. Improving the prosperity, quality of life and wellbeing of citizens all through integrated commerce.

What are our obligation to preserve Habitats, Biodiversity for those who will come after; governess. Ecologists have long recognized that Nature is an asset that provides a 'flow' of goods and services over time and that's termed 'ecosystem services' whether it's clean air fresh, water, fertile soil stable climate or disease control -- we depend on these services for virtually every economic activity. For example, the services provided by pollinators such as bees and moss their services to global agriculture have been conservatively valued at more than $200 billion annually – this is a measure of use value – the measure of worth based on the contribution of nature or an element of nature to economic activity. But bees and other parts of Nature have a non-use value. We treasure their very existence and they have a Bequest Value as natural heritage to be enjoyed by future generations. The risk is that too often today Market Value is taken to represent Total Value – value has become wholly subjective, it's in the eye of the beholder and if a good or activity is not in the market – it's not valued".[9]

As Hart[10] wrote in 1997 in his seminal 'Beyond Greening' article:

> "The environmental revolution was almost three decades in the making, and it has changed forever how companies do business. The 1960's and 1970's, corporations were in a state of denial regarding their impact on the environment.
> ... "Many companies have accepted their responsibility to do no harm to the environment. Products and production processes are becoming cleaner; and where such change is under way, the environment is on the mend. In the industrialized nations, more and more companies are "going green" as they realize that they can reduce pollution and increase profits simultaneously.
> ... "But the distance we've traveled will seem small when, in 30 years, we look back at the 1990s. Beyond greening lies an enormous challenge – and an enormous opportunity."

Looking back now we have benefitted from revenue growth from that Environmental 'Revolution' thinking through Product Stewardship, Eco-Efficiency and considering Life Cycles & Design of both surface Resources & market Products. Ecological footprints are now center stage with GHG emissions. 'Greening' today is very much framed through Sustainability Strategy, Technical Demonstration & Development [R&5Ds] and Value Creation, particularly through Value-of-Use – **Asset Governance**; then on to True Sustainability. With revenue & economic growth, the urbanisation of our Planet has resulted in our **Urban World**; the Anthropocene era. The **Total Environmental Burden** was expressed in terms of Population, Affluence (Consumption) and Technology. Others have recast this in terms of **Total Environmental Impact** as a function of Population,

Dynamic materiality: Assimilating intrinsic value... continued

Affluence (through increase Life Expectancy), with denominators of 'Technology of the Future' and 'Happiness', sacrificing material goods in place of basic human needs as a society. Thirty years on, humanity needs to go with what we have developed now! We can continue to innovate through our 'culture of ingenuity'.

Product Stewardship, focuses on minimising not only pollution from manufacturing but also all environmental impacts associated with the full life cycle of a product, or resource. This can lead to fundamental changes in the underlying product and process design. 'Properly executed, Product Stewardship also offers the potential for revenue growth through product differentiation'. **Eco-efficiency** creates economic value while continuously reducing ecological impact and the use of resources, improving resource productivity – ways of doing 'more-for-less' with environmental responsibility. We have made good inroads into pollution prevention and reducing product footprints. The TBL dimensions have helped to drive design and thereby incorporation of eco-efficiency into selected value chains – thereby enhancing them further. Enhance productivity enables cost reduction priorities to be delivered, maximising medium or near term business profitability but creating a lot more new value from investor sourced **Financial Capital**. Considering **Life Cycles & Design** does come naturally to engineers [Figure 2]. Improved recovery (IOR) is full on bespoke design; and 'design for prevention' should actually contribute as much in the future as the more 'circular economy' tool boxes. Re-purposing is simply a sub-set of Value-for-Use.

Porter & Linde[11], wrote 'the need for regulation to protect the environment gets widespread but grudging acceptance: widespread because everyone wants a livable planet, grudging because of the lingering belief that environmental regulations erode competitiveness.' Strict **Environmental Standards** actually in the long run make companies more competitive – building bridges with society and local communities bring additional benefits. Commerce private costs for adoption of best practice and prevention most often actually reduce any activity, action or non-action cleanup costs plus more often helps demonstrate competence of their associated operations; creating **Reputational Capital**. 'Operating at the expense of others' [Dolan[2]] is not a unique selling point; zero harm, zero trace is. The TBL dimensions are not for trading-off. Valuing everything delivers more **Capitals Stock**, the topic of the next article. As materiality is dynamic, so are competencies & skill through **Succession**. The 'culture of ingenuity' with properly designed Environmental Standards trigger innovations that lower the total cost of products or improve value. 'Such innovations allow companies to use a range of inputs more productively, from raw materials to energy to labour, thus offsetting the costs of improving environmental impact and ending the stalemate. Ultimately, this enhanced **resource productivity** makes companies more competitive, not less'.

The **Tragedy of Outcomes**[7] is that even if we have a model or proposed model we still need an experiment to validate that model; process or system. Due to sampling biases often experiments get repeated again and again. In commerce, there are four generic types of outcome categories: Commercial, economic, uneconomic and deemed technical failure – making experiments necessary, but, we risk getting the same commerce outcome category again; more often than one would think!

With complexity, often model inputs chosen do not reflect actual outcomes. In subsurface models often effective permeability and fluid saturation are found to be more complex than initially thought. Hence the need to history match dynamic subsurface models. With complex problems we cannot guarantee a solution when applying the same level of thinking that created them. 'Simple' System Thinking assumes that systems can be broken down into independent acting parts, providing a fast solution, which can often breakdown relatively rapidly – even with history matching. 'Complex' System Thinking assumes that systems react based on collective characteristics, dependently acting parts, providing a solution over time dependent on reacting to tipping points which arise over time. Complex Systems often require operating under a 'simple rules' approach – not simpler.

In major risks such as with Climate Change, the level of 'Emergency' can be related to 'Risk' multiplied by 'Urgency'; the time required to solve the problem divided by the intervention time available. Climate Change

Dynamic materiality: Assimilating intrinsic value... continued

is certainly complex. With complexity, the simple rules applied ("it's so complex – it's simple") also need a 'step-back' to be taken before considering implementing 'planning to operational enactment'. Urgency is certainly now key as the Tragedy of the Horizon so far has come true – we are **not moving** fast enough. Tragedy of the Horizon is created by responding using back-end loading rather than **front-end loading** solutions.

For Climate Change, there are two simple rules which should be applied to reduce absolute GHG emissions to Net Zero over the next thirty years. Simply dividing this time frame into two halves reducing GHG emissions by ~60% (2035) then the necessary remaining ~40% (2050); or considering 3 equal ten year periods reducing absolute GHG emissions by ~50% each period – i.e. halve, halve and halve again, tailored to end at Net Zero (2050). Benefits of front rather than back-end loading are well presented, espoused when addressing cumulative Stock issues such as achieving remaining global Carbon Budgets. These two simple rules would provide a simple operating window to guide commerce to achieving their Net Zero outcomes, even accelerate them. Operating a time dependent solution – reacting to tipping points when they arise over time is the only guaranteed operating procedure reacting to the Tragedy of Outcomes. Understanding the Tragedy of the Horizon at least provided the simple rules to operate going forward.

Business Sustainability is today now full-on focused and driven by Dynamic Materiality, Value Creation and Stock Governance & Governess; assimilating Intrinsic Value. Article 6 in the next SPE Review will be covering integrated thinking about 'stock' – enterprise governance 'stock' (primarily Manufactured Capital), Business Sustainability 'stock' (primarily Governess Capital) and the external 6 Capitals Stock beyond the factory area or 'production boundary' (Environs Capitals). Valuing Everything: Six Capitals Stock Model – Environs Capitals.

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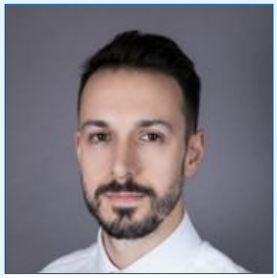

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