

Chairman's Reflections on the AAPG Energy Transition Forum 2022: Pathways for Geoscientists in a Net Zero Future.

Max Brouwers¹

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¹AAPG Forum Chairman, Chief Business Development Officer, Getech

The energy transition is happening all around us, and the speed of change is accelerating. However, with the progress, the associated challenges become clearer too. The 2022 Energy Transition Forum, held 19-20 May 2022 at the Business Design Centre in London, provided deep insights in the pathways for geoscientists towards this net zero future.

At the macro level, we face the energy trilemma, where decision makers need to balance energy affordability, security of supply and environmental impact. Rising fuel and electricity prices highlight the affordability challenge. Meeting the Paris climate goals remains a stretch, and recent events, such as the war in Ukraine, have pushed energy security to the forefront.

However, there is also reason for optimism. Around 90% of the world has net zero targets, and around 80% of the required technologies to meet the Paris climate agreement have already been developed.

Hence, the focus must shift to translating the long-term environmental goals into credible, step-by-step plans and acting on them. A key question remains as to whether we are moving fast enough; we are still at the bottom of the S-curve in the energy transition and the rate of change is hard to predict.

Independent of the speed of transition, the key role for geoscientists in achieving net zero has never been so clear. Annual investment in climate solutions across the entire value chain needs to rise from its present level of just over \$1 trillion to \$3.5 trillion a year if we are to achieve net-zero by 2050. In addition to transitional petroleum, the world needs large volumes of carbon storage, geothermal energy and critical minerals.

More specifically, energy transition scenarios highlight that a 200 to 400 fold increase in CCS is needed. Each carbon storage project requires many of the same earth science skills as an oil and gas field, ranging from regional sweet-spotting to storage site monitoring with multi-method geophysics.

The increased need for critical minerals is well documented. Battery, solar and wind are all currently experiencing cost increases due to shortages in critical mineral supply. Massive investments in the exploration and exploitation of copper, cobalt, lithium, rare earth minerals, etc. are expected.

Geothermal, quoted as the Cinderella of renewables, provides highly reliable baseload green energy. Significant investments in new technologies may result in breakthroughs that make this energy source commercial in many more places around the globe.

At the same time, oil and gas will be required for decades to come, as renewable energy cannot be scaled quickly enough to meet the affordability and security of supply the energy trilemma requires.

Since the first Energy Transition Forum, incredible progress has been made in the application of digitalization. In 2018 this topic was still in its infancy, whereas it is now mainstream – but with lots of potential to enhance the way in which we pursue the energy the world needs.

The global questionnaire to geoscientists accompanying the event, completed by nearly 1,000 professionals, highlighted that petroleum geoscientists remain negatively perceived by society, but their education has equipped them to address future energy challenges, and they encourage students to embrace geoscience as a much-needed part of the solution to the energy trilemma.

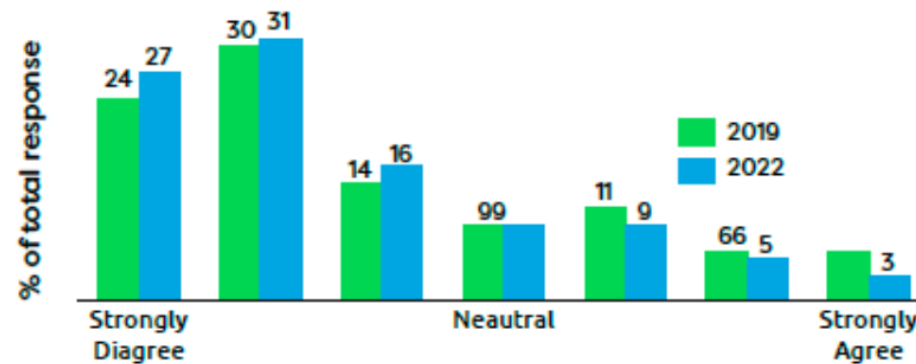
As a closing thought, geoscientists should be proud of the core part they have played in delivering the energy that allowed global societies to progress. They should be confident that we will continue to play a crucial role in providing affordable energy, as well as in mitigating climate change. Geoscientists are the linchpin of the energy transition.

The Energy Trilemma

A successful transition to a global net zero economy must resolve the energy trilemma: the vital need for energy to be sustainable, affordable and securely supplied. In recent years, the concentration has been on sustainability, but recent geopolitical upheavals mean that security and affordability are now taking centre stage, with risks to the environmental impact aspect of the trilemma. We have to balance emissions and our need for energy. In this section we summarise the main observations on the broader issues facing geoscientists in a net zero future, centred around the energy trilemma.

- Driven by climate change, the main levers for an effective energy transition are economic growth, government regulation, energy costs, transportation alternatives and consumer behaviour.
- Countries accounting for more than 70% of today's global GDP and emissions have already committed to net-zero emissions, many by 2050, implying a massive acceleration in clean energy deployment.

- Forecast scenarios from a wide range of organisations predict that hydrocarbons will be in the energy mix until at least 2050. To prevent further environmental impact on to the planet it will be necessary to economically decarbonize these hydrocarbons, bearing in mind that while there is a burgeoning industry forming around alternatives to hard-to-find hydrocarbon derivatives like plastics, it is not yet ready to replace them.
- Energy poverty is increasing, along with consequential poor health, lower life expectancy and reduced access to education, especially for women; it is estimated that 2 billion people will be living in energy poverty in 2040. Rising energy demand in developing countries must be satisfied and for many of those living in poverty, access to energy, rather than energy transition, is the primary concern. Leaving developing countries behind economically will result in global and social unrest. Knowledge of energy transition technologies must be made accessible worldwide, but it is possible that some countries will have to move at a slower speed in order to alleviate energy poverty. A globally united approach is needed; there are both moral and practical reasons for rich countries to help poorer ones.
- Geopolitical events like Russia’s invasion of Ukraine have highlighted energy security and shown how important it is to diversify the energy mix to satisfy demand. However, moving to renewable sources will not bring energy security if the supply of critical minerals and other vital components is not secure. Commodity prices of critical minerals are changing the economics for clean energy technologies, with the price of lithium, for example, increasing by a factor of twelve since 2020. This means that, despite economies of scale beginning to reduce costs, renewable energy prices are rising.
- Many people do not realise how difficult and disruptive the energy transition will be. Lessons can be learnt from previous energy transitions; the introduction of coal as an energy source, for example, resulted in massive industrialization and huge societal change in the 19th century.



Respondents to the survey reported low expectations that the world will meet the Paris Agreement target of limiting global temperature rises to less than 2°C with efforts to limit warming within 1.5°C

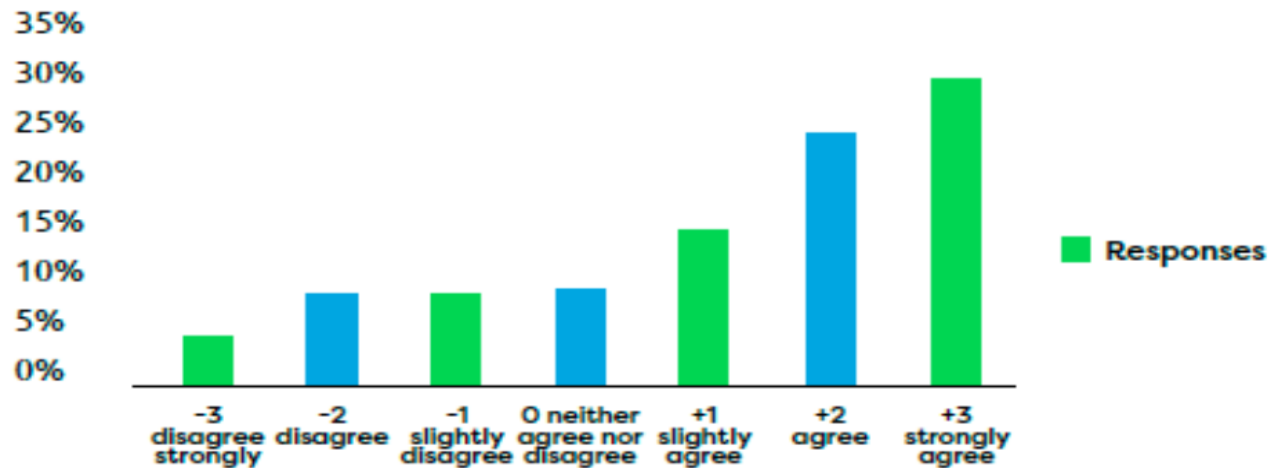
Policies for Progress in the Energy Transition

A major energy crisis is approaching us, and now is the time to set the foundations. Countries and governments across the world will choose different interventions, including taxes, subsidies and legislation, but the underlying answer to the energy trilemma has to be renewables. How can governments and institutions create policies that will increase their use and affordability and what policy options are there? Setting policies from the top down is vitally important but we have to remember that governments can declare plans but that does not mean they will be put into practice – many countries will not take action if it interferes with economic growth. Policies are of little use if they are not backed up by the funding required and the short term expense of the energy transition needs to be balanced against the long term expense of inaction.

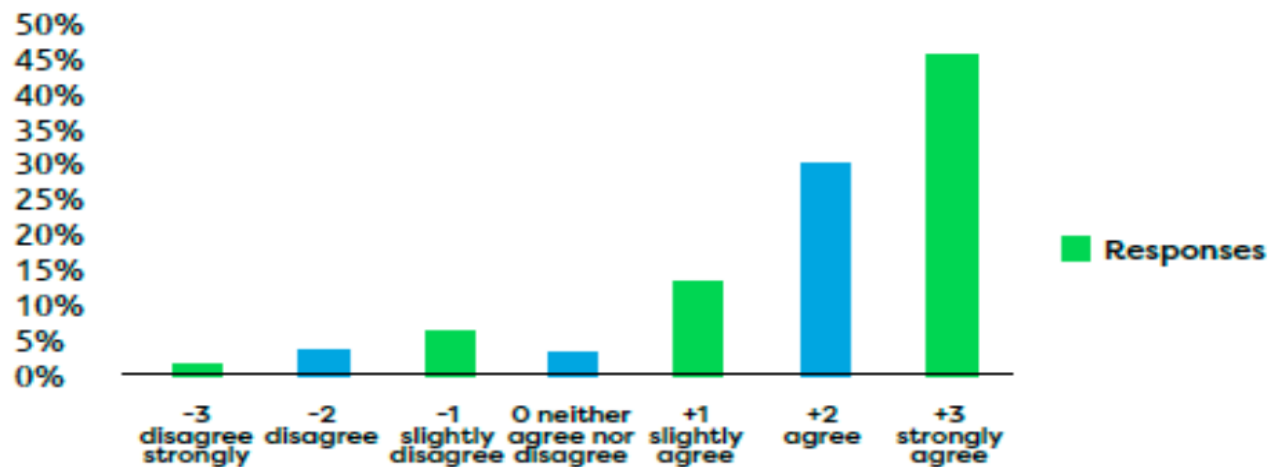
- We need joined-up thinking and policy-making across all sectors. Cooperation across borders is vital.
- How much will the energy transition cost, how will it be paid for and by whom? It is not going to be cheap, but if we do not invest now it will be even more expensive. Bloomberg estimate the world spent about \$755 bn on low carbon investment last year, well up on 2020, but McKinsey say it will take \$9 trillion annually to get close to net zero by 2050. That is about twelve times as much as the world is spending today and roughly a tenth of world GDP.
- We are not moving fast enough. It is important to unlock capital to speed things up, but it needs to be shown that money can be made from energy transition-based ideas. Carbon capture and storage (CCS), for example, is considered by many a vital part of a viable transition but at the moment is rarely cost-effective. Either customers will have to pay more for the product, or policies need to be put in place, like carbon taxing and subsidies, to increase the level and pace of CCS rollout.
- Are policy makers sufficiently aware of how crucial and rare critical minerals are and of where they are found, and are policies taking account of this vulnerability? Security of supply of critical minerals could be as vital as energy security. Policies over critical minerals need to ensure adequate investment in diversified supply sources and to enhance supply chain resilience and market transparency, as well as promote technical innovation at all points along the value train. International collaboration is key in this area. Policies with regard to recycling of critical minerals must be developed.
- A number of hubs combining heavy industry, transport, CCS, offshore wind and the production of hydrogen have been developed in various parts of the world and these are proving successful. They require major commitment from governments and buy-in from local communities, as well as carbon pricing, incentivising and tax. At the moment there is a long time-lag between initial idea and actualization; the regulations and legislation involved needs to accelerate to achieve net zero targets.
- Can there be accountability across the full value chain? Governments make laws and are ultimately accountable to the public, while companies are accountable to their shareholders.
- It will be important to develop a standard for industry in which businesses commit to a low carbon policy and show they have the technology to undertake that policy, building radical energy efficiency into all future plans.

- Policy should be informed by a collective understanding between governments, universities and industry as to what skills and expertise are required and how training and reskilling will be funded.

Exploration for oil and gas is consistent with sustainable development



Oil and gas will remain a dominant part of the energy mix for the next 30 years

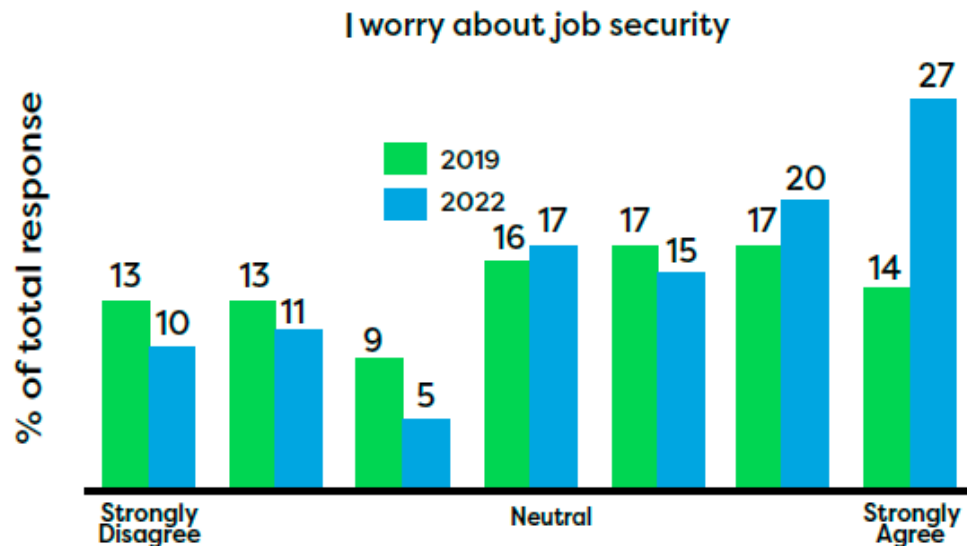


Geoscience, Technology and Solutions

- It is thought that about 80% of the technology required for the energy transition has already been invented but we need a lot more investment to get that tested and scaled up. In some cases what we have now may not be the permanent solution but it will help us through the transition. There needs to be a long term commitment to technology with much more investment but at the moment it is unclear where that is going to come from. Until it can be shown that a technology can be useful as well as make money, investment will not follow.
- Electrification will be key to the energy transition. Storage remains a barrier, although technologies in this sector are constantly improving, so the cost of batteries is an important driver, linked to the availability and price of critical minerals such as lithium. The way we store and distribute energy is shifting from primarily hydrocarbon-based to being integrated with alternative sources, often with local solutions. Major challenges persist with regard to alternative energy sources accessing the transmission grid.
- Critical minerals play a vital role but there are big issues to overcome, particularly on the supply side. Overall, about six times more of these minerals are required within renewable energy than with fossil fuel-based energy, and in some cases a much larger quantity is needed. Another major issue is ensuring sufficient quality minerals are discovered and there is a key role for geoscientists to play here, exploring for and discovering new supplies. Minerals extraction is also historically emissions intensive and ecologically destructive so the whole life cycle of an energy transition technology must be measured. Going forward it will be important to develop and maintain higher ESG standards associated with these supply chains.
- Carbon capture and storage, used to both reduce residual emissions and capture negative ones, is a key technology, but at the moment the global rate of CCS deployment is about 1% of the level needed by 2050 if we are to stay within 1.5°C target. In 2021 about 40 Mt/year was sequestered – that figure needs to rise to 7,800 Mt/y by 2050. Direct air capture of emissions (DACCS) and the production of bioenergy with CCS (BECCS) are both promising routes under development. Geoscience plays an important role in selecting sites for CCS and in ongoing monitoring.
- Hydrogen, both green and blue (i.e. made through electrolysis involving fossil fuels, usually gas) is considered key to the net-zero equation. It is particularly useful alongside intermittent renewables as hydrogen can be stored and used as required. However, despite considerable work, there are not yet any financially viable systems using hydrogen at scale and it is unlikely that this will be achieved in the near term. It is also important to measure the full lifecycle emissions; some blue hydrogen actually has a worse total footprint than natural gas.
- Projects that operate as hubs of carbon intensive industries along with CCS and hydrogen generation, plus integrate with the grid and generate electricity for infrastructure, are having promising results. As discussed in the policy section, the main challenges in developing these integrated hubs in a timely fashion include investment, planning and partnerships at the pace and scale required.
- Harnessing geothermal energy is particularly relevant to geoscientists and opportunities in the sector are continually evolving. The market had been dominated by state industries but with the realisation that it is a permanently available low-carbon base load solution that can resolve

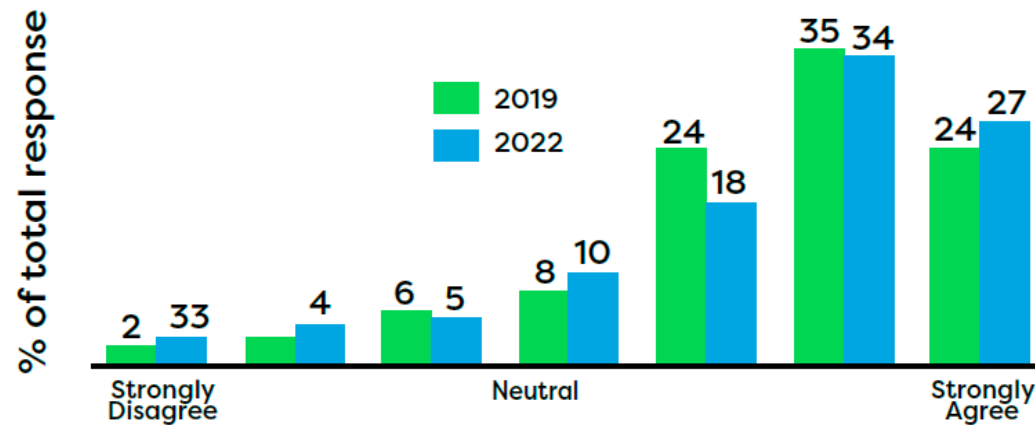
intermittencies in other renewables the market is opening up. However, CAPEX costs must fall by 60% to compete with non-carbon taxed fossil fuels.

- Offshore wind is now one of the cheapest ways to generate electricity. However, in certain areas offshore it will have to contend with CCS, as the tight grid seismic monitoring required for CCS is prohibitively challenging in the vicinity of a wind farm with present technology.
- Natural gas will continue in the energy supply mix for some time if it has a low CO₂ content and it is produced with low, accurately tracked emissions, including the elimination of flaring



- Renewable energy sources tend to be low risk/low return, as opposed to fossil fuels that are high risk/high return; will investors remain interested for the long haul?
- Entrepreneurial vision is needed to create and shape the business models of the future, applying an integrated approach and a good understanding of the critical connections between various disciplines. New business models are developing through large internet companies like Alphabet and Stripe, which are encouraging organisations to build CO₂ avoidance projects so they can buy the offset, thus creating a market. Business life is about opportunities, especially when the pace of change is so rapid.

I am willing to adapt to whatever the future may bring to this industry

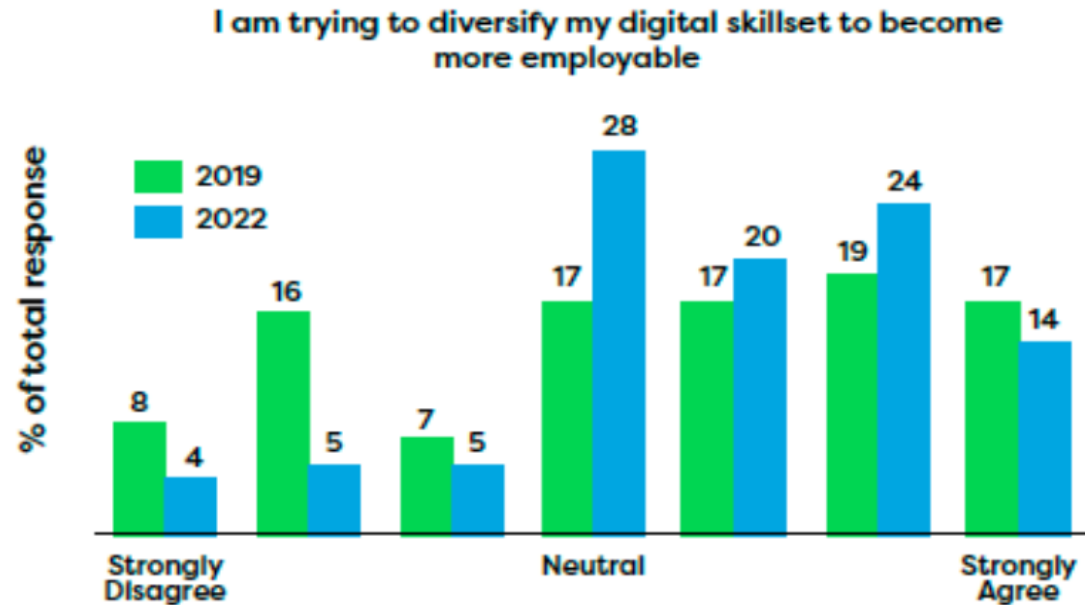


Digitalisation is Key

The pace of innovation and digitalisation is increasing in order to meet the goals for a carbon net-zero future and is impacting every part of the energy industry. To build radical plans for future energy use, comprehensive data is needed from the beginning. Data must be treated as an organisational asset and used to deliver value. It is available from a huge number of sources; the issue is how to gather, use and monetise this data to boost the energy transition.

- Data is a valuable resource and is now collected from a huge range of sources. However, it is of no use if it is kept in many individual silos without unified sharing methods – this is a significant barrier to innovation. Equally, collecting huge quantities of data into a ‘data swamp’ with no means of accessing or understanding it is pointless. Initiatives like the Open Source Data Universe are key. This community has grown very fast and it is now being used to address the ‘data swamp’ issues and challenges of multiple softwares. Having initially looked at basic oil and gas datatypes such as subsurface data, it will soon include new energy solutions. It is important that these are incorporated at this early stage of the development of sustainable technologies to avoid repeating previous mistakes resulting into data gaps.
- AI, digitalisation and cloud-based technologies can help companies to find innovative ways to create smarter energy production methods, reduce energy use in manufacturing and accelerate the development of clean energy. AWS, for example, believes it has helped to reduce the carbon footprint of the IT operations of its customers by up to 88%.
- It is important for companies to invest early in a good cloud solution while keeping in mind the CO₂ footprint involved, particularly by avoiding too much repetition of individual systems. Some companies behind cloud computing are moving to sourcing their electricity from renewables as much as possible in order to reduce this footprint.

- A company working towards energy transition must have a stable vision of where it is going, but be flexible in execution in order to unlock value quickly, where possible adopting rather than adapting solutions. Collaboration, internally and with external partners, is vital to making smart solutions.
- ‘Smart’ grids using AI will prove invaluable in places relying strongly on intermittent renewables.
- Developments in Quantum Computing (QC) will have applications for geoscience, especially in the fields of optimisation, machine learning and simulations, because QC works much faster and more securely than standard computers. Combining quantum computing with machine learning and optimisation technology can allow computers to, for example, improve net zero grids and solve complex geophysical processing in a fraction of the time. This field has a lot of potential for employment for geoscientists.
- Digitalisation is also important in existing energy systems to reduce emissions. For example, accidental leaks from gas operations emit methane, the second-largest contributor to global warming after CO₂. Digitalisation can help implement effective systems to identify and predict leaks and then adapt and advise the system on better ways to inspect and forecast, thus contributing along the whole value chain.
- With such large quantities of data available, and using recent advances in artificial intelligence, it should be possible use machine learning to ‘clean’ legacy data to make it more useful.

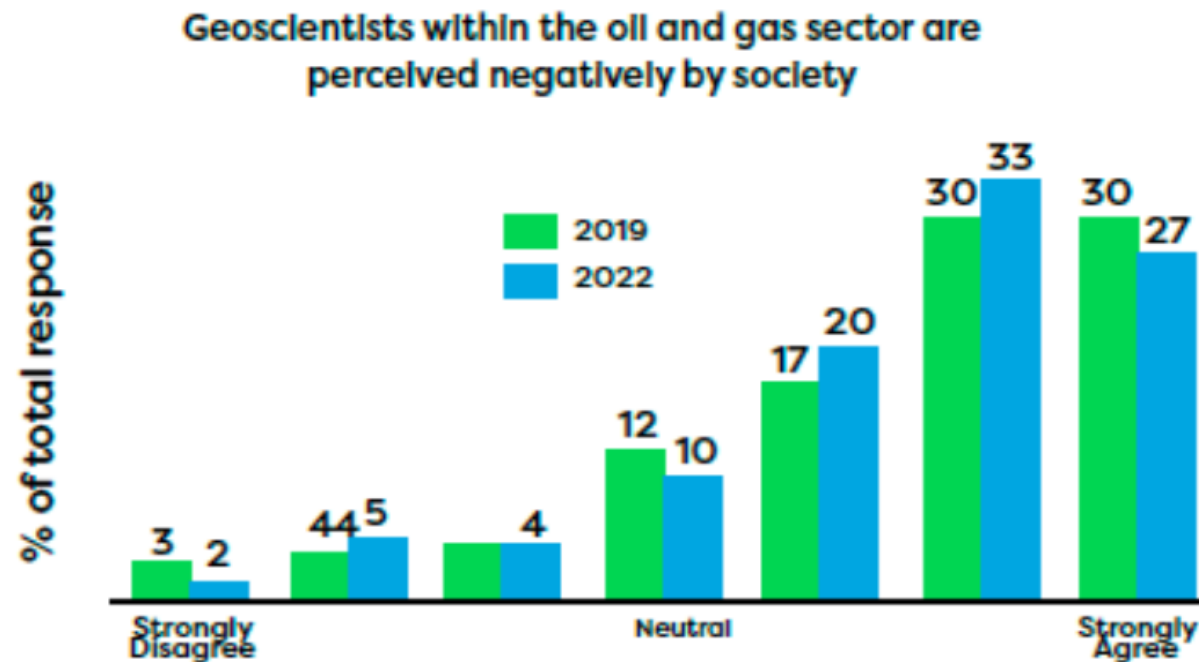


It's all About People

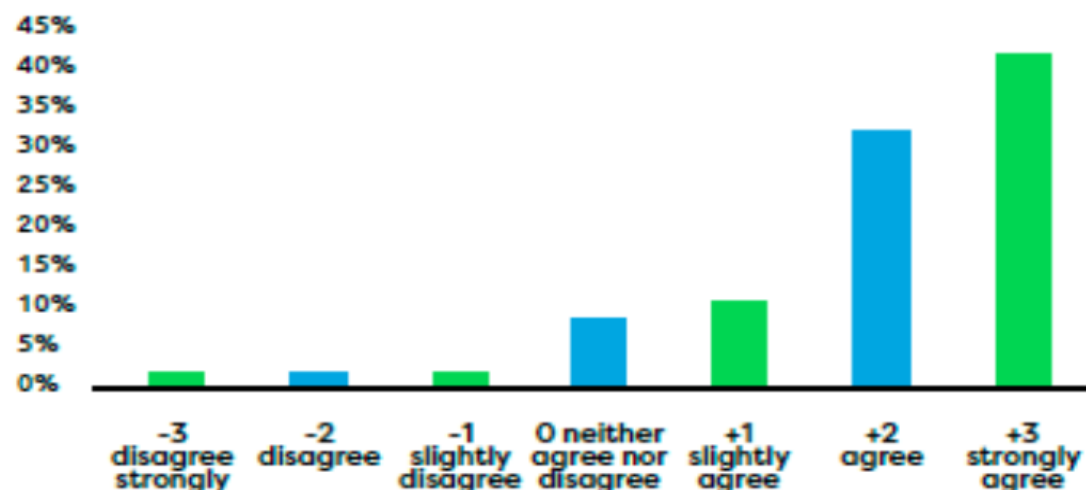
Despite all the talk about data and innovative technologies, it is people who will resolve the energy trilemma and enable the energy transition – and many of them will be geoscientists. The skills and capabilities landscape is changing and the geoscience expertise needed for the energy transition will be both deep and broad. Geoscientists are ideally placed to lead the energy transition; they have a creative and hypothesising approach to challenges and are both good at and accustomed to technological innovation and collaborative working. The oil and gas industry gives people a huge range of practical skills that are equally applicable in energy transition businesses.

- Geoscience remains closely intertwined with the energy industry, even when transitioning away from oil and gas. Geoscientists are involved whenever we put structures in the ground or investigate what is beneath us, which includes CCUS, critical mining projects, wind farms and geothermal sources, so a good grounding in geoscience is still needed.
- The energy transition will utilise a wider range of core geological skills including igneous petrologists and hydrogeologists, instead of the predominantly sedimentologists the oil and gas industry needs. The energy transition requires a broadening of specialities within geoscience and of what being a geoscientist means, offering lots of opportunities.
- Integrated Energy Companies, including oil and gas companies, will be looking for skilled people for throughout the energy transition as hydrocarbons are gradually displaced by more sustainable options and more diverse opportunities are created. There are also opportunities in consultancies and data organisations, which need knowledgeable geoscience professionals.
- Much of the fundamental geoscience skillset from oil and gas is still relevant but may be used in different ways. Current geoscientists may not know everything about the energy transition and are encouraged to immerse themselves in the energy community to learn and share knowledge. Transferable skills that will be valuable in both the existing energy industry and into the energy transition include technical skills such as reservoir modelling, geophysics and well interpretation; these will all remain at the forefront of a geoscientist's core work in energy. Non-technical skills, including project management and uncertainty and risk analysis, will also remain important. The ability to integrate complex technical and financial projects, as required for clustered hydrogen/CCS projects, for example, will be key and is a finely tuned oil and gas skill.
- Skills to be considered by new graduates or experienced geoscientists who may be thinking of upskilling include digital understanding, data manipulation and analysis, and coding, as well as more traditional business, communication, regulatory and financial skills. Both the geoscientist and the energy industry must be flexible, adaptable and agile; some skills will need deepening, others broadening.
- Upskilling should be fully integrated with the flow of work, with good quality hybrid learning as standard, and with companies allowing personnel time and allocating resources so they can update their skill set. This should include field work, not just for geoscientists – everyone involved should get a feel for how the materials they are working with look and feel at true scale.

- The energy transition is relevant to everyone but that message is not always understood. It is important to share knowledge between communities in ways that resonate with society, making the link personal to enable trust and understanding so that people realise, for example, why a wind farm needs to be built in their area.
- There is no point in making grand plans if the manpower to fulfill them is not available. With fewer students studying the geosciences, where will the next generation come from? There remains both an image problem, as demonstrated by our survey results, coupled with a lack of understanding of geology among the general public. How can we get across the benefits of a geoscience degree – the range of transferable skills acquired; the ability to work with uncertainty (a sought-after skill); the fun of field trips and the possibilities of travel within the many different roles? This needs resources, possibly from industry, directed at, for example, supporting initiatives to encourage geology in schools. Geoscientists need to spread the passion they feel for the subject, if possible using the media routes that attract young people, including social media.



Geoscientists within the oil and gas sector are perceived negatively by society



- Education, from school to post-graduate level and in-work training, needs to take account of and accommodate the energy transition. Engineering and science are important and powerful, so young people interested in these need to be nurtured and encouraged. A range of masters courses have been developed that offer more choice to new graduates and these continue to be expanded. Academia also needs to be more agile in order to adapt to changing circumstances; partnerships with companies in the energy industry are encouraged to help this. However, the cost of further education is high, with little sponsorship available, and there are some better paid in-work paths to acquiring these skills – universities are in competition with industry for the best candidates.
- It needs to be easier for people to move between academia, industry and government organisations to input a breadth of thinking into resolving the issues and to ensure that government and regulators get expert advice. It should also be easier both career-wise and financially to move between technical and managerial roles.
- It is important that we learn from the past to ensure that equity, diversity and inclusion are at the core of the energy transition, while being aware of the risk of tokenism. Everyone must be involved in and take responsibility for this; the transition is an opportunity to do it right.
- There is pleasure and satisfaction not only in working with new tech start-ups, but also in helping transform a 100-year-old supermajor into an innovative energy company, offering new experience and bringing in expertise from energy transition companies in order to help solve energy's biggest challenges, using technology and an open community to reimagine the future of energy exploration.

Geoscientists and the World's Greatest Challenge

The survey undertaken by the energy transition forum identified the following tips from experienced geoscientists to the incoming new generations of geoscientists facing future challenges in energy:

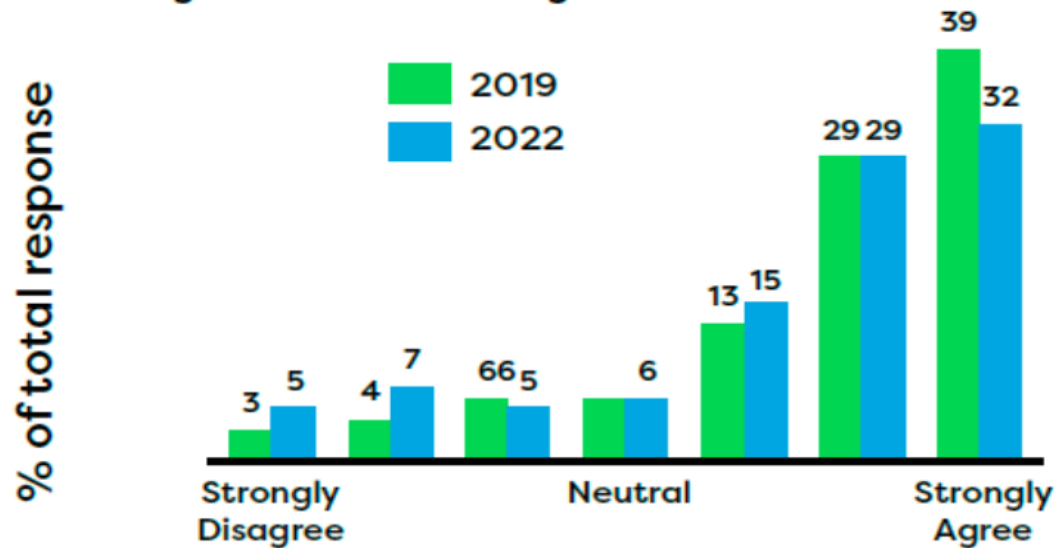
- Be strong on the geoscience fundamentals:
 - Touch the rocks;
 - Be multidisciplinary, numerate and be integrated in approach;
 - Embrace the spectrum of the energy transition; diversify your skills portfolio;
 - Stay up to date; increase literacy in data science, digitalisation, AI & ML;
 - Care for the environment.
- Be flexible, adaptable, and agile:
 - Have an open mind; a holistic approach; avoid bias;
 - Be creative; be curious;
 - Embrace change; be positive and optimistic.
- Have passion and ensure you love what you do:
 - Have pride, strong ethics, courage, dignity, honour, pursue excellence;
 - Show enthusiasm, be persistent, be resilient, be proactive, be realistic;
 - Develop professional, interpersonal and business skills, be a critical thinker;
 - Work hard, always keep learning; have fun.

If you had 30 seconds with all the leaders within the energy industry to deliver 1 message, what would it be?

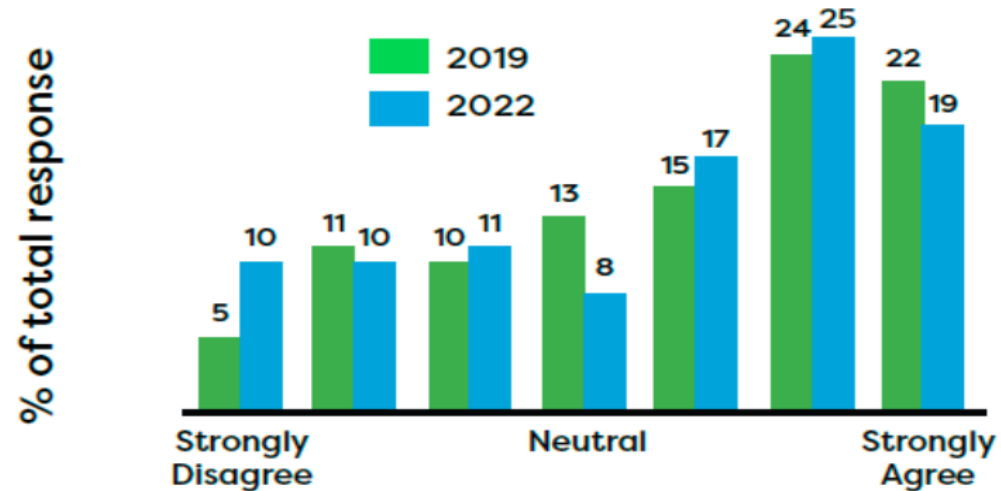
- Focus on communicating with the wider public, educators and politicians;
- Stop being an apologist for the energy sector; be proud of your contributions;
- Show the highest standards of ethics; be honest;
- Take care of your people, society and nature
- Have the courage to do the right thing;
- Build bridges and collaborate;
- Be data-driven, not model-driven;
- Take a lead role in communicating a realistic energy transition message.

There is general agreement among respondents that they would encourage students to continue their geoscience education and to pursue careers within the energy industry.

I would encourage college/high school students to study geoscience within higher education



I would encourage earth science students graduating today to begin a career within the energy sector



As this forum has demonstrated, ensuring the whole world has access to sustainable, affordable and secure energy supplies now, through the energy transition and into the foreseeable future is a complex challenge but one in which geoscience plays a crucial role. Solving it will involve intelligent policy-making, radical changes in education, major investment, imaginative funding solutions and the understanding and co-operation of everyone from senior decision-makers, people working in all aspects of the energy industry and the general public.

One thing remains clear: geoscientists will continue to play a major role in the global journey to confront the world's greatest challenge and deliver net zero.