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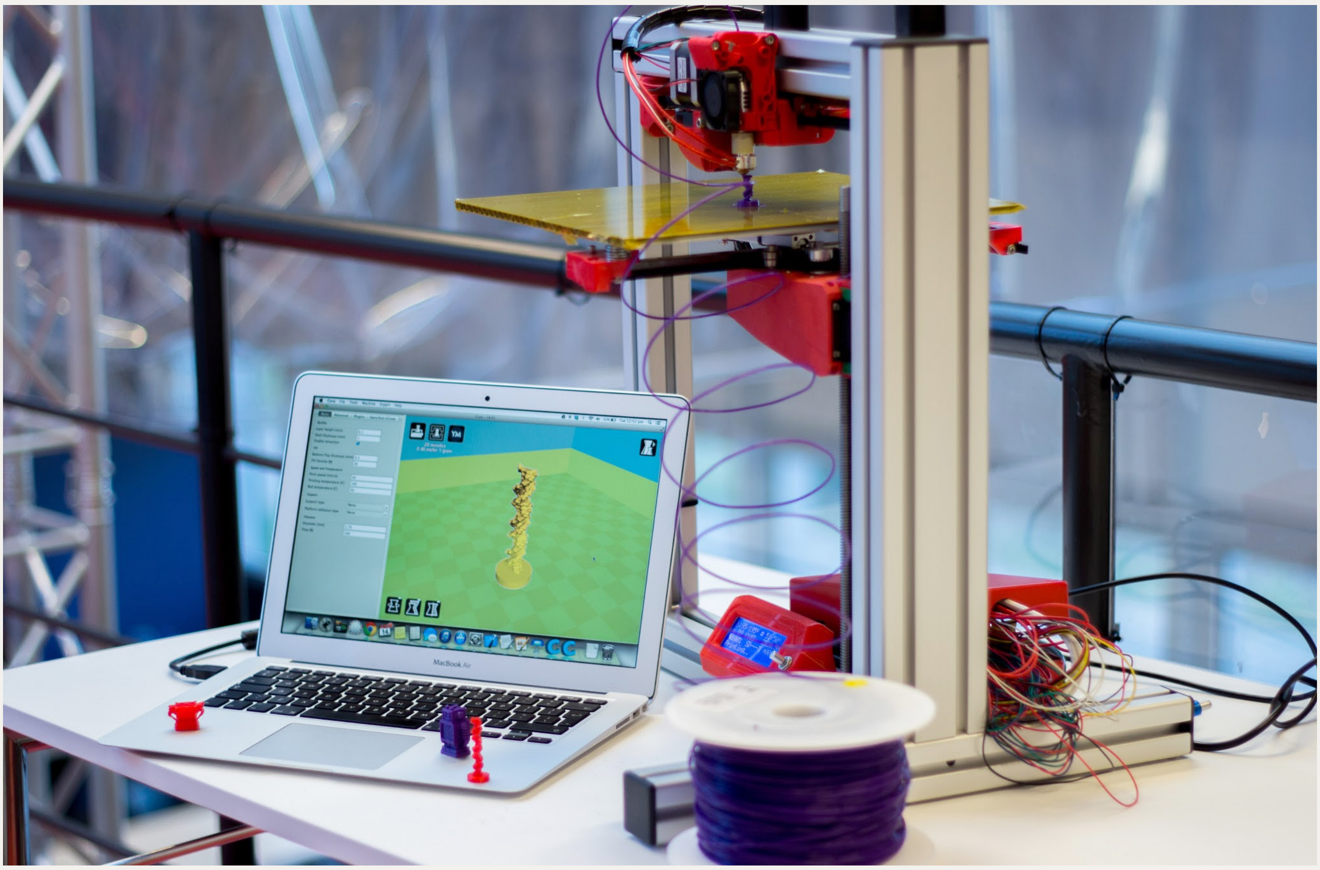
Disruptive Innovation: an Era of Upheaval for the Traditional Energy Industry?

Uncertainty throughout the energy value chain posed by the threat from disruptive technologies is casting a shadow over the sustainability of long term investments in oil and gas. Some disruptions, such as shale oil and low-cost solar power, have already emerged; others, such as electric and autonomous vehicles, 3D printing and artificial intelligence, are on the verge of becoming mainstream. Will these disruptive innovations offer opportunities for lower costs and cleaner growth? Will they require retooled business models, and will new non-hydrocarbon technologies emerge? If so, how are the world's major oil and gas companies going to forecast, plan, and adapt - will they under-invest, or over-invest? Strategic investments in new technologies can provide valuable information about their progress.



Felix 3D printer: Jonathan Juursema

Executive Summary

- The past decade has seen important disruption by new technologies both in traditional (oil, gas, coal) and new (renewable) energy.
- More disruptive change is on the way from new technologies for energy storage, trade and use, such as electric vehicles, batteries and blockchain.
- At the same time, other disruptive technologies offer advantages to oil and gas producers who can employ them.
- The threat of new non-hydrocarbon technologies may deter investment in new oil and gas production.
- A lack of new investment in producing hydrocarbons is a problem for the oil and gas industry, but not for the global economy, as long as new energy sources deliver on their promises – if not, a price spike and economic damage would result.

Implications for leading oil and gas producers

- Business models need to be flexible to incorporate new technologies that improve the efficiency and environmental impact of hydrocarbon production and use.
- Long-term strategic plans are required to balance the need for new oil and gas supplies with the threat of competing technologies.
- Well-placed investments and joint ventures can give information about the progress and capabilities of new energy technologies.
- National petroleum companies and supermajors face a choice between focussing on their core hydrocarbon business and leaving new energies to other entities, or progressively incorporating new energy technologies.

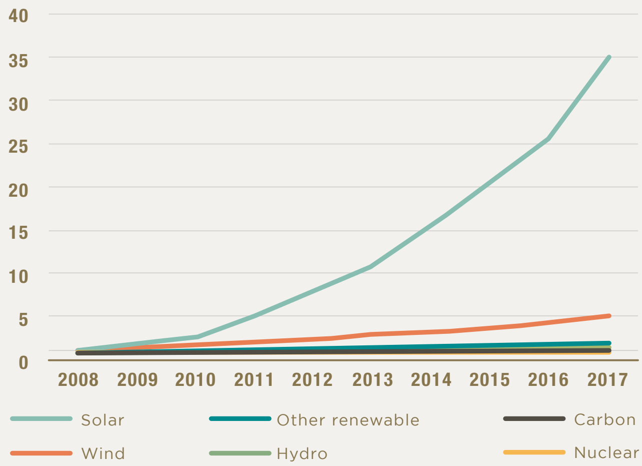
Disruptive technologies have been deployed in traditional and new energy industries over the past decade

Disruptive technologies ***displace an existing technology and destroy incumbents*** who cannot adapt, or ***they create an entire new industry***. The traditional energy business has recently seen the deployment of new technologies for producing oil and gas from shale and other tight reservoirs, and for delivering LNG to floating import terminals. These have led to sharp falls in the price of oil and gas, challenging OPEC countries, legacy gas contracts and major oil firms.

In non-hydrocarbons, renewable energy, particularly solar and wind, has achieved major falls in cost that makes it competitive with traditional power generation in many settings. Consequently, they have grown much faster than traditional energy sources, albeit from a small base (FIGURE 1).

Crucially, both these sets of technologies have been accompanied by new business models. For instance, floating LNG regasification has supported the emergence of traders and short-term contracts. American promoters have moved quickly to develop liquefaction plants on a tolling model using Henry Hub as a basis for pricing.

FIGURE 01: GROWTH IN ENERGY CONSUMPTION BY SOURCE (2008 = 1; 'CARBON' INCLUDES OIL, GAS AND COAL)[1]



Shale production was led by independent oil companies that raised finance from high-yield debt and private equity, supported by extensive hedging. Now supermajor oil companies such as ExxonMobil, Chevron and BP are leveraging their legacy assets to make shale a dependable and profitable core business.

Renewable energy producers have benefited from aggressive financing, supply chain innovations and steady manufacturing improvements. Albeit with the help of subsidies and other support mechanisms, they have upended the traditional utility model in several European countries, leading incumbents such as EON to spin off their legacy coal, gas and nuclear businesses.

More are on the horizon

Researchers and investors are advancing the next wave of potentially disruptive technologies, ranging from those in early commercial deployment to R&D (TABLE 1).

TABLE 01: DISRUPTIVE ENERGY-RELATED TECHNOLOGIES

Technology	Impact on oil & gas	Maturity
Floating LNG regasification	• Quick access to new gas markets	Commercial
Hydraulic fracturing & horizontal drilling	• Increased production and lower prices	Commercial
Low-cost renewable energy	• Lower gas and coal demand and CO_2 emissions	Commercial

Advanced batteries	• Supporting deployment of renewable energy and electric vehicles	Early commercial
Electric vehicles	• Lower oil demand • Increased power demand	Early commercial
3D printing	• Improved fabrication of renewable energy systems • Lower energy use in manufacturing • Improved maintenance for oil and gas installations	Early commercial
Artificial Intelligence, Automation, Internet of Things (IoT) & Big Data	• More efficient energy use • Demand management for renewable energy integration • Better design and operations of oil and gas production	Early commercial
Low-cost carbon capture & storage (CCS)	• Continued use of gas in power and industry; lower CO_2 emissions	Pilot
Self-driving vehicles	• Increased travel, increasing energy demand • Synergies with electric vehicles	Pilot
Blockchain	• Peer-to-peer renewable energy trading	Pilot
Advanced nuclear power	• Lower gas and coal demand and CO_2 emissions	R&D

Advanced batteries or other energy storage is necessary for renewable energy to make its full impact. Artificial intelligence and the 'Internet of Things' offer greater efficiency and improved demand management, including 'smart charging' of electric vehicles that can feed electricity back into the grid when needed, and running appliances or heating and cooling at lower-demand periods.

Autonomous vehicles, one application of Artificial Intelligence, create synergies with electric vehicles that may speed their adoption. Overall, they are likely to lead to increased demand for transport and hence energy consumption, but in the form of electricity more than oil. They would also disrupt traditional trucking, taxis and perhaps shipping, with unclear knock-on implications for oil, automotives, plastics and linked industries.

A potential peak in demand would not necessarily disrupt the oil industry, which would still have to invest in new production, but is likely t significantly lower prices, and to disrupt the refining and fuel retail businesses.

Are disruptive energy technologies affecting oil & gas more than the utility sector?

Supermajor oil companies, leading service firms and national oil exporters suffered badly from the fall in prices triggered by the shale revolution, but they have survived. Now they are increasingly incorporating shale into their own business plans, such as Qatar Petroleum's Golden Pass venture with ExxonMobil for shale gas to export LNG from the US.

Gas has continued to enjoy strong growth, due to its clean-burning nature, flexible use in power generation, and (at least in the US) cost competitiveness against coal.

By contrast, the power generation business, particularly in Europe, has been badly affected by the rise of renewables. Incumbents have recorded large losses, written down assets,

DISRUPTIVE TECHNOLOGIES: SECTOR SPECIFIC THEMES

Oil & gas production
- Shale technologies
- Automated operations
- Drones

Power
- Renewables
- Advanced batteries
- Blockchain
- Advanced nuclear power

Energy
- Solar energy
- Smart grid

Industry
- Carbon capture & storage
- 3D printing
- Automation

Transport
- Electric vehicles
- Autonomous vehicles

and in several cases split or divested their conventional generation.

The transformation is continuing, as they grapple with the challenge of making money from zero marginal-cost renewables, which send power prices to zero or even negative at times of peak supply, while the operating hours of gas plants that provide flexible generation are sharply reduced. More self-generation from solar rooftops, potentially increased by domestic battery systems, requires fixed transmission and distribution costs to be spread over a smaller usage base, even as new investment is required in smart meters and improved grid flexibility.

This transformation may not immediately affect countries that still have state-owned, regulated monopoly utility sectors. But they will face the same struggles to integrate renewables with conventional generation, even if those struggles are hidden within a single corporation. And countries whose utility sector is not able to move swiftly to make the most of the advances in renewable power will suffer from declining economic and environmental competitiveness.

In the future, the most obvious threat the oil industry faces is the widespread adoption of electric vehicles, given that 45% of world oil use is in ground transport, and a further 13% in aviation and shipping.

Electric vehicles are at a relatively early stage of adoption but are already approaching cost and performance parity with the internal combustion engine, possibly in the mid-2020s. So far their impact on world oil demand is minor – incremental improvement to vehicle efficiency has been much more significant. But, as discussed above, electric vehicles offer potential for widespread disruption.

Disruptive technologies offer gains for the oil and gas industry too

Low-cost carbon capture and storage (CCS), being trialled for various industries, and for electricity generation by companies such as NET Power[2], is vital for making long-term use of gas consistent with climate targets. It would create an entire industry of CO_2 capture, transportation and storage, which would likely combine incumbent players with newly-created specialists.

Wider use of CO_2 injection, in turn, expands enhanced oil recovery (EOR), increasing recovery from conventional fields to 60% or more of the oil in place. This intensifies competition to the development of new oil fields. It can also displace gas currently being injected for EOR. Solar steam generation for heavy oil recovery is another environmentally-friendly EOR technique. CO_2 injection or other enhanced recovery methods may be applied to shale and tight reservoirs too in the future to prolong their life and increase recovery factors from the current typical 5-10%.

A further set of technologies are not being developed specifically for the energy industry, but offer gains in efficiency both for traditional and renewable energy. These include the whole sphere of artificial intelligence, automation and big data, which can enable more successful oil and gas exploration, remote operations with no personnel on-site, faster and lower-cost drilling and completion of wells, higher recovery factors from oil and gas reservoirs, predictive maintenance, optimising refinery and petrochemical margins and many other gains.

3D printing can produce spare parts on site, reducing maintenance costs and downtime. It might also enable new techniques to improve, radically, construction times and costs in all big resource and power projects.

These new technologies are useful in themselves, but to achieve their full effect, they have to be embodied in new business models and operated by highly-skilled, and indeed differently-skilled, employees. Falling costs will enable oil and gas to remain competitive in many applications even as renewables improve. They will therefore slow or prevent disruption of the petroleum business.

However, they *will* create disruption within sectors of the oil industry – for example, service and engineering companies. They can also allow corporations that adapt to the new ways of working to disrupt the business models of those that cannot.

The prospect of disruption is not undermining investment in petroleum production… yet

Upstream oil and gas investment fell 40% from 2014 to 2016[3]. But this was not due to fears of disruption by new non-oil technologies. It was caused instead by the period of low oil prices because of the shale revolution and OPEC's initial response of increased production. The IEA and OPEC have both warned of a danger of future price spikes due to the lag in resuming investment to make up for production declines and demand growth.

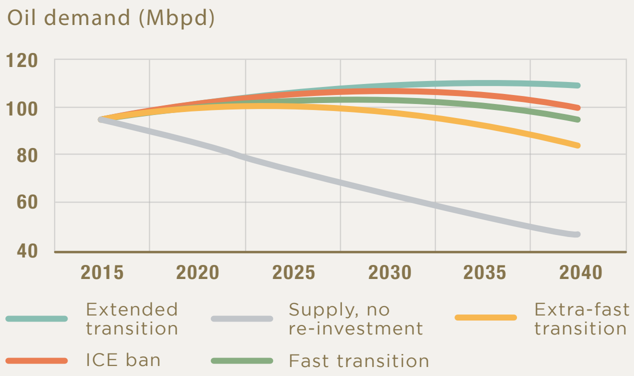
In the future, it is possible that fears of peak demand due to disruption will also lead to reduced investment. This would presumably manifest itself in lowered forecasts for long-term oil and gas prices, that in turn depress investor appetite. In addition, organisations such as Carbon Tracker[4] have highlighted the danger of a 'carbon bubble'[5] in which existing oil, gas and coal reserves cannot be exploited because of limits on CO_2 emissions.

Researchers have warned that the bursting of the 'carbon bubble' could lead to an economic crisis, which would of course hurt energy demand globally. This is not credible though, as there is no transmission mechanism from even severe losses to oil shareholders and bondholders through to a systemic crisis.

Therefore, the 'carbon bubble', even if it exists, is not a problem for the world economy as long as the estimates of reduced oil and gas demand are, in fact, reasonable. But if the prospects for renewable energy, electric vehicles or effective climate policy are overstated, demand could indeed outstrip supply. This would be the reverse of the 'carbon bubble', at least in the short-term – 'carbon starvation'.

FIGURE 2 shows world oil demand in a number of scenarios, from a slower to a faster transition to non-oil technologies, and including a ban on internal combustion engine (ICE) vehicles. This is compared to world oil supply without reinvestment in new production. Even in the 'Extra-Fast Transition' case, where world oil demand peaks before 2025, a huge supply-demand gap opens up, of about 30 million barrels per day (Mbpd), if investment does not continue.

FIGURE 02: **WORLD OIL DEMAND 2015-40 IN DIFFERENT SCENARIOS, VERSUS PRODUCTION WITHOUT RE-INVESTMENT**[6]



Future oil supply can also fall well short of requirements if the progress of non-oil technologies is overstated. If, for instance, the world expects the 'Extra-Fast Transition' case but instead the 'Extended Transition' materialises, the supply-demand gap would be 5.9 Mbpd by 2025 (well within the current investment horizon for new fields), and 11.4 Mbpd by 2030, more than the current crude output of Saudi Arabia, the US or Russia, the world's three leading producers.

The peak of gas demand is likely to be further into the future - potentially much further out if effective CCS for gas power and industry is developed. Nevertheless, gas demand growth can still be blunted by the greater competitiveness of renewable power with battery storage, so a similar challenge of forecasting gas demand arises. Forecasting LNG demand is even harder, because it is more costly than much domestic gas production, and has to compete against gas delivered by pipeline as well as against other energy sources. Therefore, major gas resource holders also face the challenge of investing to grow their market, while not over-investing if demand disappoints.

The high oil and gas prices that would ensue from a period of under-investment would cure themselves, by slowing economic growth and encouraging efficiency, new hydrocarbon investment and increased deployment of non-hydrocarbon energy. Indeed, in the longer term, a price spike might even accelerate the transition to non-carbon energy, hence why major oil and gas exporters are wise to be wary of it.

Conclusions: Implications for leading oil and gas producers

Major oil and gas producers, whether companies or countries, have a number of options to adapt to the competitive threat of new energies.

In the **first strategy**, they can stick to their **legacy business**, the production, processing and sale of oil and gas. To remain competitive against shale drillers and other producers, they need to integrate the emerging new oil and gas technologies into their business models, keeping costs low while expanding the resource base and exploiting new commercial opportunities. CCS can expand EOR and keep their production environmentally acceptable.

The **second strategy** is more risky and challenging but offers a better long-term chance of success. That is to begin integrating new energies – renewable generation and EOR, synthetic fuels, direct CO_2 capture, electricity marketing to battery vehicles – into their core business.

Companies such as Equinor (ex-Statoil), Shell and Total are beginning to adopt this approach, and gradually increasing their non-hydrocarbon investments. Petroleum Development Oman is set to be renamed Energy Development Oman[7], as it adds renewables to its portfolio.

Of course, from the point of view of a country, its national oil company (NOC) does not have to be the one carrying out the investments in new energy. Often the NOC has the best set of capital, skills and existing assets to drive this forward, but the leadership has to be ready to embrace a radically different business model.

In either case, the company has to continue to invest in oil and gas production, on a prudent expectation of future demand and prices. Over-investing leads to poor returns and wasted capital; under-investing loses market share, causes price spikes, and accelerates a transition away from hydrocarbons. The larger the country's reserves and the longer its future reserves' life, the more damaging is under-investment.

In order to judge sensibly the progress of non-hydrocarbon technologies, and to create an economic hedge, leading oil and gas producers can make strategic investments in areas such as electric and autonomous vehicles, solar and wind power and advanced batteries. They can expand in-country research, development, deployment and manufacturing of such technologies.

For tracking and understanding the process of energy disruption, the example of utilities in Europe, and likely in North America and Australia, carries important messages. These have to be understood, though, in the context of a very different underlying business model.

Perhaps the most complex task is understanding and predicting how different disruptive innovations – such as electric vehicles, autonomous driving and advanced batteries – fit together and reinforce each other. The next step from this is to see how a new business ecosystem can evolve and what threats and opportunities it presents.

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