ABDULLAH BIN HAMAD AL-ATTIYAH INTERNATIONAL FOUNDATION
FOR ENERGY AND SUSTAINABLE DEVELOPMENT

Issue 25: September 2018

Al-Attiyah Foundation Research Series

Expert energy opinion and insight

Renewables: How will Falling Costs Affect Growth?

The cost of delivery and service of solar, wind and other renewable energy is falling, reaching parity with conventional generation in several markets. Incremental gains are expected to continue, with breakthrough technologies possible but not essential for further strong growth in market share. Renewables' growth so far is almost all concentrated on power generation and biofuels, but can expand into electric transport, heating/cooling and desalination. Subsidies and other support policies are becoming less important for strong renewables growth. Major oil and – especially – gas producers need to contend with renewables as a serious competitor in the period to 2040.

Solar panels at the Qatar Foundation (https://www.qf.org.qa/content/the-foundation/issue-73/foundations-for-a-green-future)

Executive Summary

- Renewables, particularly wind and solar, have improved dramatically in costs and performance over the past two decades, and this will continue via incremental gains.
- Renewables present more of a threat to coal and gas than to oil; oil's main markets are more threatened by electric vehicles.
- On a relatively conservative view, non-hydro renewables will reach 25% of world power generation by 2040, mostly at the expense of coal, nuclear and oil.
- However, to supply more of final energy, renewables will also have to expand into industrial heat, transport (biofuels and electricity), and building heating/cooling.
- High shares of variable renewables require a major expansion of grid interconnections, demand management and energy storage (batteries and others).
- Breakthrough advances in renewables and supporting technologies are possible but not essential for continuing strong gains in market share.

Implications for leading oil and gas producers

- Gas can gain market share in the medium-term from coal and oil, and by complementing variable renewables.
- In the longer term, renewables present a serious threat to total gas consumption in the power sector, even if gas-fired capacity rises.
- Keeping gas prices moderate is important for preserving competitiveness.
- Hydrocarbon producers, particularly those with good solar and wind resources, can gain cheaper electricity and save oil and gas for export by implementing large-scale renewables programmes.
- Investing in renewables at home and abroad, including manufacturing and R&D, should be an important part of petroleum producers' development and diversification strategies.

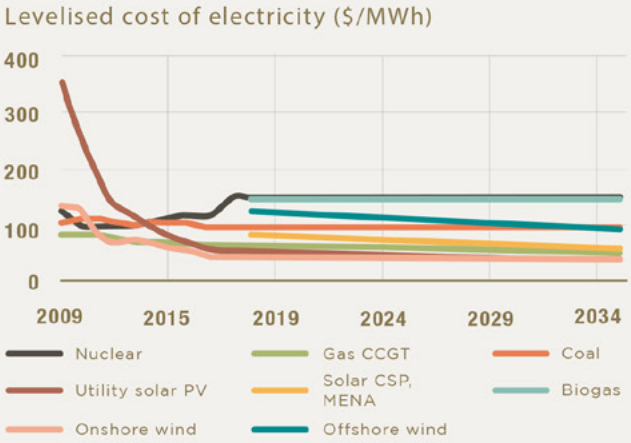
Renewable costs, especially in wind and solar, have fallen dramatically over the last decade and further improvements are expected to 2030

Cost declines are driven by the learning curve (FIGURE 1). Further improvement is expected to 2035, driven by greater efficiency and scale in manufacturing, supply chain and installation, and to some extent by improving technology.

The most dramatic cost improvements have been seen in wind and solar photovoltaic (PV), and hence they have also gained the most in new installations. FIGURE 1 reflects primarily US and German experience, and costs can vary elsewhere in the world, with solar being cheaper in the MENA region.

In suitable locations, such as the sunny Middle East, North Africa, Australia and US south-west, and the windy north-west Europe and US Midwest, renewables can now compete with conventional power on fuel costs alone.

FIGURE 01: **FALLING LEVELISED COST OF RENEWABLES[1]**



Of the other main technologies, large-scale hydroelectric is mature, technologically and in most geographic locations; however, it will become more important for pumped storage to balance variable renewable output. High-temperature geothermal is also relatively mature and limited to suitable locations, but can be significant in areas including the East African Rift system, the Philippines and Indonesia. Low-temperature geothermal could be useful for heating, cooling and desalination.

Modern biomass, biofuels and waste-to-energy are important but carry environmental and land-use concerns which restrict further growth.

Solar thermal (concentrated solar power, CSP), has lagged behind PV but recent project awards in Dubai and Morocco show considerably lower prices than before; CSP is attractive because of its ability to store heat to generate overnight. CSP can also provide high-temperature heat for industrial processes, including steam generation for enhanced oil recovery as in California and Oman.

Immature renewable technologies include ocean energy (waves, currents, tidal and thermal) and osmotic (exploiting different water salinities). These currently do not appear likely to have a large role, although recent advances in wave power could be interesting for isolated islands, offering a steady source of power.

Cost reductions are driven by incremental improvements, not breakthrough technology

Most of the recent falls in renewable costs have come, not from major new technologies, but from steady gains across the entire value chain. These include better manufacturing and economies of scale, ever-taller and larger wind turbines, more intense competition from suppliers, improved operations and maintenance, reduced 'soft costs' of legal and project management as experience is gained, and lower-cost financing as banks grow more comfortable with renewables' low risk profile.

FIGURE 2 shows the typical breakdown of bid costs for a MENA solar project, and where they can be reduced.

The auction model, of inviting bids for a set amount of renewable capacity, has proved to be much more successful in driving down costs than the approach of offering fixed premia for renewable energy. Tendering governments, such as the Netherlands, have also brought down costs for their offshore wind resource by making extensive pre-bid site surveys available.

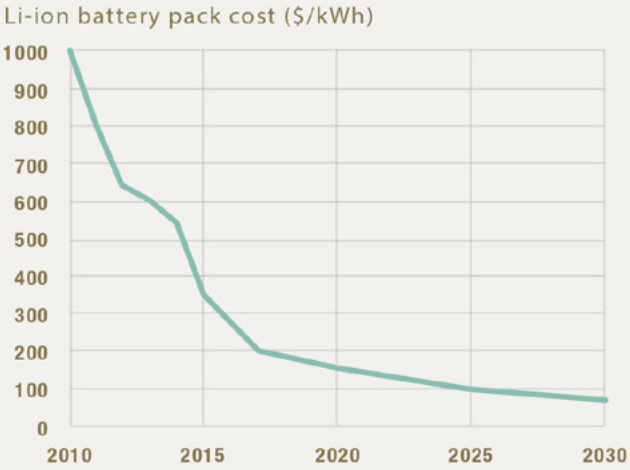
Further improvements have been made in integrating variable renewables into the grid, including co-located batteries for short-term 'firming', faster ramping from gas turbines, and better weather predictions.

Boosting the share of renewables in a grid beyond 20-30 percent of capacity will generally require the deployment of a mix of demand-response measures, long-distance electricity interconnections, dispatchable renewables (biomass, geothermal and hydro), and energy storage. A large number of storage methods are vying for the market.

Short-term storage, up to a few hours, can be handled by batteries, supercapacitors, and thermal storage, including concentrated solar power (CSP) which can generate overnight by saving the sun's heat in molten salts. Dubai has recently achieved world-record pricing for CSP with night-time storage, while batteries continue to fall in cost (FIGURE 3).

Electric vehicles, when widely adopted, could be connected to a smart grid to charge up when electricity is in surplus and release it at times of deficit. At battery costs below $100 per kWh, electric vehicle costs are estimated to be comparable to those of internal combustion engine vehicles; this level will be reached around 2025.

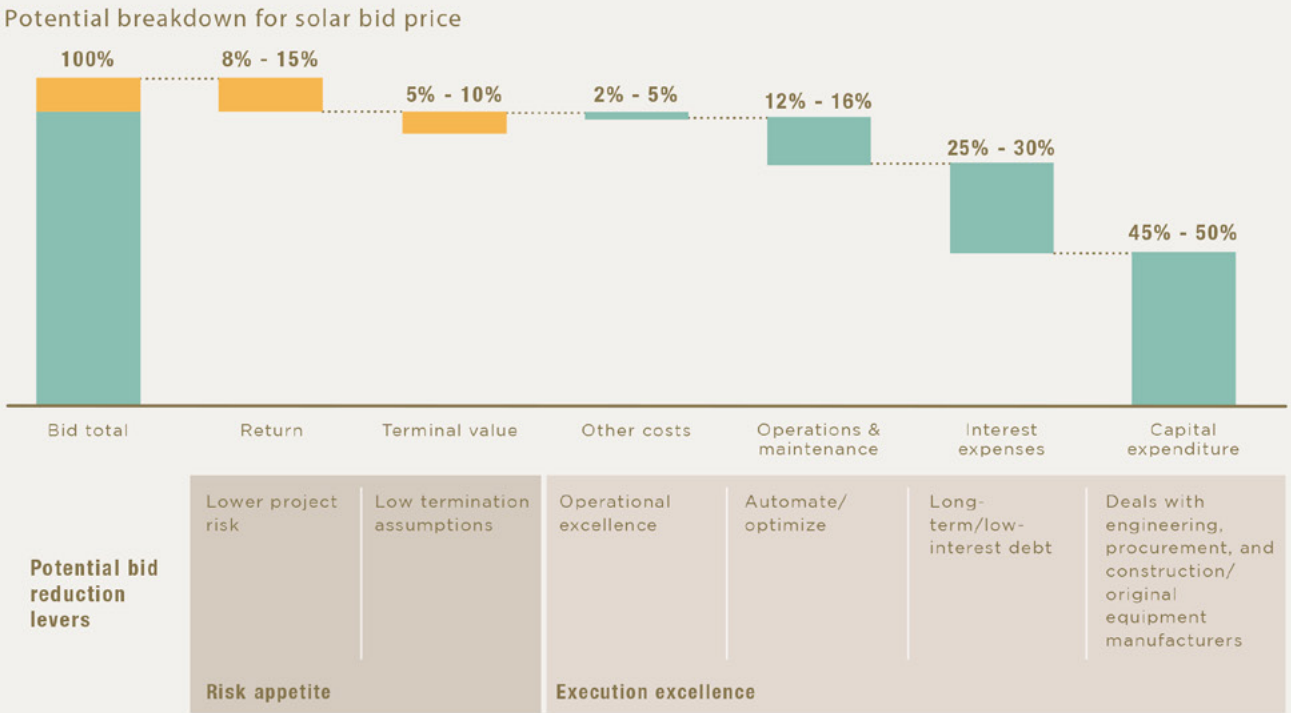
FIGURE 03: **FALLS IN LI-ION BATTERY COSTS**[2]



For seasonal storage, pumped hydro power is preferred where the geography is suitable. Otherwise, large batteries, desalinated water, and synthetic fuels such as hydrogen, are possible options but all appear costly and hard to deploy at a very large scale.

Renewables will continue making rapid gains even if further breakthrough technologies do not emerge. The development

FIGURE 02: **AREAS FOR SOLAR COST REDUCTION**[3]



of gamechangers would speed the adoption of renewables further, and enable them to enter new sectors and geographies. Some recent innovations have included floating wind turbines, which can be moored in deeper water than fixed designs, and bifacial solar panels which boost output by 10-15% by capturing sunlight reflected from the ground[4]. New solar cells, such as perovskites and multi-junction[5], offer higher efficiency and hence reduced 'balance of system' costs, but will have to compete with now mature polycrystalline silicon cells.

Gamechangers elsewhere in the renewables space could include biofuels made by algae, or new batteries with much higher energy density and lifetime.

Renewables are set to continue gaining market share

The growth of renewables is becoming a matter of superior costs and performance compared to fossil-fuelled or nuclear power.

However, other motivations are still important, particularly environmental (the need to reduce greenhouse gases and other pollutants) and energy security (reducing dependence on potentially volatile oil- and gas-exporters).

Many important world regions maintain pro-renewables policies, including premium pricing or feed-in tariffs, preferential grid access, mandates for a certain share of renewable energy, and tenders for specified amounts of renewables to be built at the lowest cost. As the cost of renewables continues to drop and their scale grows, direct financial support will be unaffordable and will be seen as unnecessary. At this point, continued rapid growth will depend on reforms of electricity markets, and technical improvements in grids to integrate variable renewables and storage. Studies suggest that going beyond an 80% share of variable renewables in a grid rapidly becomes very costly and difficult[6].

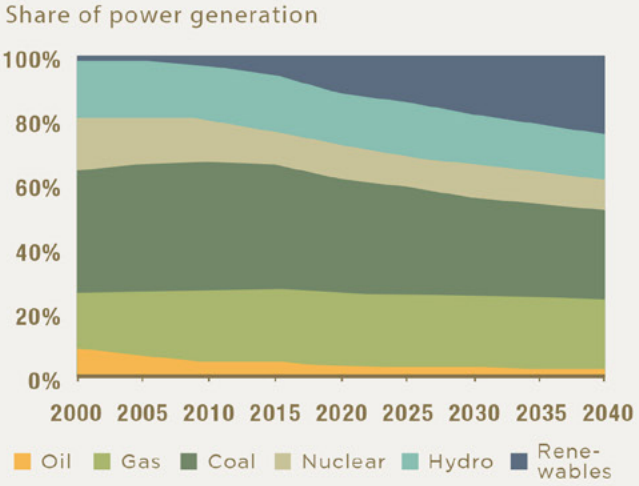
As FIGURE 4 shows, renewables are set to take market share from coal and nuclear in the power sector, while oil's already limited role in electricity shrinks almost to zero. Gas maintains its share but does not grow, even though the absolute size of the market expands.

Renewable gains are so far primarily in electricity generation; heat, cooling, industry and transport lag behind

Only 30% of final world energy consumption is in the form of electricity[7]. Total decarbonisation of the economy is required by later this century to avoid catastrophic climate change. This does not only have to be achieved by renewables: nuclear power and carbon capture, use and storage (CCUS) also have a role. However, renewables will have to enter markets beyond electricity.

Winter heating in high latitudes relies mostly on natural gas, in North America, northern Europe, Russia and Argentina, while China is converting domestic heating from coal to gas. Winter demand is large and creates a major peak compared to summer. This makes it hard and expensive to meet solely by electricity. Solar power is weak in winter and wind power can fall almost to zero during spells of cold, clear high-pressure weather systems, or during fierce winter storms.

FIGURE 04: **POWER GENERATION BY SOURCE**[8]



There is considerable debate over the alternatives, which include hydrogen (made using renewable energy and distributed through a re-jigged gas grid), synthetic natural gas or biogas, passive solar heating in well-insulated homes, geothermal heating (widely used in Iceland), district heating using waste heat from power plants or industries, and electrically-driven, highly efficient ground-source heat pumps.

Cooling in sunny climates is more straightforward: electric systems are already sized to meet air-conditioning demand, solar power output is at its maximum in summer daytime, and solar thermal systems can even provide air-conditioning directly via absorption chillers.

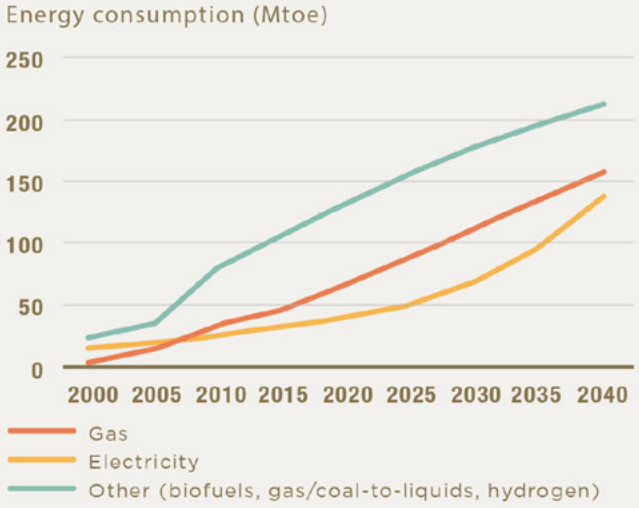
Industry's energy needs are widely varied, from high-temperature and low-temperature heat to electricity. Some industries can vary their electricity demand to favour off-peak periods while others require a steady supply. Again, a mix of renewable options will likely be adopted, alongside synthetic fuels for high-temperature processes, and CCUS for industries such as cement.

Currently, renewables' role in transport is mostly confined to biofuels, which provide a limited share (1.58 Mboe per day in 2017, versus 28.8 Mboe per day of gasoline, diesel and kerosene[9]). Yet, at least in BP's scenario, synthetic fuels (biofuels, coal/gas-to-liquids and hydrogen) still provide a larger share of transport consumption than electricity to 2040 (but a bigger share of final energy services because electric motors are more efficient).

Renewables and other components of a low-carbon power grid are likely to charge electric vehicles, and possibly even short-range shipping and aircraft as battery energy density

improves. Otherwise, aviation will rely on biofuels or other synthetic fuels, such as hydrogen, to cut its carbon footprint. Norway hopes for all short-haul flights from its airports to be electric by 2040[10]. Some ships are adopting solar power and sails to provide a share of auxiliary power.

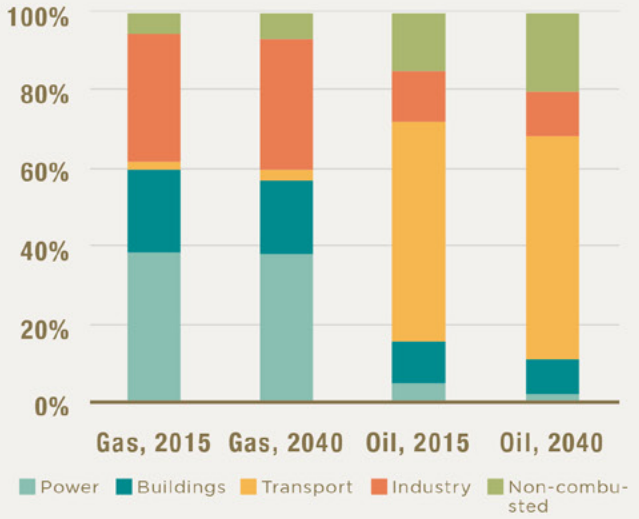
FIGURE 05: **NON-OIL CONSUMPTION IN TRANSPORT[11]**



Gas is an ideal complement for variable renewable energy

Very little oil is used for power generation (about 5% of world consumption in 2015). Conversely, about 39% of world gas use in 2015 was for power generation. Most oil is used in transport, where, as noted, the likely big competitor is electric vehicles. BP's view is that this will not change much even by 2040 (FIGURE 6). However, there are more aggressive scenarios for the replacement of oil in transport, in which it would be increasingly confined to aviation and petrochemicals.

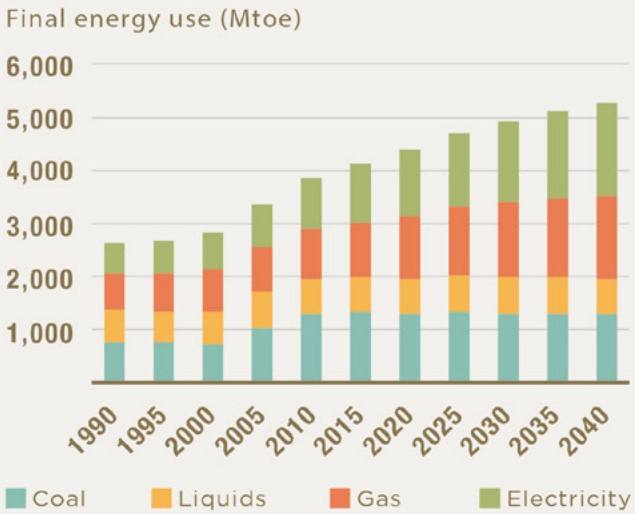
FIGURE 06: **WORLD OIL AND GAS USE BY SECTOR, 2015 & 2040[12]**



Gas is an ideal complement for variable renewable energy, due to the relatively low capital cost of gas-fired turbines and their ability to ramp up and down quickly. This may help gas gain market share from coal and nuclear in the medium-term. However, a growing penetration of renewables does imply that the utilisation of gas plants, and hence their consumption, will fall. Eventually, gas will have to compete with a combination of renewables plus storage.

Electricity will take up a growing share of final energy use (FIGURE 7), and most of the growth is likely to be supplied by renewables. While oil becomes increasingly concentrated in transport and petrochemicals, gas's main opportunity is to gain market share from coal and oil in industry and home heating. Shipping is another area where gas (as LNG) could displace oil, given tightening IMO regulations and likely restrictions on CO_2 emissions.

FIGURE 07: **HISTORIC AND FORECAST FINAL ENERGY CONSUMPTION**



Finally, gas could be converted to hydrogen, with CCUS to prevent CO_2 emissions, and used as a clean fuel in transport, high-temperature industry, power generation, energy storage and heating. This can complement hydrogen produced by renewable methods – thermal or electrolysis of water.

Conclusions: Implications for leading oil and gas producers

Renewables' steady fall in costs, particularly for solar and wind, is likely to continue even if there are no major technological breakthroughs. Renewables are already at or below cost parity with conventional generation in many markets. Their market share is still small, though growing rapidly, and conventional forecasts are likely to prove conservative. Leading hydrocarbon producers have to incorporate the expectation of significant renewable growth into their strategies.

Major oil and gas resource holders with sunny and/or windy climates – which includes much of MENA as well as parts

of Africa, Latin America, Central Asia and Australia – have a growing opportunity to incorporate solar and wind into their energy mix. Bioenergy, hydroelectric and geothermal are also applicable in hydrocarbon-exporting countries such as Brazil, Nigeria, Angola and Indonesia. This can save oil and gas for export at world market prices; lower the cost of electricity generation on an unsubsidised basis; produce an electricity surplus that can add export revenues, and; reduce both greenhouse gas emissions and local pollution.

To achieve this, they have to tackle three main tasks:

• Eliminate or at least focus energy subsidies so they do not discriminate against renewables in favour of hydrocarbons;

• Enhance the investment system for renewable energy, both large-scale and distributed (rooftops and smaller industrial and commercial installations);

• Ensure large-scale renewable procurement is in the hands of a capable and motivated entity, whether the electricity utility, energy ministry or a specialist body.

Hydrocarbon exporters can lower unsubsidised electricity generation costs, reduce their environmental impact, and save oil and gas for export, with large-scale renewable projects at home. This may require reform of gas and electricity markets and subsidies.

In the medium-term, gas will gain market share in power generation from coal, oil and nuclear, as flexible turbines complement variable renewables. However, in the longer term, the utilisation factor of gas-fired plants will drop, even if total capacity rises, and so demand growth will slow down or even reverse. To maintain competitiveness against renewables and other alternatives, gas prices need to remain moderate.

Oil is not significantly affected directly by the rise of renewables, but gains in electric and synthetic-fuel vehicles is a significant threat to oil demand. Renewables can also displace oil in industrial and domestic heating, and its limited role in power generation.

To diversify their economies and to hedge against a diminishing role for hydrocarbons, leading oil and gas exporters can invest in renewables both domestically and abroad. This can include local manufacturing and R&D to tailor renewables to their unique needs – for instance, in MENA, providing cooling and desalinated water.

The rise of renewables and their increasing competitiveness certainly poses challenges to leading oil and gas producers. Future strategies for petroleum output, and estimates for demand and price levels, have to allow for the possibility of renewables growth well beyond current mainstream projections. However, investment and deployment of renewable energy can also generate great value if embraced, and improve the economic and environmental robustness of hydrocarbon-based countries.

References

1. Qamar Energy analysis based on Fraunhofer Institute https://www.ise.fraunhofer.de/content/dam/ise/en/documents/publications/studies/EN2018_Fraunhofer-ISE_LCOE_Renewable_Energy_Technologies.pdf, Lazard https://www.lazard.com/perspective/levelized-cost-of-energy-2017/

2. https://www.iea.org/media/workshops/2018/aces/NikolasSOULOPOULOSBNEF.pdf

3. Based on Strategy&, https://www.strategyand.pwc.com/reports/the-outlook-for-renewable-energy-in-the-gcc

4. https://www.pv-tech.org/guest-blog/unbelievably-high-energy-yield-of-a-bifacial-pv-system-why-average-120-addi

5. http://www.worldwatch.org/node/4803, https://www.technologyreview.com/s/534511/a-cheap-material-boosts-solar-cells-by-50-percent/

6. https://www.vox.com/energy-and-environment/2017/4/7/15159034/100-renewable-energy-studies

7. https://eneken.ieej.or.jp/data/7748.pdf

8. From data in BP World Energy Outlook 2018

9. BP Statistical Review of World Energy 2018

10. http://www.bbc.com/future/story/20180814-norways-plan-for-a-fleet-of-electric-planes

11. From data in BP World Energy Outlook 2018

12. BP World Energy Outlook 2018