THE CHANGING ENERGY LANDSCAPE IN THE ATLANTIC SPACE

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"A paradox lies at the heart of the Atlantic Basin's energy future – it may be richer in seaborne fuel, but this will be oil, gas and coal that it should not burn" (Isbell 2014)[1].

Introduction and context

In 2015, the world reached a critical inflection point in an accelerating, irreversible process of disruption and reconfiguration of its energy systems. The new "Age of Energy Transformation" is driven by technological innovation and new business models that are changing the relative costs of various energy supply options, heightened concerns over the dismal economics and risks of nuclear power, and the recognition that continued use of fossil energies will make the planet largely uninhabitable. Global overheating, ocean acidification and disruption of the marine web of life, desertification on land and loss of fertile soil, and loss of natural resilience as ecosystems become overstressed are dangers the world community needs to address. The growing possibility that human societies might one day no longer adapt and therefore perish is dawning on more leaders around the world. The origin of this present threat lies in the Atlantic Space, in the nations on the four continents around the Atlantic Ocean. Many of the solutions are found in the same space.

The outlook for energy industries has changed significantly with recent declines in the prices of coal, oil and gas. Up to the end of 2013, one could argue that an Atlantic fossil energy renaissance was underway: fossil energy extraction was on the increase and ongoing exploration reinforced the belief that production would keep expanding in the medium to long term. Having been a net importer of fossil energy, the Atlantic seemed set to become a net exporter. This was in part a result of fracking for oil and fossil methane in the US. It was also the outcome of technological advances and cost reductions in existing oil and gas extraction as well as the prospect of new development, such as offshore fields on the coasts of South America (Brazil) and Africa (Angola).

1. This chapter is loosely based on Isbell (2014). In view of shifts in energy prices, however, the overall conclusions of this chapter are different.

The global energy systems all have their technological origin and economic heart in the Atlantic, and were "exported" (in various ways) to other basins or regions. This is obvious in the case of fossil energies.

Since early 2014, doubts about the future of the fossil fuel industry have grown. Recent price levels have undermined the expectation of future profits from new exploration and field development, while also reducing the profitability of existing extraction. It appears likely that many of the new discoveries will not be developed, and that fossil energy extraction in the Atlantic Basin may not expand as hoped for. At the same time, there is a continued shift towards renewable energy supply, which erodes demand for fossil energy in the Atlantic and increasingly also in other world regions (Lovins 2015). This development may be called the "Global Green Energy Shift", and it looks like frustrating the "Atlantic Energy Renaissance".

In order to explore these dynamics and how they might shape the Atlantic energy landscape, this chapter first takes stock of the components of the Atlantic energy system and how they came to be. We find that all the world's energy systems are Atlantic in their historical origin as well as their current economic profile. Among the different energy systems, fossil and nuclear energies are set to wane while renewable energies grow in importance in a process that will prove to be disruptive for the old energy industries. Although the outlook is somewhat uncertain, it is likely that the Atlantic will continue to dominate world energy systems.

The world's energy system is Atlantic

Fossil fuels: coal, oil and gas

Atlantic energy systems are not fundamentally different from those elsewhere. In the Atlantic, the energy systems are older and more developed with significantly greater economic volumes and technological depth. Indeed, the global energy systems all have their technological origin and economic heart in the Atlantic, and were "exported" (in various ways) to other basins or regions. This is obvious in the case of fossil energies:

- While fossil energy sources have been known since antiquity, their large-scale industrial use was only developed in the past 200 years, starting on the eastern side of the Atlantic. Previously, wood had been the most important source of storable and transportable energy, not only in domestic heating and small trade activities such as blacksmithing but also in mining and industry.
- The invention of the steam engine by James Watt enabled the operation of much more powerful pumps than before, making it possible to dig deeper coal mines. Steam engines also increased demand for coal in many applications beyond the mines. The growth of the coal industry – deep-mined hard coal and surface-mined brown coal or lignite – is closely connected to the inventiveness of European and later American culture that emerged with the decline of religious and feudal powers. The development of capital markets within "liberal" political systems based on the rule of law and due process, and a judiciary operating without fear or favour, further propelled economic growth.
- The development of technologies for mining and coal use was and to an extent still is concentrated in the Atlantic. Shifts to the Pacific, such as with coal liquefaction moving from Germany to South Africa, then

to Australia and China, are a relatively recent phenomenon. The somewhat absurd concept of "clean coal", used first in relation to liquefied coal and later for carbon capture and storage (CCS), is also an Atlantic invention.

- Oil and gas extraction and use grew to industrial scale in the Atlantic Basin. Although it is a global industry now, many of the leading businesses still have their origin, operational basis and legal headquarters around the Atlantic. The industry's technology sector is essentially Atlantic. "Enhanced" oil and gas recovery technologies – notably improved computer modelling of underground geology, directional drilling and hydraulic fracturing of oil-and-gas-bearing rock (fracking) – all have their roots in the Atlantic.
- Today, the Atlantic holds a large share of the world's unexploited fossil reserves, including 40% of oil, 20% of natural gas and roughly 40% of coal (BP 2015), and yet the future of the industry is not certain. Large profit margins (in the past) and subsidies have made it possible to access unconventional and difficult hydrocarbon reserves. New technologies have played a role, particularly in the North American shale revolution – shale gas is now over 35% of US gas production, up from 2% in 2000 – and the southern Atlantic "oil ring" with deep-water offshore oil rigs from Namibia and Morocco to Argentina and the Gulf of Mexico (Isbell 2014), but their further expansion is in doubt given current and projected oil prices.
- If the Atlantic currently accounts for less than half of global fossil fuel production, it currently still consumes more than half. With new oil and gas finds, notably off the shores of Brazil and Angola, some see rising shares in global production and a bright Atlantic future for fossil energy industries. Pipelines – built recently or being planned – and investment in seaborne transport of "liquefied natural gas" – compressed fossil methane, a power greenhouse gas contributing to global overheating – might add to intra-basin trade in oil and gas and derivative products.

This short historical sketch highlights the Atlantic Basin – North and, increasingly, South – as the birthplace and home of fossil energy systems in terms of development and mastery of technology, development of business models and economic weight, investment and control through ownership of technology, industry assets and underground reserves. Fossil energy has propelled the Atlantic nations to their present position, and has resulted in an enormous legacy – of costs and benefits – that is still being added to on the cost side. The processes of global overheating, ocean acidification, desertification and sea-level rise are now creating previously unknown stress on human civilisation, triggering or aggravating conflicts and even wars, and eroding the carrying capacity of ecosystems to the point that the Atlantic fossil fuel legacy is threatening the civilisation partly built on coal, oil and gas. The consequences on the Earth's climate of deforestation and using fossil fuels were also first articulated in the Atlantic. The earliest may have been US Congressman George Perkins Marsh from Vermont in an 1847 lecture for the Agricultural Society of Rutland County[2]. Better known are John Tyndall of Britain, who in 1860 demonstrated the infrared absorption capacity of carbon dioxide (CO_2), the main mechanism behind the greenhouse effect leading to global overheating that was then better explained in 1896 by Svante Arrhenius of Sweden.

2. For more information, see http://memory.loc.gov/cgi-bin/query/r?ammem/consrvbib:@FIELD%28NUMBER%28vg02%29%29

Electricity is the "good" Atlantic, while …

The story of the electricity industry is similar. From Benjamin Franklin via Thomas Edison and Nicola Tesla to Werner von Siemens, all the main discoveries, inventions and innovations have taken place in Atlantic Space countries. The physical units in electrics and electronics are mostly named after Europeans. The globally dominant paradigm of the electric power industry, to "predict and provide" for demand, was born in the Atlantic Basin and is linked to the specific conditions of business and industry development "in the West". The conceptual bases, economic thinking and legal traditions by which the electricity industry is governed around the world were all developed in the Atlantic nations. The export of governance frameworks for the power industry as an "enabler of progress" is one of the mechanisms through which the Atlantic countries have exported their civilisation, governance systems and lifestyles around the world.

… nuclear power is the "bad" Atlantic, but …

The Atlantic pedigree is most obvious in military and "civilian" nuclear technology. Nuclear science and technology were founded almost exclusively by Europeans, from the discovery of uranium by Martin Klaproth in 1789 to the understanding of radiation by Wilhelm Röntgen, Henri Becquerel, Paul Villard, Marie Skłodowska-Curie and Pierre Curie in the 1890s, and Albert Einstein's theoretical insights first published in 1905. Building on insights from the early 20th Century, Otto Hahn, Fritz Strassmann, Niels Bohr, Lise Meitner and Otto Frisch developed scientific understanding and prepared the emergence of military weapons technology during World War II. Key figures in the ensuing transatlantic race to build atomic weapons were Francis Perrin, Werner Heisenberg and Rudolf Peierls on the European continent, where notably Germany abandoned serious attempts in 1942, and Otto Frisch, Rudolf Peierls, Philip Baxter and James Chadwick in Britain, before Robert Oppenheimer and others built atomic bombs in the Manhattan Project in the US on the American side, while the Soviet Union, led by Russia, also drawing on German science and scientists, developed their own weapons technology. Edward Teller later developed the more advanced and even more powerful and dangerous hydrogen bomb. The fallout from the technology happened mostly in Asia and the Pacific, from nuclear tests to the bombings of Hiroshima with a uranium bomb and Nagasaki with a plutonium bomb.

The scientific insights, materials and technology of nuclear weapons were used by Enrico Fermi and then others to build the first primitive "reactors" where nuclear chain reactions could be controlled, which is a much more complex undertaking than ensuring a one-off nuclear detonation. Nuclear reactor technology spread mainly from the US and Russia, which had a similar technology base, to other countries that now have nuclear reactors. The dream was to have nuclear power that was "too cheap to meter", even though there were early warnings that this was a false hope. Rather than redeeming the evil horrors of nuclear weapons by providing limitless energy to the world, nuclear technology was found to be inherently risky and never became economically viable without subsidies and privileges.

Today, 9 of the top 11 nuclear power-producing countries are in the EU, and 10 are in the Atlantic Space. While there are non-Atlantic countries with significant nuclear power programmes, notably China and Japan (even though most reactors in Japan have been turned off since the catastrophic nuclear tragedy in Fukushima), the industry remains dominated by Atlantic nations. The unresolved legacy of nuclear waste from the industry is mostly Atlantic, but the fallout from accidents from nuclear power plants is also mostly shared between the Atlantic and the Pacific, with Kyschtym in Russia and Sellafield in Britain (1957), Three Mile Island in the US (1979), Chernobyl in the Ukraine (1986) and Fukushima in Japan (2011) being historical milestones in a long series of nuclear and radiation accidents and incidents.

The international regime governing nuclear weapons and energy technology is an Atlantic conception, and is enforced predominantly by Atlantic nations. The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) and the statute of the UN International Atomic Energy Agency (IAEA) establish conditions for access to nuclear technology and thus ensure its propagation throughout the world, a practice that carries a hefty security policy price. A series of conventions – the Paris Convention of 1960, with the 1963 Brussels Supplementary Convention, and the Vienna Convention of 1963 and subsequent instruments – limit cross-border liability for damages caused by nuclear accidents and thus protect the builders, owners, operators and host countries of nuclear power plants. This regime is heavily skewed towards favouring nuclear power generation at the expense of other energy technologies and public health and safety.

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… on the way down and out, in the Atlantic and beyond

The dismal economics and concerns over plant safety, the waste legacy, international proliferation and the ensuing security policy price brought nuclear power into a downward trend worldwide, with it being phased out in a number of Atlantic countries and, in a haphazard way, perhaps also in Japan. Overall, the rate of new construction of nuclear power plants is insufficient, by a wide margin, to compensate the loss of nuclear power generation capacity from plant closures. Uprating plant capacity and lifetime extensions slow the decline somewhat but cannot break the accelerating erosion of recent years.

A majority of EU member states now either have no nuclear power, an explicitly stated and legally enshrined phase-out policy, or a de facto phase-out policy for economic reasons where there are no plans for new power plants to replace ageing ones slated for decommissioning in coming years. A small minority of member states are currently building new plants, all of the them beyond deadline and over budget, and all of them in need of subsidies to survive in a competitive market now increasingly dominated by renewable power generation in combination with existing and emerging energy storage technologies tied together in a smart electricity grid with bi-directional flow and signal-processing capacity becoming the norm.

There is residual interest in new nuclear power plants in some Atlantic countries, including South Africa, but with the technology being clearly not economically viable, any new construction must be assumed to be motivated by military intentions to procure nuclear technology, materials and equipment, perhaps not to build nuclear weapons but at least to have the option available. Essentially, the role of nuclear power in the Atlantic energy systems is slowly ending, with no new nuclear technology emerging that would assuage concerns over cost, safety, waste and proliferation.

Promise of transformation: the Atlantic's renewable energy

Developed and matured notably in the Atlantic, renewable energy technologies have recently become cost competitive in many geographies and situations. Having reached the cost parity point with (subsidised) fossil and nuclear energy and continuing on a downward cost trend, renewable energies are destined to displace fossil and nuclear energy. In fact, all future investment in new generation plants should go towards renewable energy technologies, for economic reasons alone.

Water wheels, windmills and the use of biomass, in the form of wood, for instance, are traditional forms of renewable energy as long as the principles of sustainable management and harvest are observed. Until coal was used as the first fossil energy, wood was the most important source of energy. The concepts of "sustainability" and "sustainable management" were developed in the Atlantic Space, in Saxony between the Elbe and the Weser river basins, with reference to forestry and the use of wood in mining. *Sylvicultura oeconomica*, the seminal work on forestry practices by Hans-Carl von Carlowitz (2013 [1713]) first spelled out the principles of sustainable management of natural resources, addressing the optimal management of forests and the rational use of forest products under threat of overexploitation. Mining was the main user of timber at the time – the one that threatened the health and long-term existence of Saxon forests. Wood was essential for structural work and as a source of energy in mining operations. If humanity had remained restricted to the use of wood as a fuel, the industrial expansion would either have been much slower, or would have ended for lack of fuel some time ago. The age of Atlantic domination would not have happened.

All the modern renewable energy technologies have their cradle in the Atlantic Space, even if Asian countries, notably Japan and China, played their role.

- Photovoltaic cells for the direct conversion of sunlight into electricity were developed in the US, survived and matured in Japan, before policy innovation in 1990 created a growing market in Germany. Today, the manufacturing base is partly in China, but the Atlantic Space still dominates installed photovoltaic capacity and new installation.
- Wind turbines – much advanced from the traditional windmills – are an important part of the renewable energy industry, both onshore and offshore. They were first deployed in large numbers in the US, notably in California, in the 1980s, in a regulatory framework that did not nurture the successful operation of the plants and continued improvement of technology. It then moved to Denmark and Germany before becoming a global industry. Again, the majority of installed capacity

and new investment today is (still) in the Atlantic, although India and China are increasing the weight of the industry in the Indian and Pacific basins.

- The most successful and efficient modern system of producing liquid biomass for the transport sector is the conversion of cane sugar to ethanol, a technology dominated by Brazil and increasingly applied, with Brazilian assistance, in Africa. The conversion of corn (maize) to ethanol, notably in the US, does not produce energy rents similar to the conversion of sugar cane to ethanol, but it is a sizeable business. The only significant bioenergy not dominated by the Atlantic is the controversial production of palm oil (in Asia and the Pacific Basin) for use as biodiesel (in the Atlantic Basin); it is controversial because of detrimental land-use changes triggered by the growth of the industry and the essentially unsustainable nature of production.
- Other renewable energies, from marine or ocean energy to geothermal energy, are still emerging. In general, they can be expected to be developed mainly in the Atlantic Basin, with the possible exception of geothermal energy, where the countries around the volcanic Pacific "Ring of Fire" may have an advantage.

The old and partly dying energy systems in the world are Atlantic in origin and still dominated by the Atlantic, and the emerging energy technologies and system reconfigurations are also mainly developed in the Atlantic, but with a growing contribution from Asia.

The growth of renewable energies and the transformation of energy systems is enabled or facilitated by advances in information and communication technologies. Commonly known as "smart grid" technologies, they change the character of electricity grids, allow for electric cars to be plugged into the power grid with two-way communication so that the car batteries can provide grid stabilisation services, enable demand response to ensure the dynamic efficiency of the system as a whole (rather than of each component in isolation), and help create new and economically interesting links between electricity and gas distribution grids.

Some of the most promising technologies emerging in the Atlantic that would provide new options for energy storage, transport and conveyance are (various approaches in) the conversion of power-to-gas or power-to-liquid fuels or raw material feedstock for the chemical industry. The idea is simple. When there is insufficient demand, renewable wind or solar power, which fluctuate in their availability irrespective of demand, is used to split water (2 H_2O) into hydrogen (2 H_2) and oxygen (O_2). The H_2 is then combined with carbon from carbon dioxide (CO_2) from the atmosphere or the off-gas from combustion processes to form first methane (CH_4) and then longer chains of alkanes and their derivatives. The products are gaseous and liquid fuels, which can be integrated into existing infrastructure that is a legacy of the fossil oil and gas industries. Power-to-gas and power-to-liquid technologies are expected to be cost competitive as soon as the penetration of renewable energies is such that there is "surplus" renewable power often and long enough to operate the conversion plants for thousands rather than hundreds of hours per year.

In conclusion, the old and partly dying energy systems in the world are Atlantic in origin and still dominated by the Atlantic, and the emerging energy technologies and system reconfigurations are also mainly being developed in the Atlantic, but with a growing contribution from Asia, especially Japan and China. The legacies of the fossil and nuclear energy systems will remain a heavy responsibility for the Atlantic nations, and they would do well to cooperate in their management. This applies to global overheating and other consequences of pollution with greenhouse gases (which also result in the acidification of the oceans) and the nuclear waste and the risk of nuclear accidents and atomic weapons being used as a consequence of decades of nuclear proliferation promoted mainly by the nations of the (North) Atlantic Space.

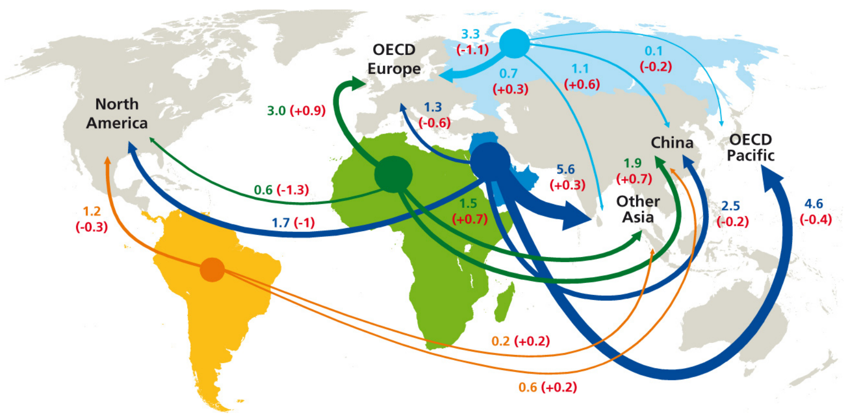
The status and trends of the Atlantic energy system

As a consequence of the high level of economic development in many Atlantic nations, the long-standing energy systems in the basin, and recent discoveries and developments, the Atlantic Basin in 2013 accounted for roughly:

- 40% of global proven oil reserves;
- 44% of daily global oil production, expected to rise to 47% by 2030;
- 67% of global "technically recoverable" shale and tight gas;
- 77% of global installed solar power capacity;
- 64% of global installed wind power capacity;
- 59% of global installed geothermal energy capacity;
- 75% of modern renewable energy production & consumption (excluding hydropower);
- 75% of investment in renewables (in 2006); the Atlantic is now falling behind Asia.

The extraction of shale oil and gas in the US has increased the competitiveness of that segment of the fossil fuel industry, at least for a while. The United States surpassed Russia as a producer of natural gas in 2009, and may yet overtake Saudi Arabia in the near future. Shale oil and gas alone contributed 283 billion dollars to US GDP in 2012. Shale oil and gas production is also driving the US petrochemical industry, in which 197 billion dollars has been invested as of 2014 (Batson 2015).

Figure 1. Crude exports in 2017 and growth over 2011-2017 for key trade routes (million barrels per day)*



* This map is without any prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.
Source: IEA 2012b.

Isbell (2014) describes the result as a shifting away from the "Great Crescent" – the Middle East, Central Asia and Russia – as the traditional centre of fossil fuel production towards the Atlantic Basin, which has been able not only to meet its own needs but also to become the dominant supplier to the Asia-Pacific region. In addition to shifting the world's energy flow, the production of expensive tight oil – shale and deep-water – has outpaced demand. This supply and demand discrepancy contributed largely to the fall in energy prices and subsidies to the fossil fuel industry over 2014 (Berman 2015).

The expected future trade patterns and the degree of regional self-sufficiency particularly in the Americas are shown in the map represented in figure 1.

The changing economics of various competing energy technologies, and notably the decline in costs of renewable power and storage, indicate that future investment is more likely to flow into renewable energies than fossil energy.

2013 vision: an Atlantic fossil energy renaissance

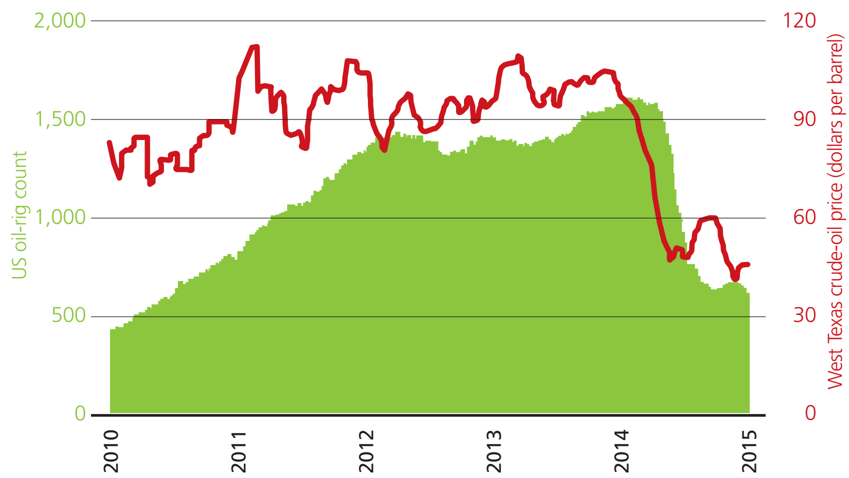
Based on data and trends until 2013, Isbell (2014) has described an emerging "Atlantic Energy Renaissance" in which Atlantic fossil fuel production increases and will continue to grow due to the technological ability to extract unconventional hydrocarbons such as shale gas and oil, and deep-water, offshore oil. Expanded fossil energy mining and extraction had already reduced the net fossil energy imports into the Atlantic Basin and would soon reverse the net trade and make the Atlantic an exporter into the Indian and Pacific regions. This (projected) shift in inter-basin energy flow presented opportunities for the fossil energy sector, while potentially undermining renewables by lowering fossil energy prices.

However, the renewable energy concentration in the Atlantic and maturity of the industry may also present opportunities, especially as the costs of renewable energy (and storage) technologies continue to decline by 15% to 25% a year. In view of the current and projected mid-term fossil energy prices, the Atlantic energy renaissance may not happen, as new production in the Atlantic cannot compete with lower-cost fields in Arabia and possibly also Iran. Overall, the changing economics of various competing energy technologies, and notably the decline in costs of renewable power and storage, indicate that future investment is more likely to flow into renewable energies than fossil energy.

2015 reality check: decline of fossil energy

The price of oil has halved since the beginning of 2014, which has also resulted in a halving of the oil drilling rigs in operation, as is illustrated by figure 2. The fossil fuel industry used to and currently still continues to reap most of the monetary benefits of the rising energy demand. Lower prices, however, erode the profitability of the sector, and stock market valuations for many of the larger companies and the sector as a whole have declined, in some cases by more than 90% since 2008. Conversely, the renewable energy sector keeps growing, albeit at a somewhat reduced pace, in spite of falling fossil prices. The Atlantic Space holds over 70% of global installed renewable energy capacity (Tedsen and Kraemer 2013).

Figure 2. Rigged market



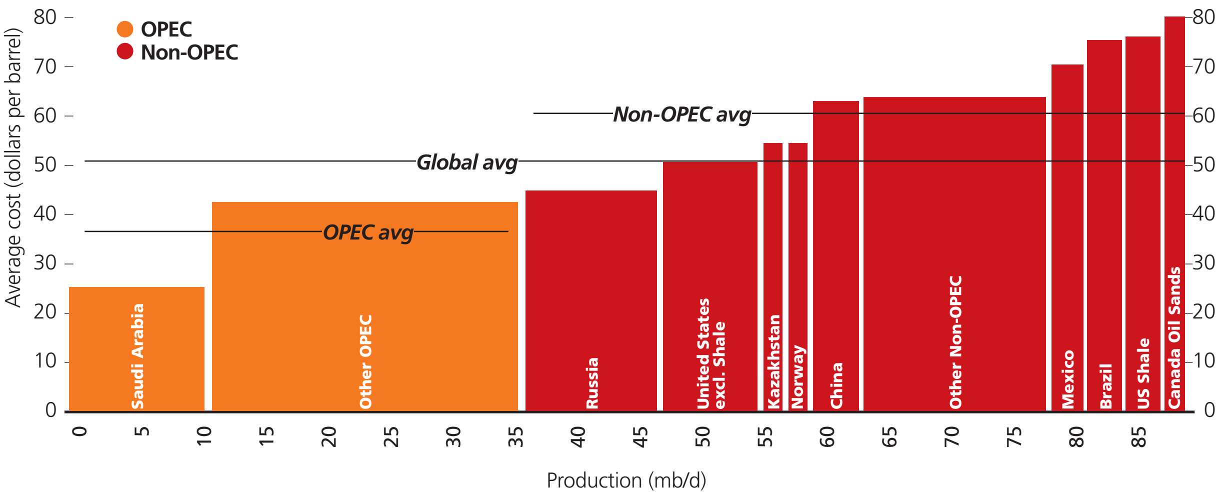
Source: *The Economist* 2015. Original sources: Baker Hughes; Thomson Reuters.

The effect of falling oil prices on deep-water offshore drilling is unclear but may be significant given the large price tag of such projects. Estimates hold that if oil prices average between 50 and 70 dollars a barrel, the number of deep-water wells might increase by 32% (Jervis 2015; Shauk 2015). Production in the Gulf of Mexico alone was projected to increase 21% in 2015. Companies with deep-water wells in that area predict that the price would have to plummet to around 20 dollars per barrel before they begin to scale back production from existing wells (Jervis 2015). Drilling was proposed and may still take place off the coast of Morocco in order to harness oil reserves off the country's Atlantic coast, while Norway planned to proceed with a deep-water project in the North Sea that by 2019 would produce 380,000 barrels of oil equivalent per day (Spencer Ogden 2015). Similar deep-water drilling prospects are also being explored off the coasts of Namibia and Argentina. All of these projects were conceived and commenced before the recent collapse in oil and gas prices, and it remains to be seen how many of them are brought to conclusion and make a profit while they extract fossil fuels.

The overall effect of the lower oil and gas prices can be gauged from figure 3. The lowest cost production is in Saudi Arabia, followed by other OPEC countries and Russia (on the left-hand side of the figure). The production that is supposed to underpin the Atlantic energy renaissance has much higher average costs and is thus on the right-hand side of the figure: Canadian oil sands, US shale, Brazilian pre-salt offshore oil and Mexican oil. If low oil and gas prices persist for some time, if the demand for fossil energies is in long-term decline because of energy efficiency gains and the rise of renewable energies, the higher cost production would cease to be brought to market: the Atlantic energy renaissance would not happen.

The underlying dynamics – namely policies promoting energy efficiency, renewable energy and storage to prevent accelerated global overheating, ocean acidification and sea-level rise, as well as growing pressure to cut back on perverse subsidies for fossil (and nuclear) energy – are projected to persist and support a shift towards a wider transition to renewables, particularly in the Atlantic Space, as the energy demands in developing countries in both Africa and Latin America continue to grow to 2020 and beyond (Tedsen et al. 2015).

Figure 3. Cost of oil production (country averages) and production levels (2014)



Source: Raval 2014.

The Atlantic green power shift

Spurred by growing concerns regarding the implications of global climate change, many governments have implemented mechanisms to promote the uptake of renewables. The European Union has achieved notable success in this regard, as 15% of energy demands were met by renewable sources in 2013 in line with the 2009 Renewable Energy Directive. Germany is well known for its transition to renewables with its implementation of the feed-in tariff (Laird and Stefes 2009; Stefes 2010; Kraemer 2009, 2011 and 2012). The feed-in tariff has also been introduced in many other countries across the Atlantic Space. The US relies largely on tax credits, subsidies, rebates and renewable portfolio standards (IEA 2012a; Tedsen and Kraemer 2013). Additionally, the Atlantic Space accounts for more than 50% of the world's hydroelectricity generation, particularly in Norway, Latin America and the Caribbean (BP 2015). Sub-Saharan Africa, with the exception of South Africa, has increasingly turned to hydropower, which now accounts for 60% of electricity generation in that region (Behrens 2011; Tedsen and Kraemer 2013).

Despite such strides to promote the renewable energy sector, economic path dependency and, until recently, large profits for the fossil fuel industry provide it with considerable advantages. Profit margins earned by the fossil fuel industry are due in large part to subsidies and privileges provided by central governments around the world. The International Energy Agency (IEA) (2015) estimates that in 2014 global fossil fuel subsidies amounted to more than 550 billion dollars. The IEA framework for estimating these figures intentionally leaves out externalities, including taxpayer money to offset the environmental and health consequences of the fossil fuel industry, as well as tax breaks, loopholes and incentives. The International Monetary Fund (IMF) has estimated that when accounting for such externalities, around 5 trillion dollars is provided in fossil fuel subsidies annually (Coady et al. 2015). By comparison, the renewable sector received only 120 billion dollars in 2014 (IEA 2015) and produces relatively few social or environmental costs.

In addition to the "green shift" from fossil to renewable energy and the decay of nuclear power in the Atlantic Basin, there is also a strong and accelerating drive for energy efficiency.

Though the shifting energy flow resulting from increased fossil fuel production in the Atlantic Basin in recent years has called into question the rate of growth in the renewable sector of the energy industry, political momentum in the face of the climate crisis and improving economics point to the continued growth of renewable energy. Models of successful transitions to renewables already exist in the Atlantic Space, including Germany, Denmark and Spain. Outside Europe, solar energy is already competitive in the southern Atlantic and Isbell (2014) has described Africa's potential to leapfrog fossil fuel-dependent development in favour of a more sustainable energy model through the provisions of the UN's "Sustainable Energy for All" initiative. Maria van der Hoeven (2015), the executive director of the IEA, has also suggested that the recent drop in energy prices has created a critical juncture in which countries have the opportunity to abolish – or at least drastically decrease – fossil fuel subsidies without producing severe inflation. She also suggests depoliticising and improving the transparency of energy pricing. Low fossil energy prices thus provide an opportunity to accelerate the transition towards renewable energy.

In addition to the "green shift" from fossil to renewable energy and the decay of nuclear power in the Atlantic Basin, there is also a strong and accelerating drive for energy efficiency. This relates to the efficiency of individual installations or equipment and whole energy systems with improvements in energy system management, which allow for demand response and flexibilities to enhance the dynamic efficiency of system behaviour over time. This shift from static efficiency of energy system components towards dynamically efficient behaviour of components within larger systems is the result of new IT technologies and the development of new business models that create value from flexibility by reducing needs for capacity. The resulting transformation of energy systems is beginning to move beyond the power grid to affect gas systems, heating patterns and the transport sector. The underlying technologies are shared globally, but have their origin and driving forces in large part in the Atlantic Basin. In all respects, the Atlantic Basin energy systems are still dominant, even if their weight may be shrinking, particularly in relation to East and South Asia.

Conclusion

The current pre-eminence of Atlantic nations in world affairs is largely due to their history of exploiting fossil energy, originally many millennia's solar energy, stored in biological matter, and now extracted and burned within a few centuries. Compared to the importance of the fossil energy system, the nuclear power sector is a mere footnote. The summary outlook for the energy systems is:

- Nuclear power and fossil energies are down, due to generally rising long-term costs, with companies in many cases heading for write-downs, economic abandonment[3] or insolvency and possible government bailouts, while fracking for fossil methane provides a costly, short-term life extension for parts of the fossil energy infrastructure, underlining its path dependency.
- Renewable energy is up across the board, but in some cases from a low base and at different speeds, with fast cost degression from new inventions, material discoveries as well as technological, business and policy learning curves, particularly in all types of solar energy and storage.
- The roll-out of information and communication technology is accelerating within existing and new energy systems. This transformation is proving disruptive to the old, dirty, dangerous fossil and nuclear energy industries, which therefore resist change and use their economic and political clout as incumbents to slow or even derail the transformation towards clean, safe, sustainable energy systems.

Overall, the Atlantic Space is characterised by two competing energy systems (ignoring the moribund nuclear power sector):

- One is a fossil energy industry using stocks of coal, oil and gas in the earth that was dominant in the past, has the economic breadth and depth to sustain momentum over a period of low prices and eroding profitability, and still enjoys significant subsidies and privileges, which may however be abolished as countries seek to reduce fiscal stress and slow climate change. It is doubtful that technology developments will allow the fossil fuel industry to maintain its current size in the Atlantic Space, especially as it competes with lower-cost producers elsewhere.
- The other is a relatively young and dynamic renewable energy industry using environmental flow resources and biological resources and that is growing. This new industry has achieved cost competitiveness with new coal (and new nuclear) plants and is beginning to erode the profitability and ultimately viability of existing fossil and nuclear plants. The improved economic competitiveness is the result of a technology learning process and economies of scale as the industry has grown. The economic positions are projected to keep improving in the medium and perhaps also longer term. This renewable energy industry is poised to take over from the fossil fuel industry wherever new energy infrastructure is built, or where significant re-investment or expansions are needed.

These two industries will continue to co-exist, one declining and the other growing, with the speeds of decline and growth and their relative weight in various parts of the Atlantic Space determined as much by changes in fossil energy prices as in policies promoting one energy system or the other. In the long run, the continued decline in renewable energy costs gives those technologies the advantage and any fossil fuel-based Atlantic energy renaissance would only be temporary.

As the Atlantic Basin addresses its fossil and nuclear legacies and defines its low-carbon future, the resulting energy transformation has profound impact on the energy industry beyond the technologies employed. One impact stems from the distributed nature of renewable energy technol-

3. See Marc Cooper (2013). The argument was popularised by Michael Grunwald (2011).

ogy, another from the fact that comparatively inexpensive energy-related equipment will be traded rather than comparatively expensive energy carriers, and a third from the prospect that the future energy system will be less expensive overall.

The Atlantic countries are most likely to dominate the future global energy systems through technical, financial, policy and regulatory innovation. They would do well to cooperate to speed up the transition and reduce its overall cost.

Renewable energy generation is by its nature distributed so that renewable power generation – mainly from wind, solar, hydro, geothermal and the oceans – or the harvesting of biogenic renewable fuels – in solid, liquid or gaseous form – can take place closer to the points of consumption, which reduces the need for grid or pipeline capacity. Emerging technologies in (renewable) power-to-gas and power-to-liquid, even if not yet economically viable, offer the prospect of additional energy storage options as well as providing hydrocarbon carbon molecules as raw-material feedstock for the chemical industry. In renewable energy, investments thus come in relatively small lots and are often within reach of individuals, families, communities and local savings associations, even in less developed countries.

In the past, the trade in fuels – coal, oil, gas and products such as diesel or kerosene – was an important part of the global energy industry. Control of technologies and critical infrastructure was important, but the turnover from trade in energy products dominated the sector economically. In the future, the international trade will be dominated by trade in energy-related equipment from solar panels, inverters and wind turbines to batteries and smart energy management systems. The trade in fossil energy products will diminish, and the trade in electricity and biogenic fuels will be more regional or national. Overall the trade volume of the energy industry is likely to decline. It is also likely that the total cost of the future energy system will be smaller per capita of population served, unit of GDP output, or kWh or joules produced. This is mainly a function of the dynamic system efficiency enabled by smart grid technologies, which will over time also affect the transport and heating sectors. The added "intelligence" will obviate the need for the massive overcapacity that characterises the old energy systems.

It is uncertain how exactly the disruptive transformation from the old fossil and nuclear energy systems to cheaper, cleaner and safer renewable energy systems with storage and smart grids will unfold, but the overall trend is reasonably clear, and whatever the detail, the Atlantic countries are most likely to dominate the future global energy systems through technical, financial, policy and regulatory innovation. They would do well to cooperate to speed up the transition and reduce its overall cost.

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