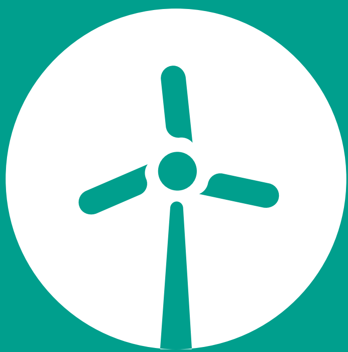
CLIMATE CHANCE

2018

GLOBAL OBSERVATORY
ON NON-STATE
CLIMATE ACTION



ENERGY

BOOK 1

Sector based action

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DIRECTOR OF PUBLICATION
Ronan Dantec, Chair of Climate Chance Associatione

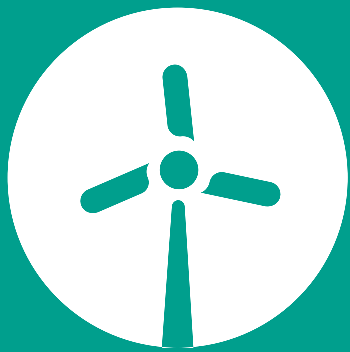
TEAM CLIMATE CHANCE
Vanessa Laubin, *General Director*
Amaury Parelle, *Coordinator, Observatory*
Thibault Laconde, *Energy-climate Consultant, Observatory*
Antoine Gillod, *Project assistant, Observatory*
Bérengère Batiot, *Responsible for Communications and Public Relations*
Veronica Velasquez, *Communication Officer*
Alice Dupuy, *Communication assistant*
Romain Crouzet, *Responsable of Programs*
Leila Yassine, *Program Coordinator Africa*
Coline Desplantes, *Programs assistants*
Vera Tikhanovich, *Programs assistant*
Florence Léchat-Tarery, *Responsible for Administration and Finance*

CONTRIBUTIONS
Germán Bersalli, Jean-Paul Céron, Maylis Desrousseaux, Ghislain Favé, Bertrand Fériot, Sudhir Gota, Aakansha Jain, Aïcha Koné, Bettina Laville, Gilles Luneau, Juliette Nouel, Riya Rahiman, Colas Robert, Guillaume Simonet, Alioune Thiam, Aude Vallade.

GRAPHIC CREATION AND LAYOUT
Elaine Guillemot LATELIERDELESTUAIRE.COM
Elodie Sha

TRANSLATION IN ENGLISH
Solten France Sarl

PARTNER FOR EMISSIONS DATA
Enerdata intelligence + consulting



ENERGY

The long road to low carbon energy

With an electrification rate of 87%, electricity has become a part of everyday life for the vast majority of people around the globe. The production of electricity and heat plays a central role in improving living conditions and economic development, but is also responsible for almost a quarter of man-made greenhouse gas emissions. Achieving a drop in emissions from this sector is therefore a major challenge in limiting the scale of global warming

Head editor• **THIBAULT LACONDE** • *Consultant, Energy & Development*
in collaboration with • **GERMÁN BERSALLI** • *researcher, Univ. Grenoble Alpes, CNRS, INRA, Grenoble INP, GAEL*

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1 • EMISSIONS PUSHED UP BY DEMAND FOR ELECTRICITY

Following a slight drop in 2015, global CO2 emissions in the electricity and urban heating sector rose again in 2016, increasing by 0.4 % to a total of 44 million tonnes of CO2. Preliminary data for 2017 indicates that this rise accelerated last year: within G20 countries, which were responsible for 80% of emissions in this sector in 2016, emissions rose by 1.9% in 2017 (Enerdata).

• EVOLUTION OF EMISSIONS LEVELS • Greenhouse gas emissions linked to the production of heat and electricity have risen by an average of 1.1% over the last 10 years. Emissions levels reached 11.5 billion tonnes of CO2 equivalent in 2016, or around a quarter of global emissions.

The breakdown of emissions is heavily lopsided, with the planet's six largest emitters (China, the US, the EU, India, Russia and Japan) responsible for 70% of global emissions. Even within these groups, emissions are subject to diverging trends - emissions levels are trending downwards in the European Union and the United States, but rising in India and China, and holding steady in Russia. Japan, meanwhile, experienced an emissions peak in 2012 and 2013, due to the increase in thermal electricity production following the Fukushima disaster and the loss of the nuclear power plant there.

These varying dynamics have led to shifts in the ratio of power on a global scale: North America, which has historically been the biggest emitter, was overtaken by Asia in 2000. OECD countries were caught up by non-OECD countries in 2005; India and China are now by far the world's biggest emitters, and their "lead" is set to increase even further in the coming years.

TABLE 1 - GREENHOUSE GAS EMISSIONS (MTCO2E) FROM PRODUCTION OF HEAT AND ELECTRICITY

(source : Enerdata)

	2005	2010	2016	2017
World	**9,638**	**10,910**	**11,591**	**n.a.**
China	2,167.2	3,077.7	3,731.2	3,890.0
USA	2,439.4	2,267.3	1,812.6	1,745.4
European Union	1,294.5	1,175.3	948.9	n.a.
India	494.7	676.2	946.7	974.9
Russia	530.6	544.9	535.3	534.1
Germany	305.5	288.8	273.7	264.9
South Africa	200.0	233.2	231.0	232.9
Saudi Arabia	108.1	142.6	158.0	159.8
Indonesia	71.4	92.9	136.8	146.1
Canada	119.9	101.5	83.4	85.6
United Kingdom	171.9	152.0	73.2	64.1
Brazil	20.7	26.4	44.8	47.8
France	37.4	42.6	22.4	26.8
Morocco	15.7	15.6	22.0	n.a.
Colombia	5.85	9.80	11.84	5.3
New Zealand	8.82	5.31	2.99	3.6
Kenya	1.50	2.08	1.13	n.a.
Fiji	0.275	0.334	0.342	n.a.
Iceland	0.003	0.003	0.002	n.a.
Ethiopia	0.010	0.055	0.002	n.a.

• ELECTRICITY DEMAND CONTINUES TO GROW • These developments are determined by two fundamental variables: demand for electricity and heat, and the respective carbon intensity of each resource.

In 2017, electricity consumption rose by 2.8% compared to the previous year. This increase is

comparable to the rises observed over the previous decade (2006 - 2016): an average of 2.7% per year (BP Statistical Review, 2018). At the same time, global population increased by 1.2% per year, a net increase in electricity consumption per inhabitant of over 1% per year.
This increase is explained by the progress of electrification: between 2006 and 2017, the proportion of the global population with access to electricity increased from 81.2% to 87.4%. This indicates that in 2017, 1.2 billion more people were consuming electricity than in 2006.

Organisation of private electrification

Historically, electrification has been achieved via access, through a national or regional electrical grid, to a centralized electricity production sector. This approach, which is highly capital-intensive, often takes significant time to implement and generally requires strong public support. Renewable energies now allow the creation of small production devices, through which it is possible to produce electricity at the level of an individual household (solar lanterns, solar home system, etc.) or a local area (micro-grid fed by a solar installation or a hydraulic micro-turbine, for example), without requiring access to the national electrical network.
These systems generally emit only low levels of greenhouse gases, but more importantly they enable individuals and small organisations to invest in their own electricity production facilities. Moreover, they are often designed and installed by local companies whose technical skills and equipment needs are much more limited than those required for conventional electrification. Conversely, this type of electrification also poses new problems, notably in terms of ensuring the quality of equipment and installations.
Such problems have been observed, for example, in the development of solar energy in Zambia: imported materials were often of mediocre quality, sales agents provided insufficient advice to users, and there was a general lack of technical skills needed for the installation and maintenance of solar systems. In order to limit these risks without hindering private initiative, the Energy Regulation Board of Zambia implemented a licensing system for importers and installers of solar materials. A code of best practices was established in partnership with companies in the sector and the Zambian bureau for standardization, and a certification training program was set up for technicians.

Source : Energy regulation board of Zambia

TEXT BOX 1

Due to the combined spread of electrification and high birth rates, the fastest growth rates in electricity consumption are found in countries with low levels of economic development. The growth rate has topped 11% in Cambodia, Ethiopia, Myanmar, Laos, Mali, Cape-Verde, Sudan and Côte d'Ivoire. However, consumption in these countries remains very low in absolute terms.

In emerging and industrialized economies, the increase in electricity consumption is linked, above all, to economic growth. In China, electricity consumption rose by 6% in 2017, at almost the same rate as gross domestic product (7%). Chinese electricity production has doubled in 10 years.
In India, the two phenomena are mixed: the growth in demand for electricity exceeded 12% in 2017, well over the 7% growth in economic activity. This difference can be explained by the progress achieved in electrification, with half a billion people gaining access to electricity since 2000 and an access rate that has almost doubled from 43% in 2000 to 82% today (OECD/IEA, 2018).

Together, China and India represented 70% of the global growth in demand for electricity, with a further 10% originating in other emerging economies in Asia.

Even though electricity continues to acquire new uses (mobility, heating, etc.) which can push up consumption rates even in mature economies, developed countries account for only 10% of global consumption increases, with growth rates in electricity demand of less than 1% on average. In the United States, electricity demand fell by almost 80TWh in 2017, compared to 2016 levels. In the European Union, the 2.3% growth in demand (or 75TWh) is equal to the level of economic growth. Demand for electricity also fell in Japan, by roughly 15TWh (OECD/IEA, 2018).

However, it should be noted that rates of consumption per inhabitant remain highly disparate between different countries. As such, electricity consumption per inhabitant in India was only 7.5% of the figure recorded in the United States (ENERDATA, 2017).

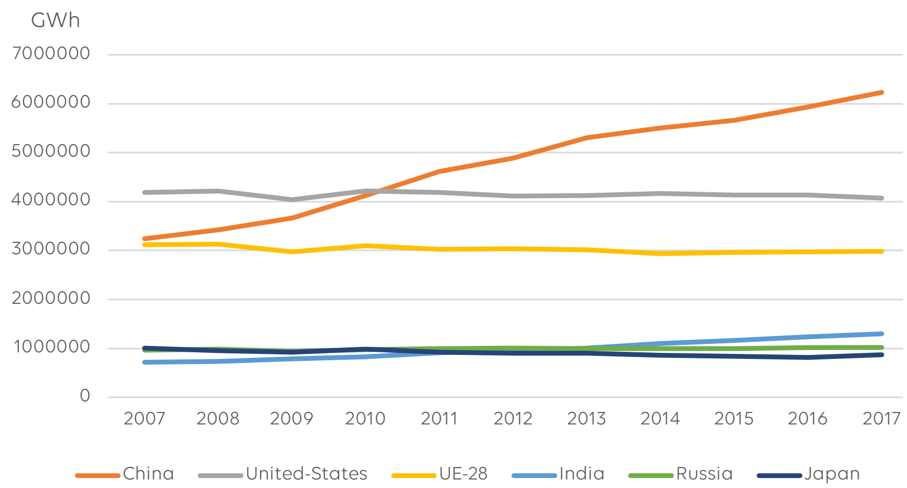

FIGURE 1. PUBLIC ELECTRICITY PRODUCTION

(Source Enerdata)

• EVOLUTION OF THE ELECTRICITY MIX • The carbon intensity of electricity production is the second factor in the explanation of the evolution of emissions levels. Electricity is supplied by a range of sources (or an "electricity mix"), some of which emit high levels of greenhouse gases, such as coal (roughly 880 grams of CO2 per kilowatt-hour produced) or oil (710gCO2/kWh), while others such as gas emit lower amounts (390gCO2/kWh). Finally, the carbon footprint of renewable energies and nuclear is zero in terms of direct emissions, and remains very low if we view these sources in terms of their full life cycle: estimates vary from 18 - 180gCO2/kWh for solar, for example, or from 7 - 56 for wind and 4 - 110 for nuclear (IPCC, 2014).

The proportion of each of these sources in the electricity mix determines the carbon intensity of global electricity consumption. This carbon intensity level has been stagnant for 10 years, despite significant progress in China, the USA and within the European Union.

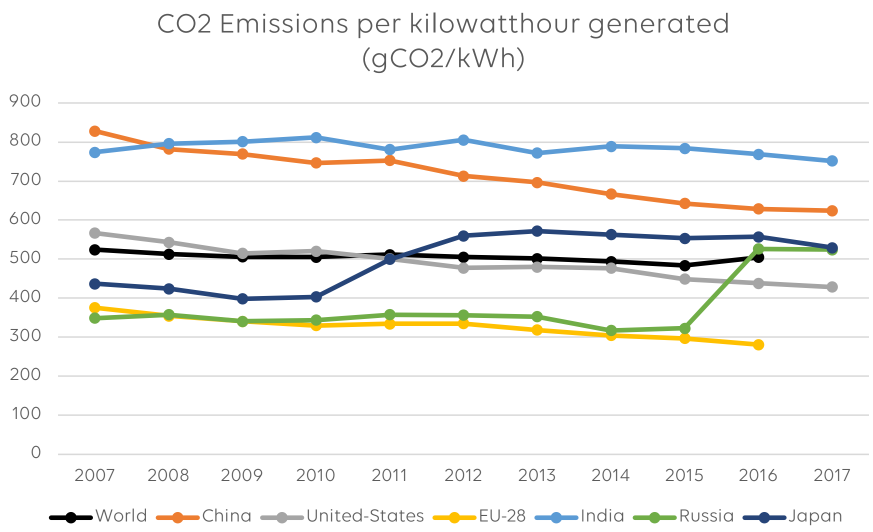

FIGURE 2. CARBON INTENSITY OF THE ELECTRICITY MIX

Data source : ENERDATA

The use of coal is by far the greatest source of emissions: it accounts for around 74% of emissions from this sector, even though coal produces only 38% of the world's electricity and 42% of its heat (IEA, 2018). In 2017, coal-based electricity production increased by 3% (280TWh) globally - a figure which represents a third of the total increase in electricity production, and more than cancels out the 250TWh reduction observed in 2016. The growth in coal-based electricity production occurred primarily in China and India. The growth of coal in Asia has only been partially offset by the decreases recorded, in particular, in the USA and Europe.

Gas is next in line, with 21% of emissions for 23% of electricity production and 42% of heat production; Gas-based electricity production increased by 1.6% (95TWh), or almost 15% of total growth, with the most significant contributions coming from the European Union, China and South-East Asia (IEA, 2018). Oil products accounted for 5% of emissions for 4% of heat and electricity production.

Decarbonized energy sources (renewables and nuclear) are responsible for 35% of global electricity production (mostly through hydroelectricity, nuclear and wind) and 8% of heat (mostly through biomass and waste).

		Electricity	**Heat**
Fossil fuels	Coal	38.3 %	42.1 %
	Oil-based products	3.7 %	4.3 %
	Gas	23.1 %	42.3 %
Fissile	Nuclear	10.4 %	0.2 %
Renewables	Biomass	1.8 %	4.1 %
	Waste	0.4 %	3.2 %
	Hydroelectricity	16.6 %	0.0 %
	Geothermal	0.3 %	0.3 %
	PV solar	1.3 %	0.0 %
	Thermal solar	0.0 %	0.0 %
	Wind	3.8 %	0.0 %
	Marine energy	0.0 %	0.0 %
Other		0.1 %	3.5 %

TABLE 2. SHARE OF VARIOUS ENERGY SOURCES IN ELECTRICITY AND HEAT PRODUCTION IN 2016

(Source: IEA, 2018)

Renewable energy sources supplied almost half of additional electricity production in 2017, bringing their share in global production to a record level of 25%, up from 18% ten years ago. In 2017, renewable energies taken together were the second-biggest electricity source on the planet, behind coal but ahead of gas an nuclear.

Hydroelectricity: at the crossroads of mitigation and adaptation

Hydropower is the only renewable energy source to have been employed on a wide scale since the early days of electricity production. Today, it remains the largest source of decarbonized electricity, far ahead of nuclear and other renewable energies. Hydroelectricity therefore plays a significant role in limiting emissions in the sector, but this method of power production also requires water resources of sufficient quality and quantity, making it vulnerable to climate change, which can cause changes in rainfall levels, limiting the production capacities of existing facilities and increasing the risk factor for new ones. It can also affect water quality: melting ice caps, for example, increases the presence of sediment and therefore causes turbines to wear out faster.

Built in the 1930s, the Hoover Dam is an icon of hydroelectricity in the USA, and serves to exemplify these hazards: its production capacity is regularly reduced by the drought ravaging the western United States. Other sources of energy, in particular gas power stations, are left to fill the resulting gap, while also increasing costs and CO_2 emissions.

Developing countries are even more vulnerable to these types of threats: in Tanzania, hydroelectricity represented 90% of electricity production in the 1990s. The drought that began in the early 2000s had major repercussions for electricity production, and therefore for the country's population and economy. In 2011, an energy crisis left inhabitants without power for 12 - 16 hours per day, leading the IMF to lower its growth forecast for Tanzania's GDP: the country did not have sufficient production capacities to stand in for its hydroelectric power stations. Faced with the uncertainty surrounding hydroelectricity, Tanzania has now chosen to develop its thermal production sector. Today, hydroelectricity accounts for only a third of the Tanzanian electricity mix, equal to natural gas and oil.

Hydroelectric plants are also sensitive to excess rainfall. In 2018, the Saddle dam in Laos, which was under construction, collapsed following a period of heavy rainfall, flooding villages downstream and killing over a hundred people. The NGO International Rivers criticized the construction of structures which were "incapable of withstanding extreme climate conditions" at a time when these were "becoming more and more frequent."

TEXT BOX 2

Finally, nuclear production increased by 3%, or 26TWh, in 2017. Nevertheless, the addition of new reactors around the globe only counteracts a small proportion of those shut down in 2017: the restarting of Japanese reactors having been offline since 2011 is responsible for 40% of the growth in production.

2 • GLOBAL POLICY TRENDS

Global energy policies remain contradictory: on the one hand, governments massively support fossil energies, and on the other, measures in favour of decarbonized energy and greater efficiency are becoming more and more widespread.

• IN 2016, ELECTRICITY BECAME THE TOP RECIPIENT OF FOSSIL ENERGY SUBSIDIES • Public involvement in the electricity sector is widespread. In particular, it takes the form of subsidies, a significant proportion of which are allocated to greenhouse gas-emitting energy sources: in 2016, the consumption of fossil energy was subsidized to the tune of 260 billion dollars, 41% of which was designated to the electrical sector - making it the primary recipient, surpassing oil and gas for the first time (40%). The development of renewable energies, meanwhile, received 140 billion dollars in 2016 (IEA, 2017). Global energy policies therefore continue to incentivize the consumption of fossil energy.

These policies are justified in the name of development, employment, allowing electricity-consuming companies to remain competitive, or efforts to combat energy instability. However, they are often short-sighted, disproportionately benefitting the wealthier portions of society who consume more energy. Such policies can therefore have the effect of encouraging consumers to waste energy, and throwing public budgets off balance (Shirai, 2017).

In addition to direct financial incentives, energy policies use numerous other measures to support fossil energies: price controls, quotas, subsidized prices, guarantees, direct investments, research and development, technical restrictions, etc. (IEA/OECD/World Bank, 2010). In the USA, for example, an obsolete regulatory framework enables non-competitive coal-fired power stations to remain in service (Carbon Tracker, 2017). Capacity markets and strategic reserves, designed to keep Europe's little-used thermal power stations available for production, are another example of indirect support for fossil energies (Zimmermann, 2017).

These measures are even more harmful when their effects are long-lasting: two thirds of fossil subsidies were introduced before 2000 (OECD, 2018), and a thermal power station has a lifespan of over 30 years.

Measures in favour of fossil energies are being partly counterbalanced by the increasing appearance of Carbon Markets (notably the Chinese market, which was launched during the COP23) and taxes on energy carbon content. These measures have the effect of making fossil energies - particularly coal - less competitive. They have been shown to be particularly effective in the UK, where the doubling of the carbon price floor to £18/TCO2e in 2015 led to a two-thirds reduction in the proportion of coal in the electricity mix (Carbon Brief, 2016).

• POLICIES IN FAVOUR OF RENEWABLES • Policies in favour of fossil energy are also being counterbalanced by the increasingly widespread appearance of pro-renewable energy measures. When they are built upon coalitions uniting public bodies, industrial groups, civil society and international organisations, these policies can even take root in developing countries rich in fossil resources, such as Mexico, Thailand or South Africa (Rennkamp, 2017).

Investments in renewable energies, especially solar and wind power, were initially encouraged through Feed-in tariffs. In 2017, over 80 countries were using this system. The main difficulty involved is setting tariffs at a level that is sufficiently high to attract investors, while also remaining sustainable (IRENA, 2018). This difficulty has led a growing number of countries, including China and Germany, to turn towards an auction system.

This change of tack has significant consequences for operators in the energy sector: energy auctions are well-suited to benefit major projects and large companies, but are difficult to access for smaller developers or non-professionals (individuals, farmers, cooperatives, etc.) However, the auction system does enable a faster drop in the price of renewables by encouraging companies to adopt more aggressive strategies. To ensure success, these companies set their prices by taking account of cost reductions expected during development of their project. This competition can result in the failure of overly-ambitious projects: in the UK, for example, solar projects selected during a 2015 call for tenders at a cost of less than 60£/MWh were all later abandoned (Energie et Développement, 2017).

Other incentive instruments may also be employed, notably including quotas that require certain operators to employ a minimum amount of renewable energies. These requirements have been applied in India and the UK, for example, as well as in 29 US states, and are often accompanied by a certification system enabling producers of renewable electricity to enhance the value of their output. Non-regulatory measures also exist, such as financial or fiscal instruments to encourage investments in renewable energies. (IRENA, 2018)

Finally, it should be noted that support is lagging behind for the production of renewable heating and cooling: in 2016, 126 countries had implemented polices to incentivize the development of renewables in the electricity sector, compared to only 29 in the heating sector (IRENA, 2018). Policies in favour of renewable heating and cooling are mostly based around quota systems.

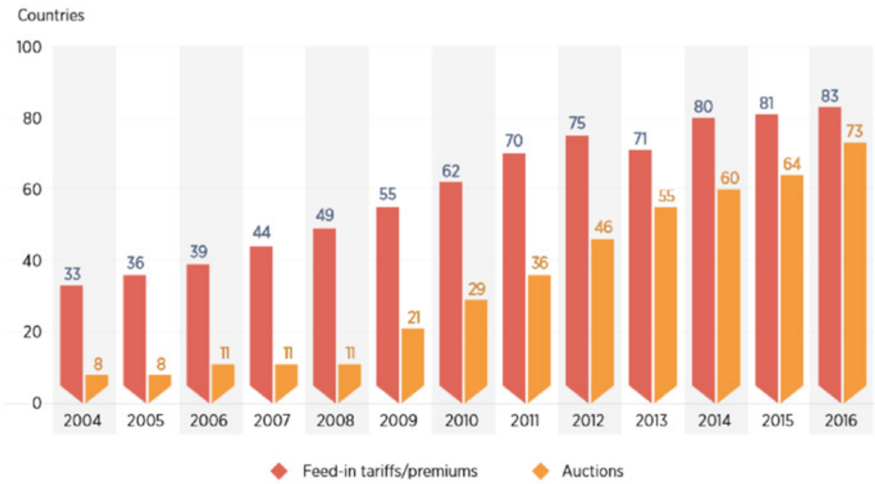

FIGURE 5. NUMBER OF COUNTRIES USING FEED-IN TARIFFS AND/OR AUCTIONS

(Source: IRENA, 2018)

3 • ECONOMIC STAKEHOLDERS AND THEIR ENVIRONMENT

The production of electricity and heat, as well as their transmission, distribution and associated services requires the involvement of a large number of companies, varying greatly in size: local, national and international producers, suppliers of equipment and services, financiers, etc. The challenges of moving towards a low-carbon energy system are different in each of these categories, as are the respective strategies to be applied in each one.

• TRADITIONAL OPERATORS IN TROUBLE • Large electricity companies play a central role. Generally, these companies are the remnants of former national monopolies, having seen their production, transport and distribution activities separated around the early 2000s as part of a wider effort to open the sector up to competition. Some companies remain entirely public (such as the State Grid of China, the world's largest electricity company), but many have been partially or totally privatized, as is the case with Enel and EDF, the 2nd and 3rd largest companies in the sector. They operate with a high degree of independence, although most remain under the control of a government or regulator given their role as a public service provider.

These electricity companies manage infrastructures characterized by very long lifespans - over half a century for coal power stations and hydroelectric dams, and several decades for nuclear reactors and gas power stations. Despite this level of inertia, they must adapt to a political - and above all, economic - context (rise in the cost of fossil energies, disinvestment campaigns, competition from renewables) which has been changing shape at increasing pace over the past two decades. This temporal disparity poses a significant risk to such companies: with their generation plants no longer suitably equipped to meet market demand, these companies would be left with non-competitive assets (or "stranded assets"). A fifth of the world's electrical power stations could find themselves in this position if the objectives of the Paris Agreement are met (Pfeiffer, 2018). In Europe and in the USA, the electricity sector has already been hit by the depreciation in value of major assets, which has reduced the profitability of large electricity companies and led to the loss of hundreds of billions of euros in capitalization (IRENA, 2017).

Faced with this situation, the strategies adopted by these companies tend to fall into one of two categories:
• "addition" strategies, which involve adapting existing infrastructures to new requirements: carbon trapping and storage, enabling emissions from thermal power stations to be cancelled out, including where these already exist, or intelligent networks within this category.
• "substitution" strategies, which aim to replace existing systems - this is particularly the case in renewable electricity production.

All the major energy developments of the 20th century were dominated by addition strategies, and this remains the case today: an analysis of the patents submitted by the 6 largest European electricity companies shows that they continue to favour this approach, even while renewable energies (accompanied by intelligent networks) are considered the technological priority for the European electrical sector (Buttigieg, 2016).

Large companies in this sector are also adapting to market changes via business reorganization: the number of merger-acquisitions in the European electricity sector increased by 30% in 2017. These operations often aim to re-centre the company around its core activity and get rid of peripheral business lines, especially where these involve fossil energies (IEA, 2018). German company Uniper, for example, has cut off its upstream gas and petrol operations, while France's Engie has relinquished gas power stations in the USA and the UK, as well as a coal power station in Australia.

Restructuring of the German electrical sector

Germany's two biggest electricity companies, Eon and RWE, were both severely affected by the withdrawal from nuclear energy and decline of coal, which represented the vast majority of their electricity production assets. They also suffered a significant drop in the wholesale price of electricity, which fell from an average of €60/MWh in 2011 to 35 today. Finally, the rapid development of renewable energies led to the appearance of new competitors, with a more decentralized production network.

Germany's big electricity companies have been slow to turn to renewable energies. In 2013, when renewables already represented almost 40% of Germany's production capacity, they made up only 18% of Eon's production and 6% of RWE's.

Faced with these difficulties, Eon decided to divide up its business operations: on the one side emerged a new Eon that would focus on renewables, electricity distribution and services, while on the other side was Uniper, which took over the fossil energy stock to manage its end-of-life phase. Initially, Uniper was also supposed to take on Eon's nuclear reactors, but the German government, worried that Eon was attempting to renege on its responsibilities, refused to allow the transfer to go ahead.

This separation has formed two companies with highly different profiles: the new Eon hopes to revive itself through growth and concentrate on investments, while Uniper must pay higher dividends to its shareholders in order to compensate for declining asset values. The separation took place in 2016, and in 2018 Eon turned a definitive corner by selling its shares in Uniper to the Finnish company Fortum for €3.8 billion. This transaction should enable Eon to finance its transformation.

By contrast, RWE initially rejected the idea of a split, choosing instead to focus on cost reduction: 2400 jobs were cut in 2014, investments were reduced, and the company's oil and gas businesses were sold off in 2015. But in 2016, the company finally placed its business operations for renewables,

networks and distribution into separate affiliates, which were then launched on the stock market.
The next step consists of a merger between the two companies: Eon will acquire 76.8% of Innogy, RWE's affiliate for renewables. In return, RWE will acquire a 16.67% stake in Eon, thereby becoming the biggest shareholder in its historic rival.

Source: Financial Times

TEXT BOX 3

The evolution of the electricity mix and the strategies of electricity companies also have consequences for equipment suppliers. Producers of turbines for use in thermal power stations, such as German company Siemens or GE in the USA, are having difficulty maintaining their production chains, and are attempting to develop into the renewable energy sector. The same is true of industrial groups in the nuclear sector, which are facing difficulties due to restructuring: this was the case for French firm Areva, which was dismantled in early 2018,as well as Japanese company Toshiba, which sold its bankrupt nuclear subsidiary Westinghouse.

• INCREASING INFLUENCE OF NEW OPERATORS AND SOLUTIONS • The difficulties experienced by large companies in the sector have facilitated the emergence of new operators; alternative producers and developers, manufacturers of equipment and batteries for the renewables sector, etc. This was the case with French group Neoen, which was created in 2008, and within a decade has become one of the biggest producers of renewable energies on the planet. Neoen notably operates the world's largest battery, the Hornsdale Power Reserve in Australia, which was developed in partnership with Tesla. Other companies have also used the transition of the electricity sector as a chance to reinvent themselves, such as Danish company Ørsted (formerly DONG Energy). Founded in 1972 to explore oil and gas resources in the North Sea, around 2010 the company established itself as a champion of wind energy and biomass: Ørsted now owns almost a quarter of the world's off-shore wind turbines.

The transition of the electricity sector has also led to the emergence of entirely new economic activities and models, particularly in electricity supply services.

Two technical and economic innovations: load management and PAYG

Load management (or demand-side management) involves voluntarily reducing electricity consumption during periods of high demand or low production, in order to help achieve network balance. With the development of variable renewable energies such as wind and solar, this type of operation could become indispensable. Mechanisms have been implemented in the USA, Russia and several European countries to reward consumers who contribute to balancing the electricity supply in this way. Technical solutions allowing individuals and companies to automatically offset a proportion of their consumption have appeared in recent years. These are operated by load management aggregators, which coordinate and sell their subscribers' reductions in consumption.I n France, load management's potential is equivalent to the production capacity of 6 - 10 nuclear reactors, and this untapped resource has given rise to a number of startups: Voltalis, Energy Pool (belonging to Schneider Electric), BHC Energy (a subsidiary of Total), Actility, Smart Grid Energy, Hydronext, etc.
In Africa, the development of the network is the main challenge, rather than supply management. The use of a domestic solar power device is one solution providing rapid access to electricity. The difficulty with these projects resides in their financing: users do not always have the necessary savings or credit to invest in these systems, whose costs can vary from

$100 to over $1000, and companies are reluctant to invest without reliable means to cover their costs. The pay-as-you-go (PAYG) model can resolve this problem.
While a number of variations of this system exist, in general it involves a company renting a full domestic solar power kit to an individual or household (solar panel, battery, electronics and connections, and sometimes also equipment such as bulbs and televisions). The company also performs the installation and maintenance of the system in exchange for an initial payment of 0 - 30% of the value of the kit, followed by a daily, weekly or monthly payment, often made via telephone. The sale and installation of these systems is often carried out by local operators, which has the effect of boosting business. In the event of non-payment the system can no longer be used, but unlike with a bank loan there is no financial risk for the user.
The PAYG model enables renewable electricity to be brought to households which previously had no electrical supply. Companies active in this field, such as Baobab+, Mobisol, M-Poka and Lumos, have already raised $360 million and have 750,000 customers, mainly in east Africa. For the companies, this business model has the advantage of creating a sustainable relationship with their customers. Some of these companies are creating added value via options and improvements to the solar kits: For example, Fenix, a Ugandan company purchased by Engie in 2017, offers a battery whose storage capacity can be increased via a simple activation code.

Source: Ademe, 2017 and Hystra 2017

TEXT BOX 4

Finally, the rapid development of the sector is stimulating the emergence and development of think-tanks and specialist consultancy firms. This is the case, for example, with New Energy Finance, a supplier of data on renewable energy for the finance and energy sector: founded in 2004, the company was purchased by Bloomberg in 2009 following 5 years of rapid growth.

The role of the financial sector

Given that electricity projects remain highly capital-intensive, the transition of existing operators and the emergence of new enterprises requires support from the financial sector. This sector is becoming more and more reluctant to invest in coal-based projects, and in fossil fuels more generally: In mid-2018, 1000 institutional investors managing 6240 billion dollars in funds had committed to divesting from fossil energies, which is twelve times the number observed 4 years ago (Arabella Advisors, 2018).
The divestment movement took shape in 2011 in the American universities managing major funds: Harvard, for example, possesses an investment fund worth almost 40 billion dollars, which the university ceased investing in fossil energies in 2017 following years of campaigning from students and professors. However, divestment is no longer limited to militant investors: among the organisations currently divesting from fossil fuels are the World Council of Churches (which unites 348 religious organisations), cities such as San Francisco and Berlin, insurers such as Axa and Allianz, and GPFG, the largest sovereign wealth fund on the planet.
Divestment is not the only tool available to financiers for influencing company choices. Other strategies also exist, including:
- «Best in class», which in theory does not exclude any given sector, but within each sector investments are only made in companies posting the best results. This is the approach taken by the DJSI World (Dow Jones Sustainability Index): this index, offered by RobecoSam and Standard & Poor's, is based

on an annual questionnaire sent out to the 3400 biggest companies on the planet, before selecting the 10% of highest-performing companies in each sector. Regional and national DJSI indexes also exist.
- Shareholder activism, which involves harnessing the power of shareholders to influence company strategies. This method is often employed by non-governmental organisations in order to make their voices heard during AGMs, but can also be used by major financial operators: during their 2017 AGMs, for example, Goldman Sachs voted in favour of half of all climate-related resolutions, up from 39% en 2016; JP Morgan, meanwhile, supported 16% of these initiatives compared to 5% the previous year (Bloomberg, 2018).
While these types of movements are gaining ground, they do not seem to be slowing down fossil fuel projects: alongside emerging green finance, plenty of brown financing remains available.

TEXT BOX 5

4 • LOCAL INITIATIVES: A CRUCIAL ASPECT OF THE TRANSITION

The development of renewable energies is generally based around production facilities operating on a smaller scale than conventional power stations, and the reduction of electricity consumption is achieved through local projects. The transition of the electricity sector therefore has the effect of handing the initiative to local regions and operators: local governments, associations, cooperatives, etc.

• LOCAL GOVERNMENTS: SUPPLEMENTING STATE EFFORTS THROUGH INNOVATION • Action at local level can enable local governments to experiment with, supplement or bypass policy implemented at the national level. In China, for example, carbon markets were created in 2011 by cities such as Beijing and Shanghai. A national system is due to be established based on these experimental initiatives. In France, the national government has chosen to give local governments the lead role in the implementation of the energy transition: most inter-communal councils are expected to produce their own Regional Climate-Air-Energy plan by the end of 2018, notably including actions to manage local energy demand and develop the production of renewable energy.
In the United States, by contrast, it is the federal government's hostility to fighting climate change that hands the initiative over to state governments. This is the case, for example, with the Regional Greenhouse Gas Initiative, via which nine states (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island and Vermont) have established a carbon market in order to reduce greenhouse gas emissions from power stations by 65% by 2030, or the Powering Past Coal Alliance which includes 7 states (California, Connecticut, Hawaii, Minnesota, New York, Oregon and Washington) and two cities (Honolulu and Los Angeles) among its members.
The role of local governments does not just supplement the efforts of the State: the re-emergence of more decentralized energy systems gives cities and regions a more central role to play in renewable energy policies. Local involvement in favour of renewable energy is stimulated by the economic advantages brought about by green energy, as well as the potential to mitigate climate change, improve air and water quality at the local level, and create jobs.

Municipal government, regulator and electricity company: the experience of Cape Town

As is the case with many municipal governments, the city of Cape Town manages a large proportion of electricity distribution in its local area: the city serves over 550,000 private consumers, or 75% of households, with the remainder falling under the responsibility of the national electricity company Eskom. In 2008, during a national electricity shortage, Cape Town sought to use this prerogative to make better use of its renewable potential and limit its energy dependence.

Lacking experience and a regulatory framework, the city decided to proceed step by step. The government first approached the South African electricity regulator, NERSA, to study the feasibility of its plans and obtain authorisation to carry out a pilot project. In 2011, following a new request, NERSA clarified its regulatory framework by authorizing governments to distribute electricity produced by facilities of 100kW or less in their local area; in exchange, the producers could deduct the electricity supplied to the grid from what they purchased. This version therefore assumes that producers would remain net consumers of electricity. Despite this limitation, it encouraged South African local governments to promote the installation of small renewable energy production facilities in their local regions. In 2013, Cape Town extended its program to support GreenCape investments, whose vocation is to stimulate the launch of renewable energy projects. At the same time, the city elected to replace its electricity meters, and worked with Eskom and the electricity industry to develop a pre-paid meter capable of recording electricity consumption and production with equal accuracy.

In 2014, NERSA raised the maximum capacity of projects managed by local governments from 100kW to 1MW. In addition to the increase in electricity tariffs, this reform led companies to put forward large-scale projects. The contract for the first 1.2MW solar project was signed in September. In order to obtain NERSA authorisation, the project was registered as two 0.6MW projects.

In 2015, NERSA initiated a broad-scale consultation process with local governments in South Africa, with the aim of introducing a new regulatory framework (currently in development). In the meantime, Cape Town is continuing to develop its own procedures: in 2016, it published its guidelines for the installation of roof-mounted solar panels; a metering methodology and buy-back tariffs were also put in place.

Source: Hermanus, 2017

TEXT BOX 6

With responsibility for regional development and management of public services, local governments are also on the front lines when it comes to deploying innovative technology in the electricity and heating sectors. They can therefore become drivers for the transition of other sectors, for example by encouraging the integration of electric vehicles, modernizing public transport fleets, and making the use of biofuels or solar water heating mandatory in order to meet municipal heating needs. In addition, lessons learned at local level often help clarify issues in the construction of national policies.

Hundreds of local governments have made commitments to achieving 100% renewable electricity, as is the case with the UK100 in Britain, which unites 90 local decision-making authorities. In 2017, municipal leaders in Japan published the Nagano Declaration, in which they committed to working towards achieving 100% renewable energy for their cities. Similarly, new objectives for 100% renewable energy or electricity were set by eight US cities in 2017, bringing the total number to 48.

Cities have also taken collective measures to consolidate the effects of their efforts. In 2017, over

250 mayors in the USA committed to achieving the objective set by the United States Conference of Mayors for 100% renewable energy by 2035 (although not all the conference's objectives have been transposed into legislation). In Germany, over 150 districts, municipalities, regional associations and cities have committed to producing 100% renewable energy by the end of 2017, by way of a network of 100% renewable energy regions. The European initiative known as the "Compact of Mayors" plays a major role in the reinforcement of dynamics throughout European towns and cities. Initiatives such as C40 Cities also stimulate collaboration, enabling cities to share best practices and drive their energy transitions forward.

• CIVIL SOCIETY RECLAIMING ITS ELECTRICITY • Beyond local public stakeholders, the transition to lower-carbon electricity is achieved via a multitude of private operators.

In the past, action by local stakeholders was often limited to NIMBY («Not in my backyard»), meaning the rejection of major infrastructures likely to disturb local ways of life. This phenomenon remains significant - as was the case with the rejection of the extension of the Hambach lignite mine in Germany, or opposition to the coal power plant at Lamu in Kenya, for example - but the decentralization of electricity production means that local operators can now play a more active role, and take back control of their electricity production.

Renewable energies make it possible for non-professionals to produce their own electricity: roof-mounted solar for individuals, wind turbines or biogas for farmers, etc. The production of heat and cold is also possible via solar water heaters and geothermal heat pumps. On a wider scale, production cooperatives or the co-financing of projects via local credit unions can help enable the development of renewable energies and facilitate their acceptance.

Shared Energy

Due to the major influence of nuclear energy, France's electricity production network remains highly centralized; however, this has not stopped the emergence of citizens' initiatives in favour of renewable energy. As early as 1991 in Chambéry, the firstroof-mounted solar device connected to the national grid was installed in France, thanks to a subscription scheme launched by the Phébus association (later to become Hespul). In the early 2000s, wind turbine projects launched by inhabitants were set up in Brittany with the Éoliennes en Pays de Vilaine association, and in the east of the country by the Agence Locale de l'Énergie des Ardennes.

In 2008, an investment fund was created to finance the installation of solar generators, and soon wind turbines as well (Solira Investissement, which in 2010 became Énergie Partagée Investissement). Among its original members were some of the major organisations in the field of renewable energies and solidarity - Enercoop, the GERES, the Nef, etc. - as well as local stakeholders. Énergie Partagée Investissement is a limited joint-stock partnership, operating under a supervisory council elected by its investors. This companies offers individuals the opportunity to invest in renewable energy projects, while sharing the risk and ensuring the application of best practices (democratic governance, local foundation, no financial speculation, etc.). The fund works closely with the Energie Partagée ("Shared Energy") Association, which is responsible for supporting project backers, along with Énergie Partagée Études (which co-finances the development phase of renewable energy projects), and with regional initiatives.

In 2011, Énergie Partagée Investissement obtained the approval of France's Financial Markets Regulator to collect investments from citizens for projects in the field of renewable energy and energy efficiency. In one year, over 2.6 million euros were raised this way. At the beginning of 2018, Energie Partagée passed the threshold of 15 million euros raised from over 5000 shareholders. The Energie Partagée network supports over 270 projects.

Source: ENERGIE PARTAGÉE, 2017 ACTIVITY REPORT

TEXT BOX 7

CONCLUSION

Demand for electricity is continuing to increase: over the course of the last 20 years, the electricity sector has been responsible for 70% of the increase in primary energy consumption (BP, 2018). Although progress has been made, this increase in consumption has not yet been offset by a decline in carbon intensity, and emissions are continuing to rise. However, behind its infrastructural inertia, the electricity sector is experiencing a phase of rapid restructuring, characterized by the loss of influence of central governments and major electricity companies, with power being ceded to local governments and new economic operators. This transformation is contributing to the emergence of economic models with lower levels of emissions, and could perhaps prefigure the transition towards fully-decarbonized production of electricity and heat.

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Kenya: innovation at the service of low-carbon electrification

Despite a low population density (42 million in habitants in a surface area of 580,000km²) and a human development index of 0.555, putting it in 152nd place in the world, over the last 10 years, Kenya has made rapid progress in electrification. Emissions from electricity generation have remained stable throughout that period. How has the country achieved these results? Can it be used as a model for low-carbon electrification?

Head editor • **THIBAULT LACONDE** • *Consultant, Energy & Development*

CONTENTS

1 • LOW EMISSIONS

In 2016. emissions related to electricity and heat production in Kenya stabilised at 1.1 CO_2 mteq. This level is comparable to that of 2015. the lowest since the mid-2000s. It represents a decrease of 55% compared to the 2013 record. No data are available for the year 2017.

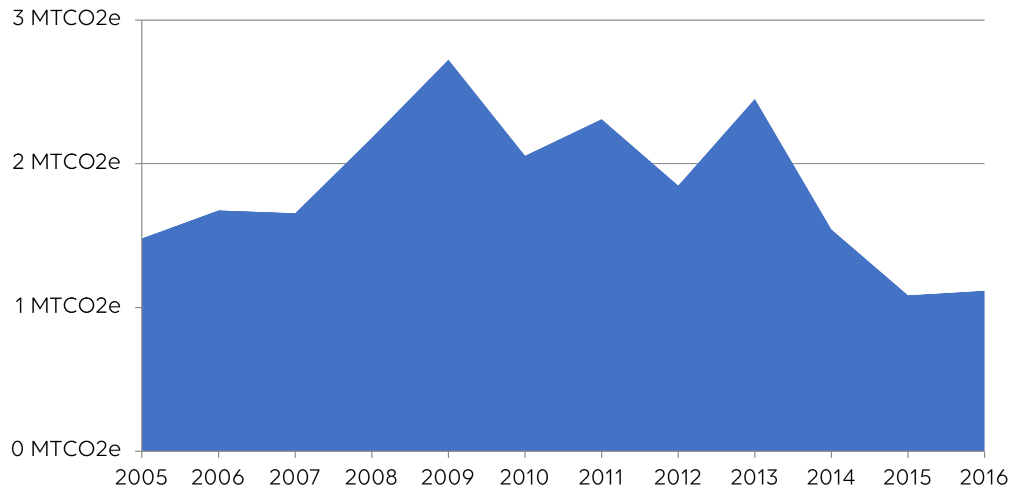

FIGURE 1. EMISSIONS FROM THE PRODUCTION OF ELECTRICITY AND HEAT

(Source: Enerdata)

• A LOW-CARBON ELECTRICITY MIX • Kenyan power sector emissions are particularly low: Spain. which has a similar population to Kenya. for example emits 67 $MtCO_2eq$ per year for its electricity and heat production. This cannot be explained solely by the country's level of development. In 2016. the carbon intensity of Kenyan electricity was 116 grams of CO_2 per kilowatt hour produced. So. to produce the same amount of electricity. Kenya emits. for example. six time fewer greenhouse gases than China or four times fewer than the United States (Ang. 2016).

This good performance can be explained by the composition of the electricity mix: Kenyan electricity generation is historically based on hydropower. with a share of geothermal energy that has grown strongly over the past decade. Fossil production. mostly based on liquid hydrocarbons. completes the mix and. during droughts. offsets the hydroelectric production deficit.

In 2016. despite relatively low hydropower generation. electricity production was 80% renewable. placing Kenya among the top 20 performers in the world for this indicator (IEA. 2018).

		2015		2016	
		Electricity production	Share of the mix	Electricity production	Share of the mix
Fossil fuels	Oil-based products	1,206GWh	12.5%	2,020GWh	20.7%
Renewables	Biomass	122GWh	1.3%	123GWh	1.3%
	Hydroelectricity	3,787GWh	39.2%	3,341GWh	34.3%
	Geothermal	4,479GWh	46.4%	4,204GWh	43.1%
	PV solar	1GWh	0.0%	1GWh	0.0%
	Wind	57GWh	0.6%	63GWh	0.6%

TABLE 1. KENYAN ELECTRICITY MIX

(Source: IEA. 2018)

• SIGNIFICANT USE OF TRADITIONAL ENERGIES • At the same time. emissions across the country are steadily increasing. Excluding emissions related to land use. changes in land-use and forestry (LULUCF). the country emitted 18.3 $MtCO_2eq$ in 2016. an increase of 116% since 2000 and 40% since 2010.

When the LULUCF sector is included. emissions were 73 $MtCO_2eq$ in 2010. i.e. three quarters of the country's emissions. According to Kenya's second official communiqué on its emissions. with increasing fossil fuel demand. this sector is the main contributor to the increase in emissions between 1995 and 2010 (Government of Kenya. 2015).

This finding offsets the good performance of the electricity sector which can be partly explained by a shift of certain emissions linked to energy consumption towards the LULUCF category: in the absence of access to energy such as electricity or natural gas. wood is used to meet heat and lighting needs. Currently. electricity still accounts for only 4% of Kenya's final energy consumption compared to 68% for biomass.

2 • KENYA'S STRATEGY FOR LOW CARBON ELECTRIFICATION

Like many African countries. Kenya faces a challenge: in expanding access to electricity while controlling emissions from the electricity sector.

• SITUATION OF THE KENYAN ELECTRICITY SECTOR • Despite the progress in electrification. demand for electricity remains constrained by insufficient supply and consumption per customer is decreasing.

Kenya's electricity sector is facing several problems. The share of hydroelectricity. whose production depends on weather conditions. makes production difficult to predict. Power cuts are frequent: around six 5-hour breaks per month in urban areas (GOGLA. 2018). Electricity is expensive. about \$0.15/ kWh compared to \$0.04/ kWh in South Africa. and this burden is poorly distributed. with rates favouring large consumers to the detriment of individuals and small businesses (Institute of Economics Affairs. 2015).

Organisation of the Kenyan electricity sector

At the end of the 1990s. the Kenyan government decided to separate electricity generation. transmission and distribution activities (so-called unbundling policies). The Kenyan power sector is organised around the three major public companies resulting from this split: Kenya Electricity Generating Company (KenGen) for production. Kenya Electricity Transmission Company (KETRACO) for transmission and Kenya Power for distribution and sale.

KenGen produces three quarters of Kenyan electricity. 30% of the company's share capital was offered for sale in 2006 and it is now listed on the Nairobi Stock Exchange. as is Kenya Power. Most of Kenya's electrical installations are owned by KenGen (69%). with a fraction also owned by the rural electrification agency (1%).

Kenya licensed another three companies (Aggreko. Cummins and Deutz) to produce and sell their electricity during the 2000 drought in order to make up for the sharp fall in hydroelectric production. A dozen independent producers (IPP) have since set up in the country: in 2008. they owned 11% of the Kenyan electricity system and by 2017 their share had reached 30%. The production of IPPs is predominantly fossil-based. mainly diesel. The additional cost related to the purchase of fuel is transferred to consumers through a levy on their bills - the IPPs are therefore accused of increasing electricity prices. The government frequently threatens not to renew their 20-year licenses.

An independent Energy Regulatory Commission. the Electricity Regulatory Board. was created in 1998. An Energy Tribunal was established in 2006. primarily to function as body to hear appeals against ERB decisions.

Sources: Kengen annual report. Daily nation

TEXT BOX 1

In Vision 2030. its development programme adopted in 2008. the Kenyan government recognises the difficulties of the electricity sector. The programme prioritises increased production and efficiency gains. To achieve this. it plans to continue energy sector reforms with the creation of a robust regulatory framework and incentives for private investors. It also envisages the creation of interconnections with neighbouring countries with surpluses and the development of new energy resources. including geothermal energy and renewable energies. as well as coal. There has been a major delay in this area: while the plan provided for a capacity of 5.5 MW in 2017 (Government of Kenya. 2013). it has not even reached half of this target with 2.4 MW (KenGen. 2017).

• GOVERNMENT STRATEGY AND ACTION • The 2017-2022 development plan drafted by the Kenyan Energy Regulatory Agency is a continuation of Vision 2030. Between 2018 and 2024. it plans the to build 1277 MW in geothermal power plants. 841 MW wind power. 703 MW solar but also three coal-powered plants of 327 MW.

Kenya is also planning to acquire a nuclear power plant with a target of 1.000 MW in 2027 and 4.000 MW in 2033. The country has signed cooperation agreements in this area with China. Russia. Slovakia and South Korea. Under this latest agreement. signed in September 2016. 16 Kenyan students were sent to Korea to obtain a master's degree in nuclear engineering.

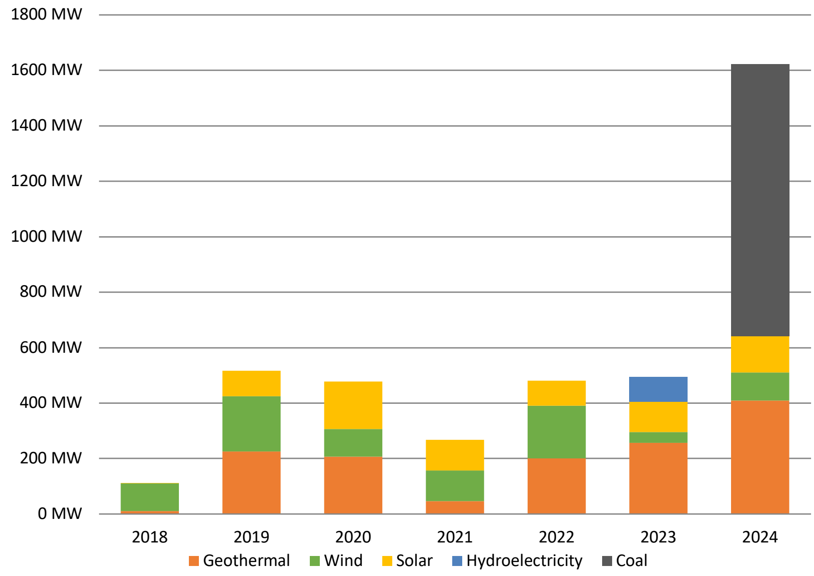

FIGURE 2. NEW COMMISSIONING PLANNED BETWEEN 2018 AND 2024

(Source: Kenya Energy Regulation Commission)

To develop its electricity production. in 2008 Kenya introduced guaranteed feed-in tariffs for electricity. These tariffs. which have been updated since then. provide investors with income for 20 years. In spring 2018. the Kenyan government announced its intention to replace this mechanism with a bidding system in the hope that competition will bring down the price of electricity.

Control of energy demand is also an important factor. Indeed. geothermal installations. which can operate continuously. provide almost half of the electricity and while it is not stored. a significant share of the production is lost during the night and off-peak consumption periods. To encourage companies to shift their consumption. in December 2017 the government created a reduced tariff of 50% for electricity consumed between 10.00 PM and 6.00 AM («time-of-use plan»). By mid-2018. 800 companies had subscribed to this tariff.

Finally. the rural electrification plan seeks to increase the electrification rate from 22% to 65% between 2013 and 2022 and. reaching 100% in 2030. This is the remit of a rural electrification agency created in 2006. In 2016. the electrification rate was 56% (World Bank).

3 • MOBILISATION OF ECONOMIC STAKEHOLDERS OF ALL SIZES

Kenya's electricity policy assigns an important role to the private sector. both in project development and public policy design. For example. the Kenyan government consulted extensively with the business community before launching the Kenya Off-Grid Solar Access Project for Underserved Counties (K-OSAP) to help companies investing in disadvantaged areas (GOGLA. 2018).

• A STRATEGY OF LARGE PROJECTS • The development of Kenyan power generation involves a policy of large projects. often unique on a continental or even global scale. In 2016. the country inaugurated the largest geothermal power plant in the world: Olkaria (280 MW). In 2017. the Lake Turkana wind farm (310 MW) was commissioned - the largest wind farm in Africa and the largest private investment in Kenya's history (REN21. 2017).

These projects are generally part of a broader development policy. The construction of the Lake Turkana wind farm. for example. was accompanied by the creation of road access. fibre optic links and local electrification projects.

Due to their size. these large projects are reserved for large multinationals or the KenGen public electricity company. The Canadian company SkyPower. for example. signed a $2.2 billion deal in

2015 for the development of 1.000 MW of solar power. while the American company GE is building the Kipeto wind farm as part of a 15-year construction and service. Similarly. KenGen produces 100% of the geothermal electricity (Government of Kenya. 2015) and for the time being is the only player capable of supporting the initial investment required for this production.

Innovation in Kenyan geothermal energy

Kenya. home to the Great Rift Valley in the west of the country. benefits from an ideal geological environment that provides it with an estimated geothermal potential of 10.000 MW. The country is concentrating these efforts on this energy to counterbalance the hazards of hydroelectric production: in terms of installed capacity. it is the 9th country. ahead of Japan. In 2016. Kenya installed 6% of new world capacity. although no new installations were established in 2017 (REN21. 2018).

KenGen does restrict itself to implementing existing technologies - the company innovates to accelerate the deployment of new productions. It has therefore developed a technology know as wellhead (because the turbines are installed close to boreholes without the requirement for the creation of a heating system).

The technology was trialled in the Olkaria region from 2012. It involves installing small turbines (2 to 5 MW) as soon as the drilling is completed so that production can start without waiting for the construction of a permanent power station. These turbines can be containerised or assembled on trailers and their installation requires little civil engineering work. They can therefore be moved easily to new projects when the permanent installations are completed.

The wellhead system enables geothermal electricity production to start in a few months. compared to 2 to 3 years for a conventional power plant. Moreover. this system can facilitate the development of geothermal energy by lowering the initial investment and providing the operator with income earlier in the project cycle.

Finally. wellhead type turbines could be used permanently to supply electricity to an isolated grid for which investment in a conventional geothermal power plant would not be justified.

Source: Saitet. 2015

TEXT BOX 2

A difficulty encountered by these major projects comes from the separation between generation and transmission activities that makes coordination more difficult. For example. the power line to convey production from the Lake Turkana wind farm is still being constructed (Daily Nation. 3 May 2018).

• SOLAR KITS. MINI-GRIDS. PAY-AS-YOU-GO… • The *Last-Mile Connectivity* project. funded by the African Development Bank. plans to connect 314.200 households located within 600 meters of a transformer to the grid. For the other non-connected households. the costs of extension of the grid. which are too high compared to the potential demand for electricity. encourage the use of decentralised electrical systems. This off-grid electrification is accessible to companies of modest size and is producing a proliferation of initiatives.

In 2016 and 2017. Kenya was the world's second largest market for solar kits behind India: 1.2 million systems were sold in 2016 and 900.000 in 2017. due to the drought that limited Kenyan revenues (GOGLA. 2018). The distribution of these systems involved a dense network of retailers and enabled revenues to be generated locally. Now more than a third of homes not connected to the electricity grid have a solar system that can meet basic needs such as lighting and phone charging (REN21. 2017). This market is of interest to foreign companies: BBOXX (Great Britain) and Mobisol (Germany). companies specialising in the production of solar kits. raised $20 million in 2017 to expand operations in Kenya. Rwanda and Tanzania.

Access to these systems may involve new business models. such as «pay-as-you-go». which has been developed in several African countries. including Kenya. This business model involves leasing a solar kit to households. The kit includes a battery. a charge controller. a solar panel. LED bulbs and a telephone charger. or even a television. Consumers pay on a daily. weekly or monthly basis which limits recovery costs for the business and avoids the use of a household loan. The payment is made by telephone. and if the payment is not registered. an integrated system interrupts the operation of the kit and the supply of electricity. These PAYG companies have electrified about 500.000 homes in Kenya and Tanzania. but are mostly financed by foreign investors. Local commercial banks are still very reluctant to finance these projects. which are deemed too risky. thus depriving local investors of capital (Sanyal. 2017).

Rural electrification also involves creating micro-grids. The creation of a local-scale grid not connected to the national power grid makes it possible to supply it with limited investments. In the past. however. this alternative was unattractive because the use of generator sets. with high fuel and maintenance costs. made electricity expensive. The lower cost of renewables is changing this situation. enabling the development of mini-grids in non-electrified areas. The Kenyan government recently obtained €33 million from the French government for the installation of 23 mini solar power plants in the north of the country. aiming for a production of 9.6 MW. Private companies are also involved in this field: PowerGen Renewable Energy. a Kenyan company specialising in the implementation of small power grids. raised $4.5 million in 2016 to invest in Kenya and Tanzania.

Micro-grids in Kenya

The public operator Kenya Power manages about twenty micro-grids powered by generators mainly in the north of the country. These facilities will soon have to be upgraded to integrate a share of solar production.

Private companies are also allowed to produce and distribute off-grid electricity. Payment by mobile phone. promoted by companies such as M-Pesa. Airtel Money or Orange Money. have played a crucial role in the development of these services.

In 2017. 40% of existing commercial micro-grids in sub-Saharan Africa were in Kenya (65 out of 150). The country will host at least a third of the new micro-grids built in Africa by 2021. Thanks to the fall in the price of photovoltaic modules. these projects should mainly be powered by solar energy. Small hydropower systems will also be developed.

Source: GORDON. 2018

TEXT BOX 3

At the end of 2016. Kenya joined Lighting Global. the programme set up by the World Bank to test and ensure the quality of off-grid solar systems.

4 • CIVIL SOCIETY: VIGILANT AND INNOVATIVE

Electrification and the development of Kenyan electricity generation respond to significant social demand. Civil society actors. however. remain sensitive to the impact of projects on living conditions and can also play an active role in finding new solutions.

• PERCEPTION OF PROJECTS BY CIVIL SOCIETY • Public opposition is often an obstacle to the development of new energy projects. In Kenya. as elsewhere. debate on these projects is divisive and polarised between the positions of developers and those of opposition groups. Access to land is one of the recurrent points of conflict. especially when projects have little local economic benefit. Communities sometimes express suspicion towards projects: risk of corruption. hazards and pollution (risk of electrocution. noise. etc.). impact on the environment and tourism. etc. These fears often reflect insufficient stakeholder commitment in the upstream phases (Johnson. 2017).

Mobilisation against the Lamu Coal Plant Project

Kenya plans to install its first coal-fired power plant on Lamu Island in the Indian Ocean. The plant is to be built under a partnership between Kenya and China. supplied with South African coal.

Those living in the vicinity of the future plant are worried about the consequences of the project on the environment and the local economy. especially fishing and tourism: the island. whose old town Lamu is a World Heritage Site. attracts many visitors. They also feared that the benefits of the project would not be distributed fairly. They gained the support of several local and international NGOS (Greenpeace Africa. 350 Kenya. Kenya National Commission on Human Rights. etc.) and personalities including Nobel Prize winner Joseph Stiglitz.

Kenyan activist Okiya Omtatah Okoiti fought against the project in the Kenyan courts. in particular by denouncing the consultation carried out by the Energy Regulatory Commission and the impact study conducted by the Kenya National Environmental Management Authority. His appeal was dismissed in February 2018.

On 5 June. World Environment Day. a charity event was held in Nairobi - a first in the history of Kenya. The demonstrators protested against the Lamu project and the coal mines in Kitui County in the middle of the country.

Source: Daily nation. Decoalonize

TEXT BOX 4

• THE ROLE OF CIVIL SOCIETY IN INNOVATION • Non-state actors. including non-profit organisations. play an important role in technical and economic innovation for the diffusion of new sources of energy. These innovations often arise at community level - a group of young people or women facing the same problems come together to try to devise a solution together. These groups can then be assisted by external actors. most often NGOs. who will advise or fund them (Muok. 2015).

The use of solar lanterns. for example. was initiated in the mid-2000s by Evans Wadongo. a student at the Jomo Kenyatta University of Agriculture and Technology. aged 18 at the time. Inspired by his childhood in a non-electrified region in the west of the country. he designed a solar lantern that was simple and suitable for the needs of Kenyan families. The lamp is made locally from recycled materials. In an example of economic innovation. communities have organised themselves into village banks to grant microloans for poor families to acquire equipment such as improved stoves or solar kits.

Microcredit and access to energy

The use of renewable energies. especially solar. for basic needs such as lighting. is generally less expensive than the use of a generator or kerosene lamps that require the purchase of fuel. However. it requires an initial investment which is an insurmountable obstacle for households which do not have any savings or the guarantees and documents needed to obtain credit. Microcredits make it possible to get around these difficulties.

In 2013. Equity Bank. a leading Kenyan bank with 10 million customers. teamed up with the US company MicroEnergy Credits to create EcoMoto. a lending solution specifically designed to enable the distribution of energy products. These credits are used to purchase solar kits (solar lanterns or solar home systems) from Greenlight Planet. d.light. Fenix and Orb brands as well as improved cookstoves. Loans range from $10 to $600 over a period of up to 12 months with an interest rate of 14%. The repayment rate is calculated to be less than the fuel price that would have been required without the purchased system. Savings over six months are usually sufficient to repay the loan. In its initial version. the loan could be obtained in 24 hours with a one-page form. A mobile phone accessible version was launched last year in partnership with the operator Equitel. and funds are now released in minutes.

This project is supported by the US Development Agency. USAID. and the NGO Winrock International.

Source: Winrock International. 2017

TEXT BOX 5

CONCLUSION

Kenya's electrification is progressing rapidly without an increase in emissions from power generation. This success is explained by the importance of renewable resources and by the government's favourable policy. but also by the mobilisation of non-state actors. Large and small companies. local communities. NGOs. etc. are all contributing to the proliferation of projects that are making Kenya one of the most dynamic and innovative countries in terms of access to energy. Nevertheless. the possibility of the significant use of coal from 2024 could undermine this virtuous circle. The project. financed in this case by China. also highlights all the inconsistencies of international climate policies. especially on funding.

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Decarbonising the chinese power mix: a daunting challenge

China's vast population, economic weight and global influence make it naturally important for China to play a leading role in global efforts to combat climate change. Although these efforts are currently insufficient to offset the rapid growth in electricity demand, there has been remarkable progress in the carbon intensity of Chinese electricity. Contrary to what one would expect from a country with an authoritarian regime and a managed economy, non-state actors – in particular civil society, local authorities and businesses – play an important role in China's electrical transition. What strategy has the country adopted and what lessons can be learned from it?

Main autor • **THIBAULT LACONDE** • *Consultant, Energie & Développement*

CONTENTS

1 • EMISSIONS FROM THE ELECTRICITY SECTOR RISE AGAIN

After a sharp rise from 1.4 billion tonnes of CO_2 equivalent in 2000 to 4.3 today, emissions from the Chinese power sector saw two years of slight decrease. A new rise began in 2017 and seems to be continuing in 2018.

• EMISSIONS WEIGH HEAVILY ON THE CHINESE AND WORLDWIDE ASSESSMENT • Between 2000 and 2016, Chinese emissions increased by 6.8 billion tons of CO_2, from 3.6 GT CO_2 eq to 10.4. At the same time, global emissions have increased by 10.2 GT CO_2 eq (Janssens-Maenhout, 2017). China's contribution to this increase is therefore massive. Electricity production accounts for almost half of China's emissions, meaning that it contributed significantly to this growth, and in 2007, China became the world's largest emitter of greenhouse gases.

In 2011, the country also became the largest producer and consumer of electricity. Beyond its own emissions, the Chinese electricity sector has a lot of weight in the evolution of the worldwide power mix.

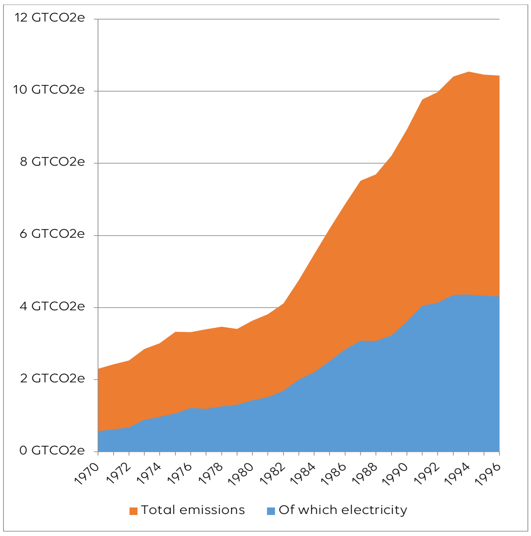


FIGURE 1. EVOLUTION OF CHINESE EMISSIONS

The increase in China's greenhouse gas emissions accelerated in the early 2000s, a period that coincided with its admission to the World Trade Organization. **This trend is linked to its role as the "factory of the world":** in 2011, international trade was responsible for a net transfer of emissions of 760 million tonnes of CO_2 between the United States and China and 640 million tonnes between the European Union and China (Men, 2014).

The rate of the increase slowed down from 2010 when Chinese growth went from double-digit rates in the 2000s to around 7% a year – what President Xi Jinping called the "new normality" of the Chinese economy. Emissions, however, remain on the rise: they increased by 1.4% in 2017 (NBS, 2018) and according to preliminary data, by 4% per year in the first quarter of 2018 (Greenpeace, 2018).

• THE DIVERSIFICATION OF THE CHINESE MIX IS PROGRESSING • At the origin of these emissions is an power mix that remains largely derived from fossil fuels: in 2017, fossil fuels accounted for 70.9% of electricity production. **This proportion is not exceptional, but China is characterised by an overrepresentation of coal.** In 2016, the latest year with available data, only 4.4% of China's fossil electricity came from gas plants (CEC, 2016). This feature places the Chinese mix among the 10 most carbon-focused on the planet. To reduce emissions from electricity production, China must diversify its mix.

Hydropower is China's second largest source of electricity after coal. In 2017, it accounted for 18.6% of the Chinese power mix, i.e. just under two-thirds of the carbon-free production. Despite an increase in production, the share of hydropower in the power mix has stagnated since 2014. This is the energy that has grown the most slowly in 2017, both in production and installed capacity. Despite major projects (Baihetan with 16 GW, Wudong 8.7 GW), the Chinese government does not expect a significant increase in capacity in the coming years.

Wind energy has been developing steadily in China for the last ten years. Wind generation increased by 64 TWh in 2017, making it the largest source of zero-carbon electricity in absolute terms. After surpassing nuclear power in 2016, it now ranks second in carbon-free energies after

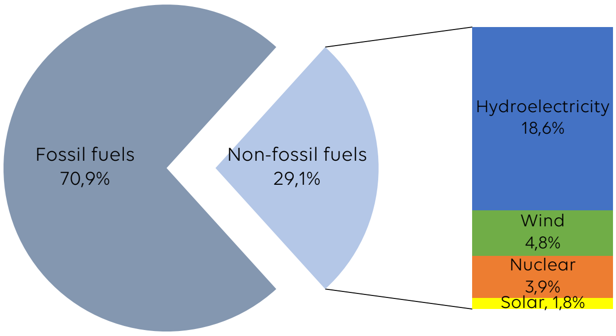


FIGURE 2. THE CHINESE POWER MIX IN 2017

hydropower.

The share of nuclear power has increased significantly since the beginning of 2010 from less than 2% to 3.9% in 2017. However, nuclear projects have slowed down in recent years. Since 2015, no new projects have been approved and only one project launched in 2017, compared with 2 in 2016 and 6 in 2015. Nuclear power has attracted 39.5 billion renminbi (€5 billion) in investments in 2017 – almost twice as much as in 2012. Beyond electricity generation, China plans to use nuclear energy to power district heating networks in the north of the country. The Chinese administration approved the construction of the first reactor for this use at the end of 2017 based on a demonstrator made in the 1980s.

China was little interested in solar photovoltaic power before 2010, but it has now been developing it at an impressive speed: An output of 53 GW was installed in 2017 alone – more than the entire park of the second best endowed country (Germany with 41 GW in 2016). The Chinese solar park reached 130 GW in 2017, in a single year surpassing the 110 GW target that the country had set for 2020. Solar electricity production in 2017 is estimated at 118.2 TWh – an increase of more than 75% over the previous year. However, solar photovoltaic energy represents only approximately 2% of Chinese electricity production and therefore contributes only marginally to the decarbonisation of the mix.

In total, the share of carbon-free energy in China's power mix increased from 16.4% in 2007 to 29.1% in 2017.

• CARBON INTENSITY DROPS BUT EMISSIONS CONTINUE TO RISE • This development of carbon-free energy lowers the carbon intensity of the Chinese power mix – i.e. the production of 1 kilowatt-hour emits less carbon dioxide. However, at the same time the demand for electricity is growing rapidly. In 2016 and 2017, it grew by 5.2% on average and reached a little over 6300 TWh. This growth is driven by the tertiary sector (+ 10.9% per year) and residential consumption (+ 9.3%) with a relative decline in industry. This evolution reflects the changes in the Chinese economy.

This is why fossil electricity production has started to grow again: after a period of stability in 2014 and 2015, fossil production increased by 97 TWh in 2016 and 224 TWh in 2017. The installed power has never stopped progressing: 50 to 80 GW of new thermal power plants are connected to the grid each year. Over the past 10 years, 120 billion renminbi (€16 billion) have been invested each year in fossil fuel energy production, making it the best-funded energy overall.

This growth in production is strongly correlated with the growth in electricity consumption: China's expansion of electricity needs is now still very largely supported by coal. Last year, fossils alone accounted for 57% of Chinese electricity production growth. **Taking command of the demand is therefore a prerequisite for the decarbonisation of the Chinese power mix.**

2. A STRONG POLITICAL AMBITION

This upward trend of greenhouse gas emissions goes against the commitments of Chinese officials both domestically and internationally.

• TAKING A STAND ON THE NATIONAL AND INTERNATIONAL SCENE • The Chinese government has been gradually addressing environmental issues in the 2000s. China established a national environmental protection agency in 2008. It was initially not competent in the fight against climate change, which was placed under the responsibility of the powerful National Development and Reform Commission. A reorganisation announced in early 2018 put an end to this fragmentation by entrusting the climate to a large ministry of ecology.

In 2014, Prime Minister Li Keqiang declared a "war on pollution" which resulted in the modernisation of the measuring system, information for the public and more binding emission standards. This policy primarily targets local air pollutants (NOx, SO_2, PM, etc.) but has climate co-benefits.

On the international scene, China's size and influence in developing countries plays a central role in climate negotiations. The agreement reached between Presidents Xi Jinping and Barack Obama on 12 November 2014 was a major factor in the success of the Paris Conference. On this occasion, China made confirmed commitments to its Intended Nationally Determined Contribution (INDC) for the following year, including: **reaching its maximum level of greenhouse gas emissions no later than 2030 and reducing its CO_2 emissions per unit of GDP by 60% and 65% in 2030 compared to 2005 levels.**

These political ambitions were set out in the 13th Five-Year Plan, which sets out China's objectives for the 2016–2020 period. In particular, it plans the following:

• To limit energy consumption to 5 billion tonnes of carbon equivalent by 2020 from 3.5 billion in 2015.
• To reduce the energy intensity of the Chinese economy by 15% and carbon intensity by 16%.
• To develop the production of carbon-free electricity.

Evolution of carbon-free electricity production during the 13th Five-Year Plan

The 13th plan sets the planned park size for the main carbon-free energies in 2020:

• Hydropower: 340 GW installed in 2020 (from 320 GW in 2015). This goal has already been reached in 2017 (341 GW installed).
• Nuclear: 58 GW installed and 30 under construction in 2020 (from 27 GW installed in 2015), this target will not be reached, no new nuclear project has been approved since 2015.
• Wind power: 210 GW in 2020 (131 GW in 2015).
• Solar photovoltaic: 110 GW in 2020 (42 GW in 2015). This goal was exceeded in 2017.

Sources : energy and developpement

TEXT BOX 1

• THE MODES OF INTERVENTION OF THE CHINESE GOVERNMENT • In addition to planning a gradual transition of its power mix towards carbon-free energies, the central government relies on two main means of action: the creation of increasingly stringent performance standards and the use of financial incentive mechanisms (guaranteed rates and future carbon market).

The use of the regulatory tool is illustrated by the change in the Chinese heat park. Permitted limits for air pollutants are already equivalent or more restrictive than the American or European counterparts. By 2020, performance standards will come into effect: new plants will have to consume less than 300 grams of coal

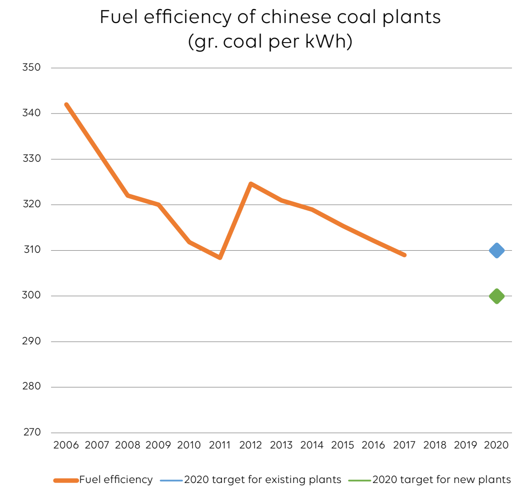


FIGURE 3. NEW CHINESE COAL POWER PLANTS BY TECHNOLOGY

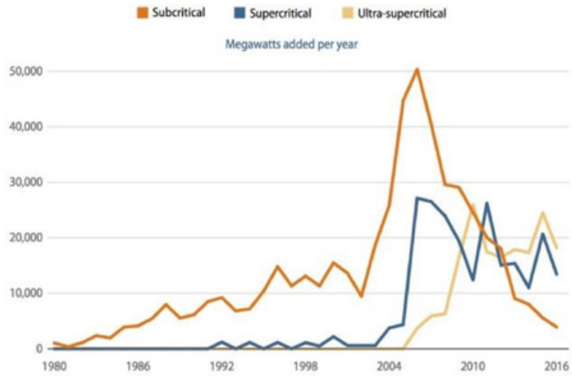
per kilowatt-hour, existing plants will have to consume less than 310 grams or close down. In comparison, the 100 largest US coal plants currently in use consume an average of 375 g/kWh and none would meet future Chinese standards (Center for American Progress, 2017).

These standards lead to the rapid adoption of less emitting technologies that will make the Chinese heat park one of the newest and most efficient on the planet. In particular, this results in a large proportion of supercritical power plants, i.e. plants operating at a temperature of more than 565°C and a pressure of 250 bar, or ultra-supercritical plants, in which the temperature reaches 585°C and the pressure reaches 300 bar. These plants offer better energy and environmental performance than their subcritical counterparts. Approximately 19% of Chinese coal plants are ultra-supercritical, 25% are supercritical and 56% are sub-critical. In comparison, the United States has only one supercritical coal power plant (Platt's, 2017). In addition, China has set up quality standards for its coal production and a systematic control system (Bai, 2017).

FIGURE 3

China's shift toward cleaner coal-fired power technology

Technical makeup of China's coal-fired power capacity additions, 1980–2016



Source: Authors' calculations are based on S&P Global Platts, "World Electric Power Plants Database, March 2017," available at https://www.platts.com/products/world-electric-power-plants-database (last accessed May 2017).

These standards have significantly reduced the consumption of coal and therefore CO_2 emissions per unit of electricity produced: in 2006, it took more than 340 grams of coal to produce one kilowatt hour, today it takes on average less than 310 grams. In the 100 most efficient plants, coal consumption dropped to 286 g/kWh.

To reduce emissions from power production, the Chinese government is also employing economic incentives. These include guaranteed feed-in-tariffs for solar and wind energy – in mid-2018 it was announced that it will be abandoned in favour of a bidding system.

Reform of incentive mechanisms for solar energy

The faster than expected propagation of solar photovoltaic installations threatens to create an excessive cost for consumers. These facilities benefit from a guaranteed feed-in tariff financed by a levy on electricity bills. In 2017, this mechanism was in deficit of more than 100 billion renminbi. Since 2017, China has taken steps to slow down the growth of solar photovoltaic energy. The feed-in tariffs for solar electricity have been lowered and the Chinese government has set up a regulatory system for the construction of photovoltaic solar installations: according to criteria such as the price of land and the erasure rate, some areas of the territory have been ordered to halt their projects (mainly in the north-west) and others to halve them (the western two-thirds of China and the south-east coast as well as Beijing, Tianjin and Shanghai). These measures have not been effective enough: in the first quarter of 2018, 9.7 GW of solar photovoltaic systems were installed in China. In early June, the government announced the suspension of the feed-in tariff for most new installations. A bidding system is to be created instead. A similar announcement was made mid-May for wind energy.

TEXT BOX 2

China is also preparing to create a national carbon market. Seven local pilot projects have been implemented since 2011 in the municipalities of Beijing, Shanghai, Tianjin, Shenzhen and Chongqing and the provinces of Guangdong and Hubei. These pilot projects covered nearly 3,000 installations in 20 industrial sectors and up to a quarter of the Chinese gross domestic product (EDF, 2018). Following these experiences, a national system was formally launched in December 2017, but it will only truly come into operation in 2020. Its operation still contains many unknowns, in particular the sectors in question and the timeframe, the emission ceiling and the mechanism for allocating carbon credits. At least initially, the Chinese carbon market should only concern the production of electricity, but even when limited to the electricity sector, it will be the largest carbon market in the world, covering 1.5 times more emissions than the EU ETS.

3 • THE ROLE OF LOCAL AUTHORITIES

China has a decentralised administrative organisation in which provinces, prefectures and districts have real autonomy – control from Beijing is often exercised a posteriori when needed. These communities play an important role in implementing China's energy and climate policy.

• PROJECT MANAGER OF LOCAL CLIMATE POLICY • It is increasingly common for emission reduction plans to be adopted at the urban scale. Consultation with local stakeholders is an integral part of this process, which allows diverse points of view and conflicting interests to be expressed. However, it often leads to the formation of coalitions between policy makers, industrialists and real estate developers who support the status quo and prioritise economic development. This trend is sometimes counterbalanced by the intervention of experts and researchers asked to support the local authorities. They can exert a considerable influence on the process and be the spokespersons for marginalised concerns in the environment, agriculture, tourism and other fields. They also facilitate communication and exchanging experience at the provincial and national levels (Westman, 2017).

In addition to traditional regulatory tools, the implementation of which is not always effective, local emission reduction plans regularly call for the development of low-carbon public services and facilitation measures. In the latter case, the local authority partially replaces the non-governmental organisations protecting the environment, which are not very present in China.

The climate policy of the municipality of Rizhao

The city of Rizhao in the Shandong Province has set itself the goal of achieving carbon neutrality. For this, it uses several types of tools. The first is regulatory: for example, real estate projects not planning to install solar water heaters are refused. This policy has made it possible to achieve a solar thermal equipment rate of 99% in the centre of the city but is less efficient in the periphery where only 30% of homes are equipped with it.

A second means of action is the creation of low-carbon public services: for example, public transport has been developed to provide more stops and more frequent passages leading to an increase in the number of trips taken. At the same time, the bus fleet has been updated by eliminating the most polluting vehicles for the benefit of hybrid and electric ones.

Financial incentives have been used to encourage the development of "eco-activities" such as easier access to land and more favourable taxation. These measures allowed the sector to grow twice as fast as in the rest of the province: + 15% per year on average between 2010 and 2013.

Finally, various incentive schemes (awareness-raising, training, benchmarking, etc.) have been put in place, in particular to limit the consumption of energy in the industrial and residential sectors.

Sources : Westman, 2017

TEXT BOX 3

These actions are very often developed in partnership with companies, research centres and international organisations. Local climate action is therefore an opportunity for real networking of Chinese and sometimes foreign sub-state actors.

• THE RISKS OF COMPETITION BETWEEN LOCAL AUTHORITIES • The Chinese government wants to give local authorities a growing role in investment decisions in their territory. In this context, each community seeks to stimulate its economic development through major projects and to acquire infrastructures that will enable it to attract investors. This competition can have perverse effects with overbidding resulting in overcapacity and potentially an increase in greenhouse gas emissions.

Thermal overcapacity – a side effect of decentralisation

In October 2014, the Chinese government authorised the provinces to launch coal power plants without prior approval. This reform was designed to ease administrative procedures and better take into account local needs and impacts, but it had perverse effects that required the central government to take back control.

Provincial governments have anticipated increasingly restrictive regulations that would make new projects difficult to carry out. In order not to see its development limited in the future by limited electricity production or dependence on imports, each province tried to over-equip itself. In addition, the wholesale price of electricity remains administered, and it has been slow to adapt to the lower cost of coal which has made these projects attractive for investors. Between 2013 and 2017, China's fossil fuel park increased by 27% while fossil energy consumption grew only by 8%. As a result, the load factor of the thermal park – already relatively low at 57% – has fallen to 48%, meaning that Chinese coal plants operate on average only 175 days a year.

In 2017, the central government had to intervene to prevent these overcapacities from worsening: it canceled nearly 150 projects, some of which were already under construction, and instituted a moratorium on the construction of new thermal power plants over a large part of the country.

Sources : Yuan et Alii, 2017, Yu et Alii, 2018

TEXT BOX 4

4 • AN IMPETUS FROM CIVIL SOCIETY

Civil society has played a major role in raising awareness of environmental issues and their appropriation by the central government and local authorities. In the 2000s, the degradation of the environment became one of the main subjects of discontent and agitation of the Chinese population: between 2000 and 2013, pollution was the reason for half of the "mass incidents" having attracted more than 10,000 participants (Steinhardt, 2015).

The popular movements against pollution of spring 2015

In February 2015, Chai Jing, a former Chinese national television presenter, shared an air pollution survey on the internet. The 103-minute documentary entitled "Under the dome" has been viewed 75 million times since the first day of its broadcast. In April, the explosion of a paraxylene plant in the Fujian Province resulted in the evacuation of 30,000 people and brought industrial risks to the attention of the public. Several movements against pollution and coal projects in particular were reported in the weeks that followed.

In mid-April, for example, several thousand protesters gathered in Heyuan near Canton to demand the abandonment of a planned extension of a coal power station. The week before, a violent demonstration in the same province led to the abandonment of an incinerator project. At the same time, in the Naiman banner in the Inner Mongolia coalfield, the crackdown on a demonstration against pollution reportedly lead to one death and the arrest of 50 people. This period also saw mobilisations in Shanghai (against a chemical factory project), in Tianjin (against a steel mill), etc.

The Chinese authorities pay close attention to these movements. They try not to give them time to become structured, often by combining suppression and concessions. Protesters therefore regularly win and the projects are canceled or displaced.

Sources : Chinadialogue, Forbes, The Guardian, Reuters

TEXT BOX 5

Beyond these movements motivated by opposition to local projects, civil society and academia can influence China's energy and climate policy at the national level. For example, creating nuclear power plants inland was strongly criticised in 2014, which led to a de facto moratorium: since 2015, no new projects have been approved. This pause is tantamount to abandoning the goal of developing nuclear energy in the 13th Five-Year Plan.

Finally, environmental concerns are reflected in consumer preferences: 87.9% of urban Chinese would like to know the origin of their electricity and 97.6% would prefer to buy "green electricity" including, for 90.6% of them, if it is more expensive (CREIA, 2016).

FIGURE 5. INTEREST IN BUYING GREEN ELECTRICITY AND WILLINGNESS TO PAY

5 • BUSINESSES AND ECONOMIC CIRCLESS

The mobilisation of civil society and the increasing attention of consumers and authorities has led companies to adapt their practices and communicate better. For example, the performance of thermal power plants has become a crucial issue for the companies that operate them, some of which even display live emission levels on light panels near their facilities (Center for American Progress, 2017).

Climate action of the State Grid of China

State Grid of China was established in 2002 to manage the Chinese power grid and has since expanded internationally to the Philippines, Brazil, Portugal, Australia, Italy, etc. It employs 1.72 million employees and supplies electricity to more than 1.1 billion customers with a turnover of 360 billion dollars in 2017. According to Fortune magazine, it has the largest turnover among power companies and the second largest turnover of all companies worldwide. According to its sustainable development report, State Grid's climate commitments firstly concern the efficiency of its network: reducing line losses, allowing the integration of new renewable capacities, facilitating exchanges of electricity between provinces, developing storage means, particularly pumped storage, etc. The company also promotes energy efficiency and the electrification of transport and heating – even if the climate balance of these actions is questionable given the dependence of the Chinese power mix on coal. State Grid is also responsible for the recovery and recycling of 70 tonnes of sodium hexafluoride per year – a potent greenhouse gas used as insulation in high-power electrical installations.

State Grid is also a member of many international groups and initiatives for climate and sustainable development: Global Compact, World Business Council for Sustainable Development, Global Sustainable Electricity Partnership, etc.

Sources : State Grid, 2018

TEXT BOX 6

• A SECTOR LARGELY CONTROLLED BY THE GOVERNMENT • The large Chinese electricity companies are mostly public and are generally part of the approximately hundred Chinese companies placed under the direct supervision of the government through the State-owned Asset Supervision and Administration Commission. This is the case of the network operators (State Grid of China and China Southern Power Grid), the five major electricity producers (China Datang Corporation, China Guodian Corporation, China Huadian Group, China Huaneng Group, China Power Investment Corporation) as well as the operator of the Three Gorges Dam, mining companies active in the field of electricity (Shenhua Group and China Resources Group) and leading nuclear specialists (China National Nuclear Corporation, China General Nuclear Power Group and China Nuclear Engineering and Construction Group). Many of these companies have listed subsidiaries, for example China Yangtze Power for China Three Gorges Corporation.

In total, **these public enterprises under government control account for more than three quarters of China's electricity production.** Despite the trend towards liberalising the economy, energy is a sector in which the Chinese government intends to maintain and even deepen its control (Cunningham, 2015).

In theory, China stands out by its subordination of a large part of the electricity sector to the government. In practice, public companies and especially their subsidiaries have a certain autonomy. Because of their size and their historical links with ministries, they can even exert a significant influence on the regulatory body and influence China's energy policy (Andrews-Speed, 2010).

• THE PLACE OF LOCAL AND PRIVATE INITIATIVE • Smaller private companies exist – for example Chint Group in the field of electricity distribution. There are also public enterprises owned by local governments such as the Shenergy Group in Shanghai. These small, generally local producers owned a little less than 30% of the Chinese electric park in 2010 (Wang, 2012).

These companies are poorly represented in nuclear power and hydropower, and they have also suffered from the closure of the worst-performing coal plants ordered by the government in the early 2010s: among the 72 GW that were shut down, the majority were owned by local businesses.

Developing new energies is therefore an opportunity for them. While large state-owned companies have served as a vehicle for Chinese wind energy investments which they widely control, solar photovoltaic energy is largely private (Bergsager, 2016).

Solar thermal energy – success of a private initiat

China is characterised by a massive and old use of domestic solar thermal energy: it comprises 324 GWth, which is more than 71% of the world park. The country has nearly 80 million of these facilities using solar radiation to produce hot water generally at the scale of a household. According to the estimates of the International Energy Agency, they allow avoiding the emission of 90 million tonnes of CO_2 each year (Weiss, 2018) – i.e. the equivalent of total emissions of a country such as Colombia. New installations have slowed down: from 44.5 GWth/year at their highest number in 2013 to 27.7 GWth in 2017, but China continues to dominate this market since 75% of new solar thermal installations in 2016 took place in this country.

Unlike solar photovoltaic energy, solar thermal energy was developed in China to meet local needs. The research benefited from public funding in the 80s and 90s, but the move from the technology to mass production and its very wide distribution was done virtually without financial or political support from the government.

Sources : Urban, 2016

TEXT BOX 7

CONCLUSION

The Chinese government has a central role in determining and implementing emission reduction targets in the electricity sector. However, its decisions can only be understood in the light of the impetus given by civil society. In the same way, achieving the objectives is dependent on the action of local authorities and companies, who in practice enjoy large autonomy from the central power. If regulatory intervention remains one of the tools available to the Chinese government, the implementation of its climate ambitions will also largely depend on the effectiveness of this dialogue between the state and non-state actors.

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Germany, a model under construction?

At the turn of the 2000s, Germany embarked on a transformation of its electricity production that is still ongoing today. While the fight against climate change requires rapid decarbonation of the overall electricity mix, the energy transition led by the world's fourth largest economy is one of the few large-scale experiments which can be used as a model.

Main autor • **THIBAULT LACONDE** • *Consultant, Energie & Développement*

CONTENTS

1 • THE EVOLUTION OF THE GERMAN ELECTRICITY SECTOR

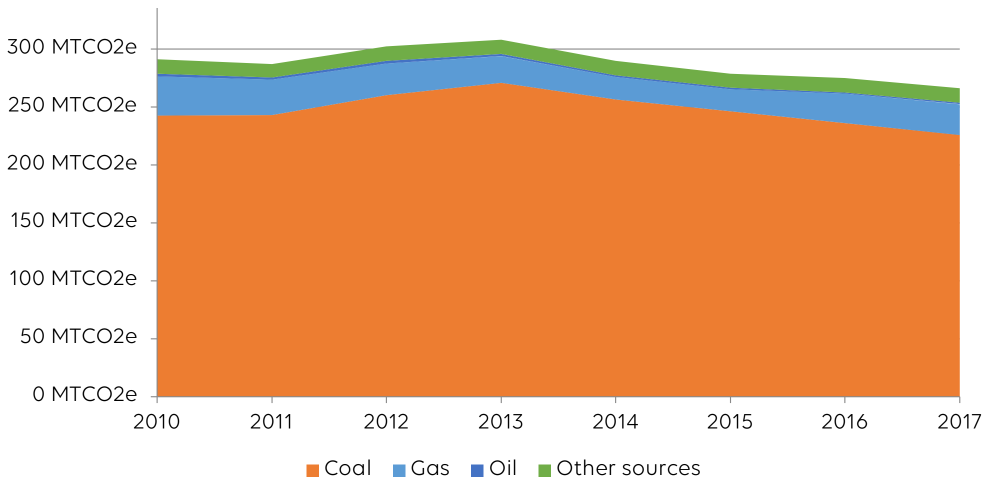
• DOWNWARD-ORIENTED ISSUES • In 2016 and 2017, emissions related to electricity and heat production in Germany decreased by 3.9 and 8.9 CO_2 mteq, respectively.

This decline, which came after an increase in 2011 to 2013, confirms a long-term downward trend observed since the 1990s, the rebound in the early 2010s being explained by cyclical causes: the return of growth after the 2008 crisis and acceleration of the shutdown of nuclear power plants in the aftermath of the Fukushima accident.

Since 2013, the sector's emissions have begun to decline again at a steady pace: between 2013 and 2017, annual emissions fell by 41.4 CO_2mteq or 14.2%. This decrease is due to the decline in emissions from coal-fired power plants (-45.1 CO_2mteq/ year between 2013 and 2017) partially offset by increases in gas use (+ 3.7 CO_2mteq/ year). This gas-coal substitution has accelerated over the last two years.

The fall in emissions is even greater when compared to the amount of electricity actually generated. Indeed, German electricity generation has increased markedly over the last twenty years, from 576.6TWh in 2000 to 654.8TWh in 2017. This increase has seen Germany, an importer of electricity in the late 90s, become the largest electricity exporter in Europe.

Between 2015 and 2017, German electricity generation increased further by 6.7TWh. Consequently, while electricity sector emissions fell by 4.6% over this period, the carbon intensity of electricity declined even more rapidly: in 2017, generating a megawatt hour of electricity in Germany emitted 5.6% less CO_2 than in 2015.



	2013	2014	2015	2016	2017
Total	306.2477	288.6509	277.6279	273.7003	264.8552
Coal	270.9566	256.3565	246.2193	236.3306	225.8448
Gas	23.0119	19.5899	19.3029	25.149	26.7576
Oil-based products	1.9132	1.3156	1.293	1.2058	1.2125
Other	12.2792	12.7045	12.1057	12.2207	12.2528

FIGURE 1. EMISSIONS FROM ELECTRICITY GENERATION AND URBAN HEAT BY FUEL ($MTCO_2E$)

(source : Enerdata)

• A REMARKABLE EVOLUTION OF THE ELECTRICITY MIX • This drop in emissions and carbon intensity is significant, but it is not commensurate with the evolution of the German electricity mix, which has undergone a profound transformation over the past two decades.

Since 2000, Germany has experienced a rapid development of renewable energies, from just a

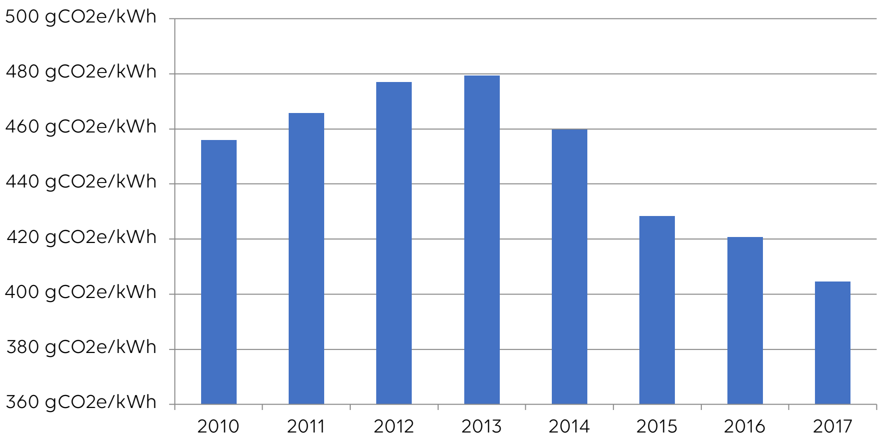


FIGURE 2. CARBON INTENSITY OF GERMAN ELECTRICITY

Sources : Enerdata and AGEB

few percent to today, when they represent more than one third of the electricity mix. This increase has more than offset the 3-fold decline in the share of nuclear power, which led to a 10-point drop in the share of fossil fuels in the electricity mix.

These transformations have continued in recent times. Between 2015 and 2017, renewable energies increased from 29.1% to 33.3% of the electricity mix and even to 40% in the first 35 weeks of 2018 (Energy charts, Fraunhofer Institute). This change is being driven mainly by the development

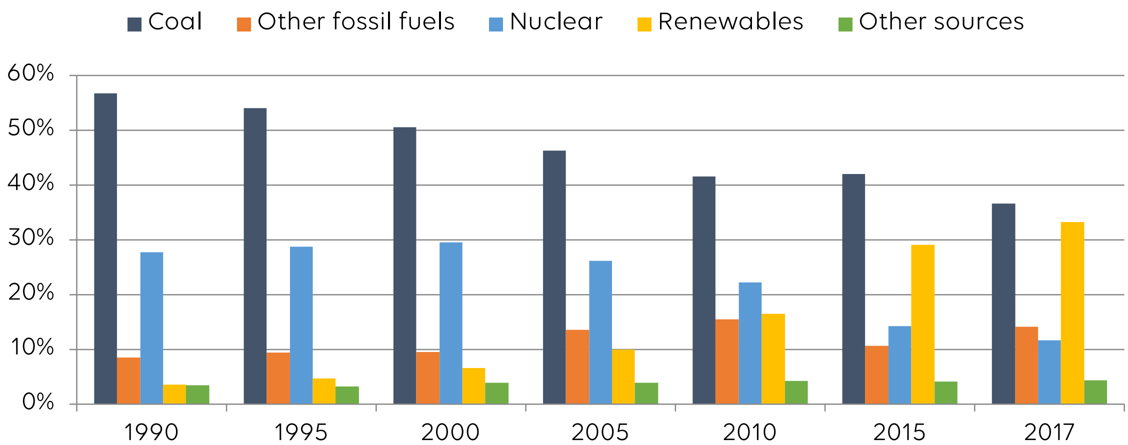


FIGURE 3. EVOLUTION OF THE GERMAN ELECTRICITY MIX

(Source: AGEB)

of off-shore wind power, for which generation has more than doubled in 2 years.

At the same time, coal (-5.4 points) and nuclear power (-2.5 points) continued to decline. The decline of coal is slower for lignite, which pollutes more but is produced locally, than for bituminous coal, which has all been imported since the closure of the last two German mines in 2018: -1.3 points in 2 years for lignite vs. -4.1 points for bituminous coal. Finally, the last two years have seen a rapid increase in gas, which has increased by 3.6 points in the German electricity mix. This increase is not entirely new but it accelerated sharply in 2016.

2 • A STRONG POLITICAL IMPULSE

This evolution of the German electricity mix is the result of an energy policy devised in the 1980s and continued throughout the 2000s despite unforeseen circumstances and political alternations.

• BUILDING AN ALTERNATIVE AND A CONSENSUS • In the 1980s, the German electricity mix was dominated by fossil fuels (about 65% with a large majority of coal) and nuclear (about 30%) with a small share of renewables, mainly hydroelectric.

It was at this time that the energy transition project that Germany is now implementing began to take shape. This shift originated in the anti-nuclear movement, which was very active in the 1970s. In the mid-1980s, it achieved its first success with a moratorium on the construction of new reactors. In connection with economic actors investing in renewable energies and part of the government, the movement then began its metamorphosis towards an energy and political project that was an alternative to the traditional pro-coal position of the SPD and pro-nuclear position of the CDU/ CSU (Aykut, 2015).

In East Germany, the environment was at the heart of the challenge of the communist model: the Umweltbibliotek («environmental library») was created by dissidents in East Berlin in 1986 and dismantled the following year by the Stasi. Reunification gives Germany the opportunity to rethink its industrial fabric. In the East, energy demand collapsed with heavy industry, five nuclear reactors closed and thermal power plants were modernised.

An important step was taken in 1990, when the Kohl administration established a guaranteed purchase tariff and priority access to the network for renewable energies. These principles are the two foundation blocks of the German energy transition. At the turn of the millennium, the consensus in favour of a gradual exit from nuclear power was sufficiently strong for it to be ratified by the Convention of 14 June 2000. This agreement between the ruling Green-SPD majority and the four nuclear power plant operators, limits the amount of electricity that can be produced by German reactors. The closure of the last of them was then planned for 2020. At the same time, the *Erneuerbare-Energien-Gesetz*, the law on renewable energies, allows for an acceleration of new installations, notably solar and wind.

This policy was initially criticised by the right which campaigned for an «exit from the exit». But the slogan was not reflected in practice: In 2010, while the CDU/ CSU governed without the SPD or the Greens, the Energiekonzept, a major law on energy, set ambitious targets for the middle of the century - a 50% drop in primary energy consumption in 2050 compared to 1990, an 80% reduction in emissions, an 80% share of renewables, etc. - and put back the end of atomic power to 2036. The timetable for the exit from nuclear was relaxed but the principle was not questioned.

• POST-FUKUSHIMA • This postponement of the exit from nuclear was fleeting: the following year, the Fukushima catastrophe persuaded Angela Merkel to think again. As of 15 March, 2011, 4 days after the earthquake, the law extending the lifespan of the power plants was suspended and 7 reactors were shut down by decree. The Energiewende, a new «energy package» of 11 laws, was passed by the Bundestag in June 2011 by a very large majority.

These texts return to a definitive end for nuclear power in 2022 and accelerate the process by confirming that the 7 decommissioned reactors, plus the Krummel reactor, which was experiencing repeated failures, would not be recommissioned. They also planned to reduce electricity consumption by 10% between 2010 and 2020, to double renewable production to 35% of the electricity mix in 2020 and to spend 3.5 billion euros on renewable energy research between 2011 and 2014 (an increase of 80% compared to the previous period). Finally, they confirmed the renewable targets and emission targets for 2050.

This policy comes at a cost: 15 to 40 billion euros per year or 0.5 to 1.2% of German GDP (Agora Energiewende, 2017), 60% of which is borne by households. Despite these investments, Germany will largely miss its emissions targets for 2020 (BMU, 2017): the country targeted 751 CO_2mteq in 2020, or -40% compared to 1990, but it was still at 905 in 2017. This failure is not attributable solely to the electricity sector, which accounts for only one third of German emissions, but it does cast doubt on Germany's exemplary nature in this area.

Be that as it may, the political consensus around the German energy transition was completed by the volte-face of the main right-wing party in 2010-2011 and it remains solid - only the far-right party AfD today voices any opposition to this project. For its part, the vast majority of the population supports this policy: 93% of Germans think that the *Energiewende* is important, only 8% think that renewable energy is developing too quickly and 58% think, conversely, that it is too slow. The Germans are optimistic about the next stage of their energy transition: 63% think that it will be possible to replace coal-fired power stations with renewable production (BDEW, 2018).

3 • THE ROLE OF CIVIL SOCIETY AND SUB-NATIONAL ACTORS

In spite of these difficulties, unforeseen circumstances and political alternations, for nearly 20 years Germany has followed the energy policy which it defined in 2000. The electricity mix is evolving slowly, but this stability is indispensable to its transformation. It is largely explained by the role that non-state actors have played in the design and implementation of the country's energy policy.

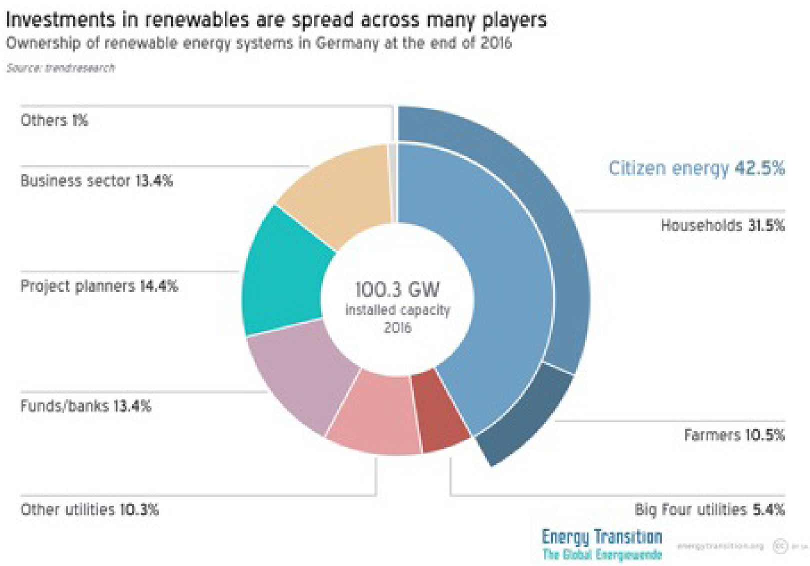


FIGURE 4. TYPES OF INVESTORS IN GERMAN RENEWABLE ENERGY PROJECTS (ENERGY TRANSITION)

(Energy Transition)

• CITIZENS, COMMUNITIES, NGOS ... THE ROLE OF LOCAL INITIATIVES • Building on a tradition of local energy management, the development of renewable energies has led to the emergence of numerous cooperatives and a reappropriation of electricity production by consumers. Today about half of renewable capacity is privately owned or farmed, compared to only 5.4% for large energy companies (Trend Research, 2017). This ownership of the energy transition by local communities promotes project buy-in and redistributes part of the costs of the German energy policy.

Local initiatives are not limited to seizing the development opportunities offered by the energy policy decided at the federal level - it often goes much further: many communities are committed to achieving 100% renewable energy or carbon neutrality.

The Baden Wurtemberg energy and climate policy

Located in the industrial heartland of southwestern Germany, the Baden Württemberg Land is one of the most prosperous regions in Europe. It contributes about 0.3% of world greenhouse gas emissions.

In its 2013 climate protection law, Baden Württemberg set itself the goal of reducing its greenhouse gas emissions by 25% between 1990 and 2020 and by 90% by 2050. These objectives are to be achieved at the same time as the exit from nuclear, on which the Land is historically highly dependent: atomic power provided 48% of its electricity in 2010. To compensate for the disappearance of nuclear, it has targeted 38% renewable electricity in 2020, 12% of which is solar and 10% wind, and 86% in 2050. Its regulations have been revised to this end - planning rules, for example, have been relaxed to accommodate the installation of wind turbines.

To reconcile industrial prosperity and climate protection, energy will also have to be used more efficiently. The Energiekonzept 2020, adopted by Baden Wurtemberg in 2007, provides for a reduction in the energy intensity of the local economy of 2% per year. Electricity demand will be stabilised and primary energy consumption will fall. Several initiatives have been launched to achieve this, such as the Zukunft Altbau to raise the awareness of homeowners, the energy check (EnergieSparCheck) that co-finances the study of energy efficiency in the residential sector and the KlimaschutzPLUS scheme which subsidises local investment in the renovation of public buildings.

In 2008, Baden Wurtemberg was the first Land to pass a law on renewable heat. This law imposed a share of renewable energy in the heating for any renovation of residential buildings.

Sources : Ministerium für umwelt, klima und energie wirtschaft baden-württemberg

TEXT BOX 1

These proposals are not always unanimously accepted. In this case, German civil society is also able to reclaim political and economic ownership of the levers for the specific implementation of the energy transition at the local level.

The battle for control of Berlin's electricity grid

To overcome the resistance of some companies and communities, it is sometimes necessary to control the distribution network. This strategy was initiated by the «Schönau rebels» who took control of electricity distribution in a Black Forest village in 1997. Today Elektrizitätswerke Schönau, the company created for the occasion, supplies more than 30,000 homes with renewable energy.

The same battle is taking place on a different scale in the German capital. Privatised in 1997, the Berlin power grid became the property of the Swedish electricity company Vattenfall at the beginning of 2001. The Berlin Senate, theoretically responsible for the regulation of the grid, rarely exercised its powers and the local authority was regularly criticised for its failure to act, while the development of renewable energies would require a modernisation of the electricity grid. In the early 2010s, Berlin was ranked last for the integration of renewable energies and the capital was still mainly supplied by 3 coal power plants.

In response to this situation, two citizens' initiatives were put in place to regain control of the grid: the Berliner Energietisch, formed in summer 2011, and Bürger Energie Berlin, created in December 2011.

In pursuit of the same objective, these two initiatives illustrate different means of action available to German citizens. The Berliner Energietisch is an informal collective of associations and citizens that set itself the goal of imposing stricter regulations on the grid operator through a popular referendum. Bürger Energie Berlin is a cooperative whose goal is to take direct control of the grid, initially when the concession was renewed in 2014. These strategies also correspond to different forms of citizen engagement: participative demo-

cracy in the first case, cooperative economy in the second.
The Berliner Energietisch initiative sought to collect 20,000 signatures in 4 months for submission to the Berlin Senate. It collected 30,000 but the project was rejected due to opposition from the majority CDU. 172,000 signatures were needed to reverse this decision - 228,000 were collected, forcing the authority to hold a referendum. This was originally scheduled for 22 September 2013 at the same time as the parliamentary elections but was postponed until 3 November, which made it possible to defeat the proposal: although 83% of voters, or 24.1% of those registered, voted for the proposal, at least 25% of registered voters were required for its adoption.
In 2014, Bürger Energie Berlin raised nearly 12 million euros from 2,500 Berliners, which enabled it only to make an offer for a minority stake in the distribution grid. The call for tenders was again awarded to Stromnetz Berlin, a subsidiary of Vattenfall.
The battle continued with the 2016 election of a new SPD - Die Grünen - Die Linke majority which was in favour of remunicipalisation.
Sources : www.buerger-energie-berlin.de et Blanchet, 2014

TEXT BOX 2

• INTENSE ACADEMIC ACTIVITY • The design of the German energy transition is the result of groundwork carried out in part by universities and think tanks. Since the 1980s, the Öko-Institute, a research institute specialising in the field of the environment and from the anti-nuclear movement, has published a book entitled: «Energiewende: Growth and prosperity without uranium or oil» (Buchan, 2012).

Technical research organisations have played a key role in the development and demonstration of renewable technologies. For example, in 1987 the Fraunhofer Institute created the first European mountain refuge entirely powered by solar power (the Rappenecker chalet in the Black Forest). In 1992, the Fraunhofer built the first solar house not connected to the electricity grid in Freiburg, to demonstrate that a family can meet its domestic energy needs from renewable energies.

Today Germany has some of the most influential energy policy research organisations: Fraunhofer Institute, Agora Energiewende, Adelphi, Potsdam Institute, etc. These bodies help to shape the German energy transition and energy exports.

• SEEKING ALLIANCES WITH ECONOMIC ACTORS • The German energy transition is inseparable from the emergence and development of companies specialising in new energy technologies: these entities contributed to the design and promotion of the project in the 1990s and were able to change scale thanks to the rapid development of renewable production from 2000. The energy policy has therefore had the side effect of making Germany one of the industrial champions in the field: in onshore wind, for example, three of the top ten global manufacturers are German (BNEF, 2017). It is also a source of employment: in 2015, the renewable energy sector employed more than 300,000 Germans, twice as many as in 2004 (BMWI, 2016) - which is why German workers' unions generally support the project while keeping a watching brief on its effect on the fossil fuel sector.

The role of unions

The powerful German unions are important energy transition stakeholders. They have national influence because of their traditional alliance with the Social Democratic Party, but their members are also often active in implementing the transition on the ground.
German unions are generally in favour of the energy transition and the new employment it creates. From 2011, the president of the IG BCE, the energy and mining union, which has more than 660,000 members, declared that nuclear power had no future in Germany.
The union's position is more ambiguous on fossil fuels. In 2014, they supported Energy Minister Sigmar Gabriel in opposing a rapid exit from coal, even stating that it would be acceptable for Germany to fail to hit its targets for 2020.

In general, trade unions seek to maintain a balance between opposition to job losses in conventional power generation - a sector in which they are well established - and improved working conditions in the sectors experiencing strong growth such as renewable energies or energy efficiency. At its congress in May 2018, the DGB, the association of German trade unions, which has 6 million members, for example, reiterated its support for the Paris Agreement objectives and called for a «fair Energiewende» that ensures affordable energy for all and creates quality employment.

Sources : Clean energy wire

TEXT BOX 3

Companies involved in the energy transition, from large companies such as Siemens, Enercon or SMA, to cooperatives and Stadtwerke (municipal boards), innumerable SMEs and startups, contribute to the definition of the country's political approach, through associations such as the Bundesverband Erneuerbare Energien (German Renewable Energy Federation), Agentur für Erneuerbare Energien (Renewable Energy Agency) or the wind (BWE), solar (BSW) and biomass (BBE) energy unions.

Siemens, a successful transition at company level

Founded in 1847, Siemens is one of Germany's leading energy companies. In the 1970s and 1980s, Siemens was a major player in nuclear construction in Germany and a regular target of opponents of atomic power. The company permanently withdrew from nuclear construction in 2011 in the aftermath of the Fukushima disaster and turned resolutely towards green technologies.

Siemens undertook a reorganisation to take advantage of the development of these activities by breaking away from some of its historical branches, such as railways or lighting. At the end of 2017, the company cut 6,900 jobs in its gas and electricity division. The same year it merged its wind division with its competitor Gamesa to form a global wind turbine manufacturer. Siemens is also active in smart grids, electric vehicles, energy efficiency, etc. The proceeds of this «environmental portfolio» represent half of its revenues and the company estimates that they led to reductions in greenhouse gas emissions by 570 million tonnes in 2017, the equivalent of 70% of German emissions. The company has set up a dedicated start-up development division (Next47) and is now developing innovative projects for the further development of renewable energies in Germany, such as the Wildpoldsried renewable micro-grid. This does not mean that Siemens cannot take part in debates on the German energy transition, which its CEO considers «good on principle but poorly managed» (open letter to Martin Schulz, 22 November 2017). For example, the company has informally contributed to discussions by the ecologist party, Die Grünen (the Greens), on exiting from coal, and in early 2018 it offered to help the Lusatian mining region convert to electric mobility.

In 2016, Siemens joined the Carbon Pricing Leadership Coalition, the World Bank's carbon price initiative. In 2017, the Corporate Knights organisation recognised Siemens as the most sustainable world company, particularly for its commitment to renewable energy and its own energy performance. Siemens wishes to achieve carbon neutrality in 2030 and is the first global industrial group to have made this commitment.

Source : Siemens

TEXT BOX 4

Not all energy companies have benefitted from the German energy transition. Since the 1990s, the four main electricity producers (RWE, Eon, EnBWE and Vattenfall) have expressed their opposition to the development of renewables in the press and courts. However, this has not prevented the German government from involving them in the decisions. In particular, the exit from nuclear power was negotiated with these four companies and the agreement specified the amount of electricity that could be produced by each reactor before its closure to enable them to plan and adapt. Be that as it may, the adoption of the Energiewende in 2011 led to a period of crisis for the major German power companies, resulting in multiple reorganisations (Kungl, 2018).

Finally, the government has sought to maintain the competitiveness of the manufacturing industry, which accounts for almost a quarter of the country's production. For both the majority of the political class and the powerful German professional organisations, maintaining German industrial competitiveness is seen as one of the keys to the success of the energy transition. Energy-intensive industries are generally exempted from the additional costs associated with the energy transition and, conversely, benefit from the fall in the wholesale price of electricity.

4 • NEW CHALLENGES

Despite its progress, the German energy transition is not complete. Germany faces new challenges if it wants to continue reducing its emissions through renewables and to become a benchmark.

• TOWARDS THE END OF COAL • Despite dropping sharply in the electricity mix, the residual share of coal and, in particular, of lignite, which emits more carbon dioxide, makes the German electricity mix one of the main sources of emissions in Europe. A coal exit project, similar to the nuclear exit project adopted in 2000, is essential if Germany is to meet its emissions targets after 2020 and maintain its credibility in the fight against climate change.

The country is trying to replicate the successful method of the 2000s, but the political consensus that has driven the transition until today no longer exists, mainly due the economic and social importance of coal in the disadvantaged Länder of the East.

Building consensus on the exit from coal

A commission on exiting coal was set up by the government on 6 June 2018. It has to make proposals to the coal regions in October and make recommendations in December so that Germany can move closer to its emissions targets for 2020. Its final report is expected by the end of the year; it must contain a roadmap for the exit from coal and set the date for the closure of the last plant.

The commission has 4 co-chairs, 8 ministry representatives, 6 representatives of coal regions, 3 members of parliament and 24 qualified individuals. Its membership reflects the search for the widest possible consensus. Länder coal producers will play an important role: in addition to the 6 regions represented (North Rhine-Westphalia, Saxony, Brandenburg, Saxony-Anhalt, Lower Saxony and Saarland), former leaders of Brandenburg and Saxony are among the four co-chairs and representatives of local coal-dependent local authorities are among the qualified individuals, such as the president of the association of mayors of Lusatia, another coal-mining region.

The qualified individuals are from the business world (companies, trade unions and business associations) and the academic world (one of the co-chairs is a former leader of Agoraenergiewende). An important place is also reserved for NGOs (such as Greenpeace and Friends of the Earth) and for local citizen movements.

Sources : www.cleanenergywire.org/factsheets/germanys-coal-exit-comission

TEXT BOX 5

• THE PROBLEM OF CHANGING THE SCALE OF ENERGY DECENTRALISATION • Decentralised initiatives have played an important role in the German energy transition - indeed, they are among its most notable aspects. But progress in these modes of energy production and distribution must also accept a growing role in running the network and in the electricity market, so a tighter framework will become necessary (Beermann, 2017).

In order to reduce the cost of renewable energy development, the 2017 Renewable Energy Law replaced the old feed-in tariff guaranteed by an auction mechanism. This complex and competitive system has a high failure rate that sometimes discourages projects led by non-professionals: preliminary data suggest that the number of citizen projects has dropped by 25% (Trend Research, 2017). The 2017 law also made the definition of citizen projects more flexible, which seems to have enabled some developers to obtain this label.

The reform of the renewable energy support mechanisms and the growing institutionalisation of production could therefore encourage large groups to the detriment of citizen projects, which will stop one of the main drivers of the German transition.

CONCLUSION

It is now very likely that Germany will complete the replacement of all its nuclear production by renewable energies in 2022, thus completing a transformation of its electricity mix that was planned at the end of the 1990s. But this success is but a first step: to honour its climate commitments, Germany must now commit to exiting from coal. If it manages to do this, it will show that its method is replicable, thus reinforcing its ambitious energy policy model based on consensus and leaving a large space for civil society.

PLEASE DO NOT HESITATE TO REACT TO THIS STUDY, AND NOTIFY US COMPLEMENTARY REPORTS AND DATA VIA THIS ADDRESS : CONTRIBUTION@CLIMATE-CHANCE.ORG

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Canada, the long road towards decarbonisation of the electricity mix

Canada needs to achieve total decarbonisation of its electricity production by 2050 if it is to achieve its climate commitments. Fossil fuel power stations emitted 79 megatonnes of CO_2eq (carbon dioxide equivalent) in 2015, which represents 10.9% of the 722 Mt of total GHG emissions in Canada[1]. Yet this country is the second producer of hydroelectricity in the world, after China and at the same level as Brazil. Canada's hydroelectric reservoirs can provide balancing services to enable wind and solar power to be better integrated into the electric power grid. Geothermal energy and biomass also offer significant potential for both electricity and heat production. The new renewable energies also facilitate the gradual decentralisation of Canadian electricity systems, offering new opportunities for both public and private businesses and for community initiatives.

Main autor • **GERMÁN BERSALLI**, *researcher, Univ. Grenoble Alpes, CNRS, INRA, Grenoble INP, GAEL, 38000 Grenoble, France*

CONTENTS

1 - Environnement et changements climatiques Canada (Environment and climate change in Canada), 2017

1 • THE GRADUAL DECARBONISATION OF THE ELECTRICITY MIX

Because of its geography and very severe climate, Canada is one of the countries with the highest energy consumption per person[2] on the planet. With 17 tCO_2/capita in 2017 (emissions due to energy), it is also one of the highest emitters per person, just below the United States and Australia and over twice the level of the EU (data from ENERDATA, 2018).

This sector is a leader in the decarbonisation efforts of the Canadian economy, in stark contrast to other sectors such as transport. After peaking between 2000 and 2002, CO_2 emissions due to public energy and heat production have shown a downward trend. **The decrease in electricity produced from coal and oil, along with the increase in hydroelectric and wind power, and to a lesser extent nuclear, explain the 31% decrease in emissions by the sector between 2007 and 2017 (Figure 1).** This movement has been strongly supported by Ontario, which completed the closure of its coal-fed power stations in 2014 (Division des inventaires et rapports sur les polluants du Canada [Division of inventories and reports on pollutants in Canada], 2018). The 2.6% increase in 2017 is accounted for by a steep increase in electricity consumption (7%)[3] and by the accompanying increase in average production (7%) of gas-fired power stations.

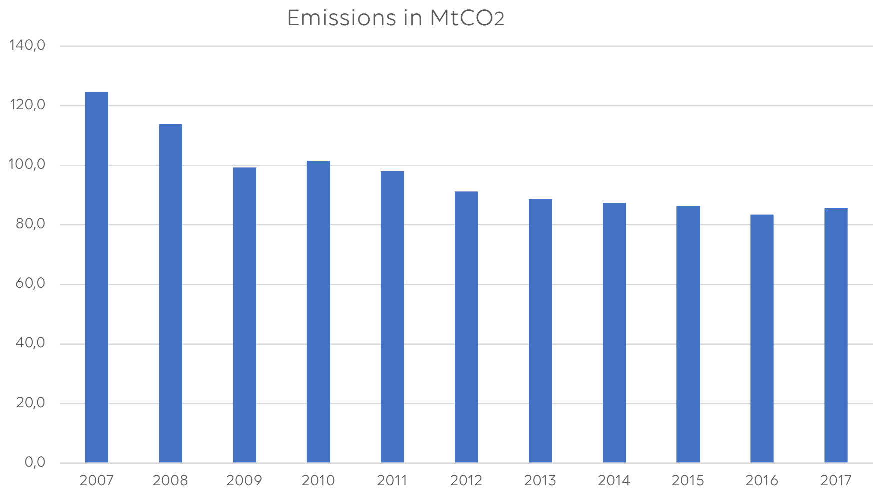

FIGURE 1. CO_2 EMISSIONS FROM THE PUBLIC PRODUCTION OF ELECTRICITY AND HEAT

Source : drawn up by the author using data from ENERDATA.

The declassification of old power stations and the addition of renewable capacity has taken the green energy share of electricity production in Canada from 63% in 2015 to 64.7% in 2017. Over the same period, the share of renewable energies other than hydroelectricity increased from 6.3% to 7.9%. This is explained by the surge in wind power from 26,060 GWh in 2015 to 35,995 GWh in 2017, and to a lesser extent by solar power which went from 2,900 GWh to 4,430 GWh. Electricity produced from coal has decreased (from 65,943 GWh to 63,706 GWh) whereas that produced from gas has increased (from 56,408 GWh to 62,763 GWh) and oil-based electricity has remained stable. **Hydroelectricity clearly remains the principal source with 349,664 GWh in 2015 and 37,164 GWh in 2017 whereas nuclear has shown a slight decrease from 101,423 GWh in 2015 to 99,343 GWh in 2017.**

2 - In 2017, energy consumption was 7.84 toe/capita and electricity consumption was 15.6 MWh/capita, among the highest levels in the world.
3 - The reasons for this rise are not yet fully established but are likely to be linked to the increased pace of economic growth, which reached 3% in 2017, as well as to climate change factors.

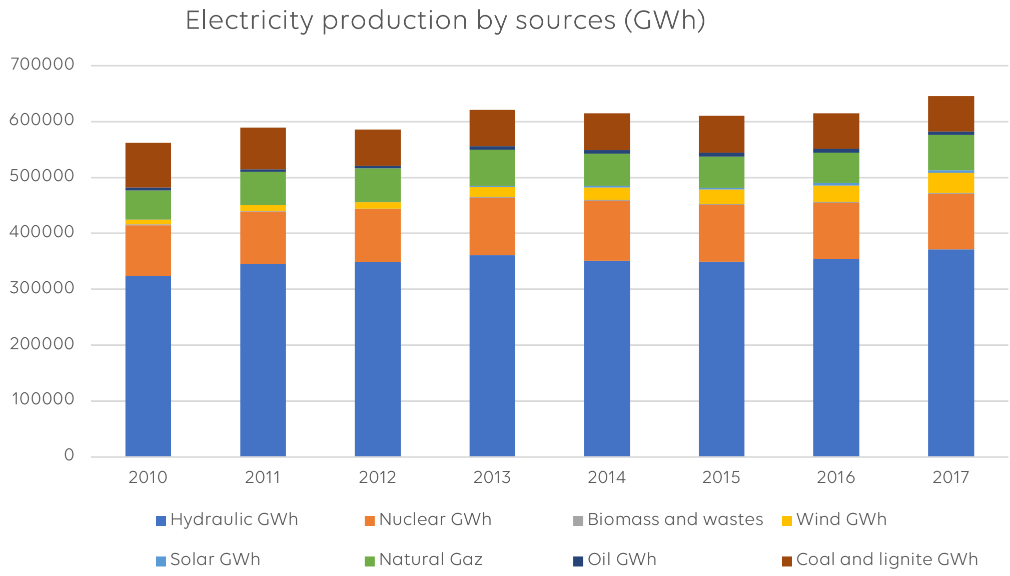

FIGURE 2. EVOLUTION OF THE CANADIAN ELECTRICITY MIX

Source : drawn up by the author using data from ENERDATA

This evolution in the energy mix allows us to position the carbon intensity of public energy production in Canada (CO_2 emissions per kWh produced) well below the world average (Figure 3). Radical decarbonisation suggests that a carbon intensity close to zero could rapidly be reached, at the same time as electricity use becomes widespread in other high carbon sectors such as transport.

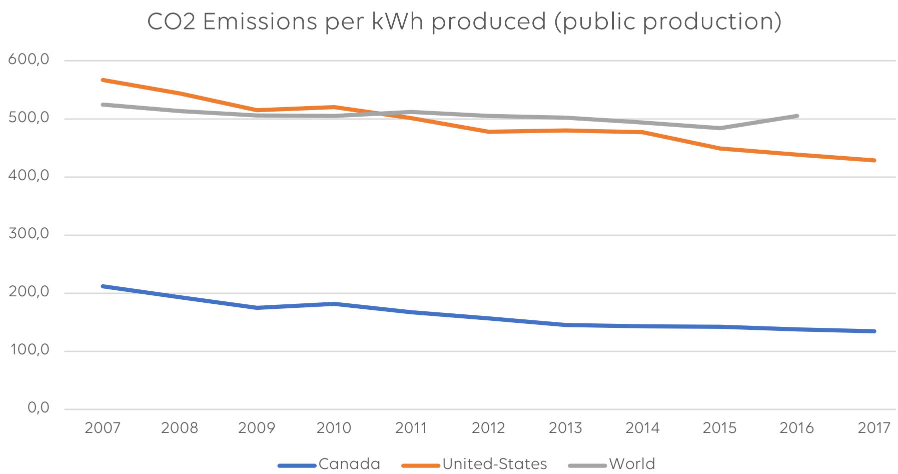

FIGURE 3. CARBON INTENSITY OF THE ELECTRICITY MIX

Source : drawn up by the author using data from ENERDATA

2 • FEDERAL POLICIES ARE QUITE AMBITIOUS YET NOT YET SUFFICIENT

According to the terms of the Paris Agreement, Canada has committed to reducing its GHG emissions to 30% below 2005 levels by 2030, a target equivalent to 523 $MtCO_2eq$ per year, that is, a decrease of 28% compared to 2015, when the total GHG emissions in Canada were 722 Mt CO_2eq.

In 2016, Canada published the 'Pan-Canadian Framework on Clean Growth and Climate Change' whose central element is **a plan to impose a compulsory tariff on carbon, requiring all provinces and territories in Canada to set up either a capping and emissions trading system or a price-based system, such as a tax on carbon.** Compliance with the pricing systems proposed by the provinces and territories to meet the federal standard will be evaluated, so that they come into force in 2019.

A federal ceiling price of 20 $CAN/tCO_2eq (15 $US/tCO_2eq) will also come into force on 1 January 2019 for provinces that have not yet proposed a system or a satisfactory minimum value. This benchmark price will progressively increase up to 50 $CAN/tCO_2eq by 2022 (Climate Action Tracker, 2018).

Carbon tax and 'carbon dividend'

The federal carbon tax has been a subject of heated debate in Canada[4] , especially because of the uncertainties surrounding its impact on the economy and household incomes. On the other hand, this law on the pricing of GHG emissions obliges the federal government to transfer all revenue generated by this pricing to the province or territory from which it originates, in the form of payments to provincial governments or rather, as suggested by the federal government, directly to private individuals and businesses. This approach, consisting of taxing carbon and then transferring the tax directly to households in the form of 'dividends' is called a 'fee and dividend' or 'carbon dividend' and has become popular in the United States with associations such as the Citizens Climate Lobby and the Climate Leadership Council. A recent study shows that households could receive more money on average than they had paid via the tax (Sawyer, 2018), a fact which was not enough to persuade all the Canadian provinces. Ontario and Saskatchewan were strongly opposed to the federal government initiative and instigated legal action to challenge the federal government's legal authority to impose such a tax. However, four provinces had already put in place a system for carbon pricing – British Colombia and Alberta (carbon taxes) and Quebec and Ontario (emissions trading system).

TEXT BOX 1

The Pan-Canadian Framework also proposes supplementary measures to further reduce emissions across the whole of the economy while accelerating the pace of innovation and job creation. The Low Carbon Economy Fund (LCEF) makes available 2 billion Canadian dollars (1.34 billion Euros) to support implementation of the Framework in the territories. 70% of this Fund will help provinces and territories to reach the objectives they set in the Framework, and 30% is to help stakeholders in Canadian society (provinces and territories, local authorities, governments and local community organisations, businesses and NGOs) to devise and implement innovative projects. In addition, in the autumn of 2017, Canada co-founded the Powering Past Coal Alliance to accelerate the elimination of electricity produced from coal. In February 2018, the Minister of the Environment and Climate Change announced modifications to the existing rules, aimed at ending electricity produced from coal by 2030, together with a revision of the standards for electricity produced from natural gas (Environnement et Changements climatiques [Environment and Climate change] Canada, 2018).

Despite all this, Canada's commitment to the Paris Agreement is considered "highly inadequate" by NGOs and academics. "*Commitments with this rating fall outside the fair share and are not at all consistent with holding warming to below 2°C let alone with the Paris Agreement's stronger 1.5°C. If all government targets were in this range, warming would reach between 3°C and 4°C*" (Climate Action Tracker, 2018). **There is also a fundamental tension between Canada's climate objectives and its place in the hydrocarbon market:** "Implicit in the national discourse about the intersection of our historically resource-based economy and the challenge of decarbonisation is the message that Canadians do not have to make choices: we can decarbonise domestically while still benefiting from the global market for conventional and non-conventional fossil fuels. Extensive citizen

4 - See for example the following report : www.cbc.ca/news/canada/carbon-tax-canadians-cost-prices-1.4753664

dialogues as part of the Generation Energy process[5] , however, challenge the logic and wisdom of this assumption" (Burch, 2018).

Carbon pricing and the development of wind power

Several studies show that the considerable technical and economic potential of wind power in Canada could enable electricity production to be radically decarbonised more rapidly and at a lower cost (Dolter & Rivers, 2018; GE, 2016). Canada has several regions where the annual average wind speed at an altitude of 50 metres reaches 7 m/sec or more, including the plains of southern Alberta and Saskatchewan, southern Ontario and northern Quebec. Hydroelectric reservoirs can provide balancing services to enable wind and potentially solar power to be better integrated into the electric power grid. This potential may be supported by carbon pricing, and the authors estimate that a carbon price of 50 $/tonne of CO_2eq (planned for 2022) could reduce GHG emissions in the electricity sector by 20 to 21% in comparison with 2005. Nevertheless, if Canada wishes to substantially decarbonise the electricity sector by 2030, the price of carbon will have to continue increasing beyond 2022..

The optimal composition of electricity production in Canada changes as the price of carbon increases. Investment in energy from wind power offers an inexpensive way to reduce emissions and becomes increasingly attractive as the price of carbon increases (Fig. 4). At 200 $/tonne of CO_2eq, wind power makes up almost 30% of the optimal production mix. In scenarios of 100% decarbonisation, wind power represents 35% of production when electricity trading between provinces is possible and 33% when it is not. These levels of penetration by wind power are comparable to the 35% of production judged technically achievable by the GE study (2016).

The study also highlights the relevance of increasing energy exchange between the Canadian provinces (from east to west) to facilitate balancing the electricity system when faced with the variability of wind power

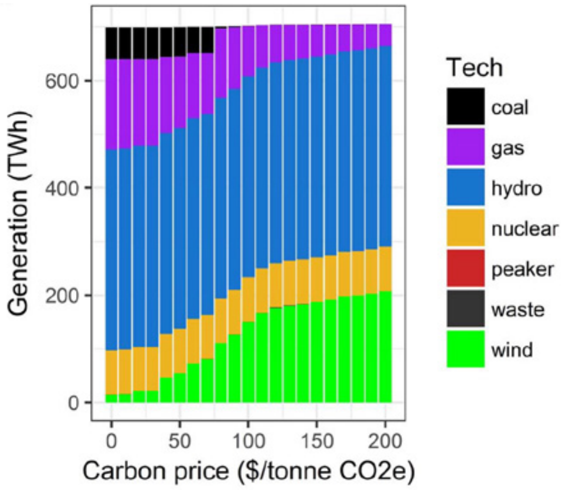

FIGURE 4. ANNUAL ELECTRICITY PRODUCTION IN CANADA IN THE CARBON PRICING SCENARIO

Source : Dolter et Rivers (2018)

TEXT BOX 2

3 • THE CENTRAL ROLE OF CANADIAN LOCAL AUTHORITIES

Hydroelectric power stations are a major source of energy for electricity production in Quebec, Newfoundland and Labrador, Manitoba and British Colombia. Provinces that depend on coal and natural gas include Saskatchewan, Nova Scotia, New Brunswick and Alberta. Geographically, each province where electricity is produced from fossil fuels is adjacent to a hydroelectric province. **Nevertheless, the existing transport structure only allows a limited number of east-west inter-province connections, which limits electricity trading between provinces and therefore the integration of renewable energy sources**. Figure 5 below shows the huge contrast in the energy mix of two adjacent provinces.

Canadian provinces have advanced skills in environmental matters and some have been very active in carbon pricing. British Colombia, Quebec, Ontario and Alberta introduced different

5 - Voir : www.nrcan.gc.ca

arrangements for carbon pricing. They also implemented various mechanisms to support the roll-out of clean energy for electricity production (see Text box 2)

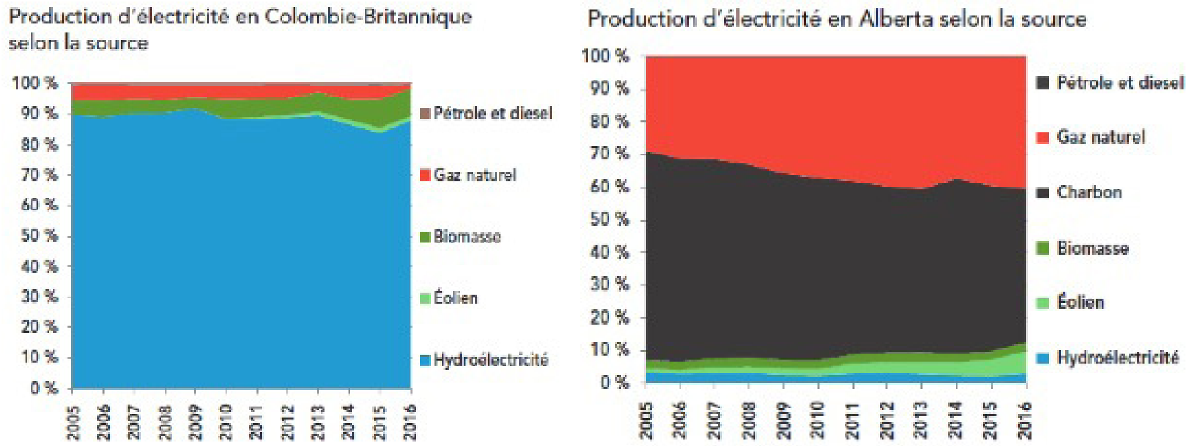

FIGURE 5. EVOLUTION OF THE ELECTRICITY MIX IN ALBERTA AND BRITISH COLOMBIA

Source : National Energy Board 2017

In addition, several Canadian cities such as Toronto, Vancouver, London, Edmonton and Windsor have set objectives and put in place actions for mitigation, in particular for the production of electricity (or electricity and heat) locally and from renewable energy sources.

The provinces in action

The 'First Annual Summary Report' of the 'Pan-Canadian Framework for Clean Growth and Climate Change' was published in December 2017. It highlights specific actions undertaken by the Canadian provinces during 2017.

• **Newfoundland and Labrador** continue working to complete the hydroelectric project at Muskrat Falls. When it is finished, 98% of the province's electricity will come from renewable sources. The surplus will be exported to Nova Scotia and elsewhere. The Holyrood Thermal Diesel Generating Station, which produces over a million tonnes of GHG emissions per year, will be declassified.

• **The North-West Territories** have installed 55 kilowatts of solar energy with an efficient variable-speed generator in the community of Aklavik, and are undertaking design works for large-scale wind turbines at Inuvik. They are also trialling the combined production of heat and electricity on a small scale from biomass at Fort Simpson to reduce diesel use in these far-flung indigenous communities which are off the grid.

• **Prince Edward Island** is one of the world leaders in the field of developing energy from wind power. Wind power energy meets twenty-four per cent of the energy requirements of Prince Edward Island and future expansion is planned by 2020 and 2030.

• **Alberta** has announced the Renewable Electricity Act and launched a renewable electricity programme aimed at creating a renewable energy production capacity of 5,000 megawatts by 2030. The province has also announced that 35 million dollars has been set aside for financing leadership initiatives in climate change, especially solar and renewable energy projects in the communities of the First Nations and the Métis Nation.

• **Quebec** has announced an action plan for its 2030 energy policy in which it commits to increasing its capacity for renewable energy production by 25%. This province also created Transition Energétique Québec (TEQ) (Quebec Energy Transition) to support, stimulate and promote energy transition, innovation and efficiency, and to finalise the implementation of all the programmes and measures necessary to reach its energy objectives.

Source : Pan-Canadian Framework for Clean Growth and Climate Change (2017).

TEXT BOX 3

In 2012, in partnership with Toronto Hydro, the capital city of Ontario launched the first phase of a programme that will enable buildings belonging to the city to be equipped with solar photovoltaic (PV) panels. The first phase of the feed-in tariffs was completed in June 2014 and the second phase in 2016, which led to the installation of 20 PV solar systems on the roofs of the city's buildings, with a total installed power of 2.5 MW. On an annual basis, phases 1 and 2 combined make it possible to reduce GHG emissions by approximately 147 tonnes and generate more than 3,300 megawatts (MWh) of electricity, which is equivalent to the energy consumption of around 280 households. In October 2016, Toronto began the third phase of the FIT programme, which will see the installation of over 40 PV solar systems for total installed power of 6.0 MW. These installations will produce approximately 7,800 MWh of electricity per year - the equivalent of the consumption of some 350 households - and will reduce GHG emissions by around 353 tonnes each year.

The city of Vancouver is internationally recognised as one of the most ecological cities on the planet. The capital of British Colombia has a long history of support for climate action, from the Clouds of Change reports in 1990 to the Community Action Plan for Climate Change in 2005 and the Greenest City 2020 Action Plan in 2011, and now the Renewable City Strategy and Plan. This plan, whose aim is to achieve a city with 100% of its energy supplied from renewable sources by 2050, targets buildings, transport and waste as well as cross-cutting opportunities, and also the reduction of energy consumption. The results of the plan's progress are published annually[6] . In addition, the city strongly opposed the expansion of the TransMountain oil pipeline between Edmonton and Burnaby, recently relaunched by the federal government. "*Vancouver's path to be the greenest city in the world started decades ago. Thanks to the passion of the people who choose to call Vancouver home, it will continue long after 2020*" (Greenest City 2020 Action Plan Part Two: 2015-2020).

Flexible nuclear reactors for New Brunswick - a sustainable choice?

The government of New Brunswick has signed an agreement with the American company Advanced Reactor Concepts which seeks to develop small flexible reactors in this province of eastern Canada. Thanks to the Point-Lepreau power station, nuclear power has played a significant role in the electricity production of New Brunswick since the 1980s. The provincial government strongly supports scientific research to develop small nuclear reactors which are seen by certain stakeholders as a decarbonisation solution but remain very much criticised by other stakeholders.

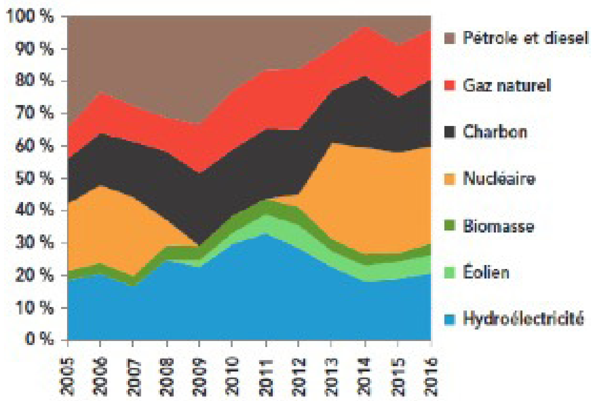

FIGURE 6. ELECTRICITY PRODUCTION IN NEW BRUNSWICK

Source: National Energy Board, 2017.

With a surface area of 72,908 km² and a population of 747,101 (2016), New Brunswick is one of the smallest provinces in Canada. In 2016, it produced its electricity from various sources and 29.9% of these were renewable. However, the continuing high percentage for coal (20.7%) largely explains the fact that the level of GHGs in electricity production, at 280 g of GHG per kWh, is double the Canadian average (National Energy Board, 2017).

Following the agreement with the provincial government, Advanced Reactor Concepts (ARC) announced an investment of 5 million dollars in R&D activities in New Brunswick and will open an office in Saint-Jean to develop reactors

6 - https ://vancouver.ca/files/cov/greenest-city-action-plan-implementation-update-2017-2018.pdf

with a capacity of 100 MW. This company is seeking to develop and market a sodium-cooled reactor of metal construction. It uses the technology of GE Hitachi Nuclear Energy. The company's reactor could be on the market from 2028. The provincial government will not invest finance in this specific project, but it recently announced financing of 10 million Canadian dollars for a nuclear research group formed by the New Brunswick Energy Solutions Corporation, a partner in the project[7] .

According to ARC, this new type of reactor has several advantages. One is that the modular components of the reactor may be transported as separate parts to an assembly site and rapidly brought into service. In addition, the reactor may be used for non-traditional purposes, such as in desalination plants for seawater and sites extracting shale gas. However, these new agreements in favour of nuclear have been the subject of fierce criticism from various NGOs and political groups, such as the Green Party of New Brunswick[8] . They stress the risk of accidents, the ever-present problem of radioactive waste, the non-renewable nature of these resources and the high cost.

TEXT BOX 4

4 • A HIGHLY CONCENTRATED INDUSTRY FACED WITH NEW INNOVATIVE BUSINESSES

The Canadian electricity sector is organised around provincial public companies. In fact, the provinces have constitutional jurisdiction over natural resources. The process to partially liberalise the markets in the 1990s modified certain industry parameters, for example the functional separation of electricity production, transport and distribution activities. Most provincial governments are still directly involved in the electricity market as managers of a more or less significant part of the electric power network.

A number of local authorities manage local distribution networks in their territory. Some municipally-owned companies, such as EPCOR in Edmonton, are major players in electricity production, under their corporate name or through their management of companies listed on the stock exchange.

Over recent years, the partial or total deregulation of wholesale electricity sales has created a number of independent producers, who build and manage electric power stations and sell their production over the long term - using contracts with a duration of up to 35 years - or on the electricity market, where such a market exists.

The principal companies in the sector are grouped together in the Canadian Electricity Association which has been in existence since 1891. This association publishes an annual report, Sustainable Electricity, which evaluates progress in the sector in matters of economic, social and environmental sustainability. Among the initiatives undertaken by businesses in the sector in 2016-2017, the following may be noted:

• Capital Power is reducing coal consumption and CO_2 emissions thanks to renewable biomass. The private company Capital Power is actively pursuing co-combustion of biomass (wood waste) with coal at its Genesee power station, located to the west of Edmonton. This is the first time a trial of this size has taken place in Canada, involving the co-combustion of woody biomass and coal in an electricity power station. Integrating biomass into the fuel mix at Genesee has the potential to reduce coal consumption to 30%.

7 - ICI.Radio-Canada.ca, 9/07/2018, Research into small nuclear reactors in New Brunswick.
8 - Acadienouvelle, 10/07/2017. Mini nuclear power stations: a 'mad adventure' to be avoided

• Nova Scotia Power has focused on developing renewable energy over the last ten years. Nova Scotia Power has tripled its production of renewable energy to 28% thanks to biomass and wind power, and has reduced its GHG emissions by over 30%. It is set to achieve a 58% reduction in emissions, compared to 2005 levels, by 2030, a performance that is almost twice the level of national objectives. A major reduction in GHG emissions is expected when Nova Scotia becomes linked by sea to the hydroelectric plant under construction at Muskrat Falls in Labrador.

• Alectra and Enbala are working together on the management of smart electric mini-networks. Alectra provides the advanced technology necessary to ensure the operational stability of electricity networks by managing the power of the energy distributed. Enbala's real-time energy balancing platform offers an extremely flexible approach to create energy resources that can be controlled and distributed via flexible loads, energy storage (including electric vehicles) and renewable energy sources. In 2013, Alectra set up a project for a pioneering micro-network in Vaughn, Ontario, to rise to the challenge of renewing the workforce on the large-scale electricity distribution networks and show that renewable energy can effectively meet the growing demand for electricity.

As far as the development of geothermics is concerned, Canada is lagging behind in respect of the enormous potential that exists for the production of heat and electricity, especially in the west of the country. Businesses in the sector and political representatives of the provinces of western Canada both[9] stress that the expertise and skills of the oil industry can be used to advance projects for geothermal power plants. Among the latest initiatives is that for a power plant near the town of Estevan headed by the company *DEEP Earth Energy Production* which had carried out several conclusive tests since 2014. It plans to sink the first wells from June 2018. In the area of Estevan, Saskatchewan has aquifers on which DEEP is conducting its geothermal operations. They contain a subterranean layer of brine - extremely salty water - preserved beneath permeable rock 3 kilometres from the surface. To release energy or geothermal heat from this, all that is required is to draw out this water at a high temperature (120 degrees Celsius), then pass it through a turbine which will extract the heat or energy. The cooled water is then reintroduced into the aquifer. It reheats rapidly on contact with the rock on its journey to the depths (*Source: DEEP Earth Energy Production*). The Saskatchewan State company *SaskPower* signed a contract in the spring of 2017 to purchase electricity from DEEP, which could produce 5 megawatts per power plant. One single power plant will be able to supply 5,000 homes with electricity. DEEP is planning to build more than ten of them.

5 • THE MEDIA, USERS AND THE SOCIAL DIMENSION OF THE TRANSITION: THE EXAMPLE OF SMART NETWORKS

The challenges of a transition towards an economy of low carbon emissions are largely social and political rather than technical (Burch, 2018). To achieve this, there is a need for deliberate policies at various levels on the one hand, and, on the other, proactive behaviour on the part of citizens. Other stakeholders such as the media or NGOs also play an important role as intermediaries as well as opinion formers on this subject. Smart grids have been known for several years and are a revealing example of the role of users and the media in the energy transition because they incorporate technologies that can directly affect our daily life.

In recent years, several research teams in Social Sciences have focused on analysing the rather problematic establishment of smart networks in Canada and the United States[10] . Smart networks are designed as a cutting-edge tool aimed at transforming the ways societies produce, distribute and consume electricity. A smart grid is a network that links producers and consumers to ensure a safe, sustainable and economically efficient electricity supply. It includes tangible and intangible information and communication technologies (ICT), such as smart meters, real-time information

9 - Voir : //ici.radio-canada.ca/nouvelle/1023713/geothermie-reconvertir-puits-petrole-orphelins-budget

10 - Consulter : (Peters et al. 2018 ; Mallett et al., 2018a ; Mallett et al., 2018b ; Jegen et Philion, 2018 ; Winfield et Weiler, 2018 ; Meadowcroft et al., 2018).

for consumers, dynamic pricing and the incorporation of electric vehicles into the networks. For their supporters, smart networks constitute a key element of the transition to sustainable energy, aimed at mitigating climate change, improving energy security and preventing surges in energy prices (Jegen and Philion, 2018).

The development of smart grids is relatively recent in Europe and North America. In Ontario, a strategy of rapid roll-out for smart meters was launched in 2004 and is still to this day considered the most advanced experiment in terms of the formulation and implementation of policies for smart networks in Canada (Winfield and Weiler, 2018). In this province, smart grids have been put on the policy agenda as an ambitious strategy to improve the network while mitigating climate change. In contrast, in the neighbouring province of Quebec, the roll-out of smart networks occurred later, lacked political relevance and was limited in its scope. The principal objectives linked to their introduction were the security of the supply and economic efficiency, with little stated ambition for a more fundamental change in the way the energy industry works.

In 2011, Hydro-Québec - a public monopoly - launched its programme to replace 3.75 million traditional meters with smart meters. Although the new infrastructure was designed to enable bi-directional communication, the meters are in fact used by Hydro-Québec to collect data on the use, voltage and quality of electricity, yet no hourly rate has been introduced and consumers cannot check and adapt their energy use in real time. Furthermore, the authors show that key players in the electricity sector of Quebec did not establish any link between a smart network and strategic challenges such as climate change and energy transition. Media analysis shows, however, that the media coverage on smart networks was generally negative and mainly focused on the potential detrimental impacts of smart meters.

The analyses by Mallett et al. (2018) start from the observation that different provinces in Canada continue to promote the integration and expansion of smart networks within their electricity systems, but roll-out rates vary despite them having similar policies and programmes. To try to understand the reasons for this discrepancy, they focus on the way smart grids are perceived by users and reflected in the written media. The authors emphasise the fact that the media coverage of smart networks began as generally positive but this was reversed some time later. In other words, and according to the theory of Gartner's 'hype cycle', there is first a bias in favour of innovation when support for new technology increases rapidly in a more abstract and general way, then decreases as users experience these new technologies in reality. The negative perceptions of these technologies were greater in British Colombia and Quebec, two provinces where users had more negative experiences with the way they were initially introduced to smart meters (often in a letter from their public service informing them that their analogue electricity meter would be subject to compulsory change). On the other hand, media coverage was more positive in Ontario, where the fact that there are more local electricity distribution companies helps put in place strategies that are better adapted to the characteristics of each territory.

Peters et al. (2018) finally highlight the fact that 'environmental scoping' was largely absent from the socio-political discourse (citizens, media and key participants) during the establishment of smart grids in British Colombia. A clearly communicated vision of the way smart networks can help mitigate climate change may increase acceptance and participation by citizens. To sum up, the results of these studies remind us that political decision makers must pay particular attention to the dynamics and characteristics of each territory in order to enhance the success of the policies and programmes involving new technologies.

CONCLUSION

The provinces of Canada have very strong prerogatives in terms of energy and the environment. Most of the provinces have therefore set objectives to reduce GHG emissions and have taken measures towards achieving them. All these actions are harmonised in a federal plan aimed at the total decarbonisation of the electricity sector in the decades to come. Municipal authorities are also active in the climate field, urged on by citizens who are increasingly concerned. Finally, new technologies associated with renewable energy facilitate the decentralisation of energy systems, which opens opportunities for new businesses in various areas such as geothermal and the smart management of networks.

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PRESS & COMMUNICATIONS :

• Bullfrog, entreprise canadienne vendant des produits d'énergie renouvelable, a été accréditée par CDP en 2017.

• Manitoba Hydro, exportateur d'hydro-énergie basé à Winnipeg, produit 97% de son électricité à partir de sources renouvelables. C'est un exemple d'initiative territoriale récurrent.

• Government of Canada, Government of Canada committed to modernizing heating and cooling plants in National Capital Region, pour un aperçu de la stratégie nationale en matière de chauffage/ refroidissement des villes.

• https ://ici.radio-canada.ca/nouvelle/1111590/recherche-petits-reacteurs-nucleaires-nouveau-brunswick-point-lepreau

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• https ://business.financialpost.com/commodities/energy/total-destruction-of-the-market-investments-in-clean-tech-cool-off-as-subsidies-ends

Portugal: a blazing energy transition hampered by the resilience of coal

Portugal, a country that is home to 10 million people, has become one of the European champions of renewable energies for electricity production, thanks to the growth of onshore wind, hydro-electricity, biomass and - more recently - solar energy. The spread of renewable energies also encourages new operators to emerge, both domestic and foreign, in a sector that is traditionally oligopolistic. However, the intense decarbonisation of the Portuguese electricity system has been faced with several challenges, requiring action from public and private operators at different levels. For example, the need for a rapid "exit" from coal, the physical interconnection with the rest of Europe, and the development of smart grids are some of the main challenges.

Head Editor • **GERMÁN BERSALLI** • *Researcher, Univ. Grenoble Alpes, CNRS, INRA, Grenoble INP, GAEL*

CONTENTS

1 • MOVING TOWARDS THE DECARBONISATION OF ELECTRICITY PRODUCTION?

Following the 2015 Paris Agreement, Portugal has been committed to achieving a carbon neutral economy by 2050. Since October 2017, the government has been working on a roadmap that aims to identify and analyse the implications of the trajectories that are most effective for pursuing the national goal of carbon neutrality. Despite an advance in renewable energies for generating electricity, continuing with coal prevents true decarbonisation of the sector.

• THE PORTUGUESE ELECTRICITY MIX: THE GROWTH OF WIND POWER VS THE RESILIENCE OF COAL • Despite significant investment in renewable energy over the past ten years, reducing CO_2 emissions from public electricity and heat production has proved to be a struggle (Figure 1). **On the one hand, we have seen an increase in electricity production, which pushes up the level of emissions, and, on the other hand, an opposite effect: a decrease in the carbon intensity of the electricity mix thanks to progress in renewable energies occurring at a faster rate than in fossil fuels. However, the second effect is barely enough to offset the first, which explains why the level of emissions only dropped very slightly over a ten year period**. Chart 1 also shows a large fluctuation in the level of emissions from one year to another. This can be explained by the significant variations in rainfall patterns and therefore hydro-electricity production, offset by increased use of fossil fuels. As such, CO_2 emissions decreased by 9% in 2016 but bounced back by 20% in 2017. Last year's emissions reached 17.1907 million tonnes of CO_2, 76% of which came from coal-powered power plants, 20% from gas-powered plants and 4% from diesel power plants.

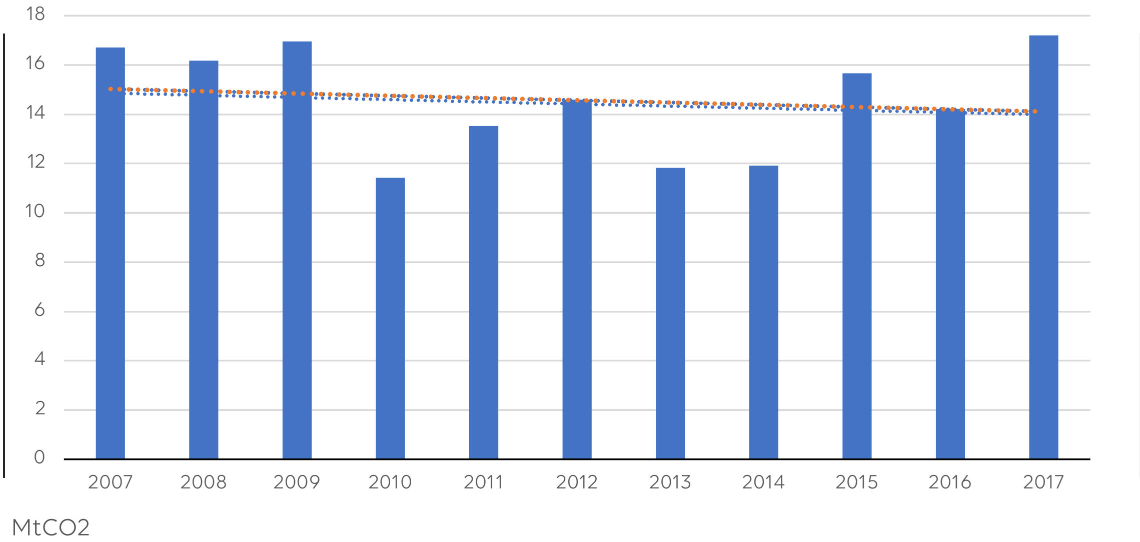


FIGURE 1. CO_2 EMISSIONS FROM THE PUBLIC PRODUCTION OF ELECTRICITY AND HEAT.

Source: Compiled by the author using data from ENERDATA

Public electricity generation in Portugal amounted to 49,447 gigawatt hours (GWh) in 2017, slightly lower than the record 51,983 GWh in 2016. The country has a fairly diversified electricity mix (Figure 2). In 2017, natural gas represented 32.9%, followed by coal (24.9%) and wind energy (20.3%). The remainder of the electricity mix was composed of: hydro-electricity (12.4%), biomass (5.7%), oil (1.9%), solar (1.4%) and geothermal (0.3%). Over the past decade, wind energy production has increased substantially; however, this has not been accompanied by a nominal decrease in production by coal-powered plants. As for gas-powered plants, their production levels vary from one year to the next to offset the fluctuations in hydro-electricity. The latter's share ranged from a maximum of 30.6% in 2010 to a minimum of 12.4% in 2017. **Finally, it should be noted that the share of**

wind energy in Portugal's electricity mix was the fourth highest in the world in 2016, behind Denmark, Lithuania and Uruguay. Solar energy, on the other hand, is still struggling to carve out its place in the Portuguese electricity mix.

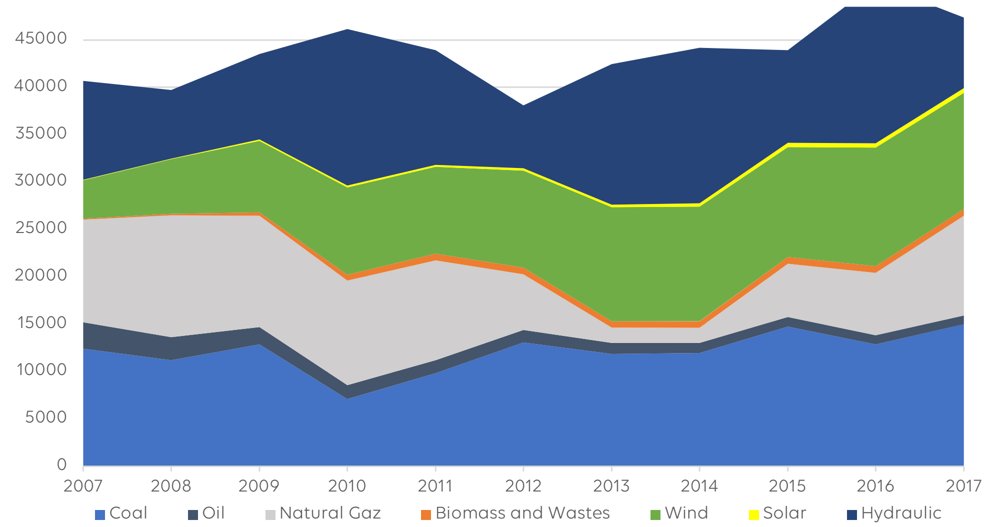


FIGURE 2. ELECTRICITY GENERATION BY SOURCE (GWH/YEAR)

Source: author's compilation using data from ENERDATA

Given the growth of wind power and the high variability of hydro-electricity production (from one year to another), the carbon intensity of Portugal's electricity mix (Figure 3) has experienced a slight downturn, but still demonstrates considerable fluctuations. With an intensity of around 300 grams of CO_2 per kWh, the country (like the majority of its European neighbours) still has a lot of work to do in order to achieve a fully-decarbonised electricity production sector.

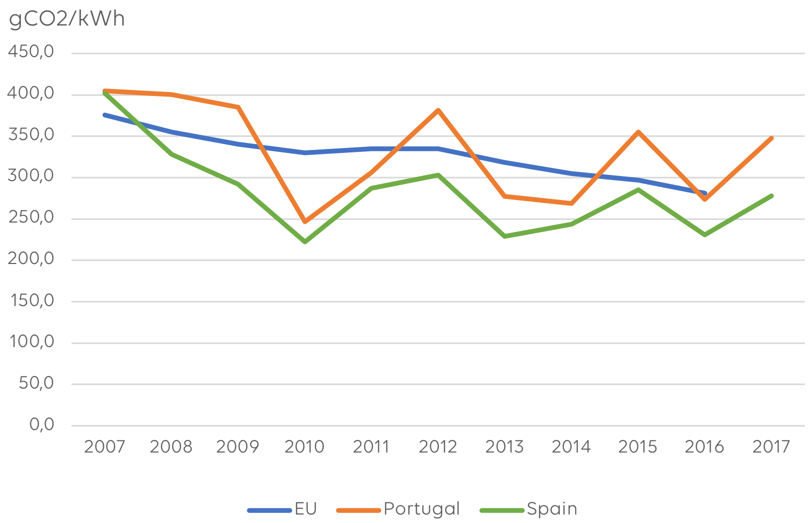


FIGURE 3. CARBON INTENSITY OF THE PORTUGUESE ELECTRICITY MIX.

Source: Compiled by the author using data from ENERDATA

• A SOMEWHAT AMBITIOUS NATIONAL POLICY FRAMEWORK • The purpose of the *Programa Nacional para as Alterações Climáticas 2020/2030* (National Climate Change Programme 2020/2030) is to ensure the reduction of greenhouse gas emissions, in order to achieve a goal of -18% to -23% in 2020 and -30% to -40% in 2030 compared to 2005 levels, ensuring compliance with national commitments in terms of mitigation and bringing Portugal in line with European objectives. It sets specific targets for emissions reduction, and identifies a set of sectoral measures and policy options for development in the future. In this way, integrating mitigation objectives into sectoral policies is encouraged and a dynamic approach to planning is recommended, giving each sector (transport, energy, agriculture, forestry) greater autonomy in identifying policy tools.

As such, Portugal has adopted the 2020 target of sourcing 31% of its energy from renewable sources in final energy consumption, including 10% in transport; a general energy efficiency target of 25% for 2020 (more ambitious than the 20% target set by the EU) and a specific 30% energy efficiency target for public administration. Furthermore, in "*Compromisso para o Crescimento Verde*" the country committed to achieving 40% renewable energy in final energy consumption by 2030.

Given the strong potential of renewable energy in Portugal, the electricity sector, which includes dedicated production and cogeneration, is one of the main driving forces behind reducing national emissions. The most important way of encouraging renewable energy is a feed-in tariff for existing facilities. **A remuneration scheme came into force in 2015 for new small production facilities. Generally speaking, all technologies used in the generation of renewable electricity are eligible for support.** In addition, connections to the network are provided for renewable energy producers. Currently there is no direct assistance programme for renewable energies in the heating sector (in January 2017). Furthermore, Energy Efficiency Funds have provided grants for investments in solar water heaters through "Efficient Buildings 2016", which started in July 2016.

In November 2016, the Portuguese Minister of the Environment confirmed that the country's power plants would cease burning coal by 2030. This was reiterated when the roadmap for carbon neutrality by 2050 was launched in October 2017. The Sines power station in Portugal, inaugurated in 1985, is one of the EU's most climate-damaging coal-powered plants[1].

2 • THE DEVELOPMENT OF RENEWABLE ENERGIES AND THE DIVERSIFICATION OF OPERATORS

The development of renewable energies in Portugal has largely been led by EDP Renováveis (EDPR), which was established in 2007 as an independent company of the incumbent operator, EDP (Energias de Portugal). **By the end of 2017, EDPR was ranked fourth in the world in terms of wind energy production. Small start-ups have been emerging alongside this giant in a Portuguese electricity sector that is particularly dynamic in wind power and, more recently, solar power.**

• CONSOLIDATION OF ONSHORE WIND ENERGY • The power generation sector - which has long been oligopolistic - has four major players, including the EDP. **However, over the past decade this company has seen its market share decrease due to the emergence of several new renewable energy producers. In 2013, they already accounted for 40% of electricity on the wholesale market (IEA, 2016).**

Portugal has been experiencing spectacular development in onshore wind energy since the 2000s. **The country's installed capacity has grown from 100 MW in 2000 to 5,269 MW in 2017 (Figure 4), which has been made possible by a very generous feed-in tariff system (Figure 5).** A portion of the extra cost is passed on to electricity consumers, while another portion increases the deficit - and accumulated debt - of the electricity system. This prompted critical reactions (Peña et al., 2017), and the government decided to end this support system in late 2012. As such, plants put into operation from 2013 onwards could no longer receive these grants, which slowed down the sector's growth. However, a new promotion scheme came into force in 2015 for self-generators and small production facilities with a maximum installed capacity of 250 kW. As far as offshore wind power is concerned, there are as yet no turbines operating off the Portuguese coast because the ocean floor is too deep. Offshore wind power will be achieved via floating wind farms, a dozen of which are in the planning stage.

1 -Europe Beyond Coal Overview: National Coal Phase-Out Announcements in Europe, 2018

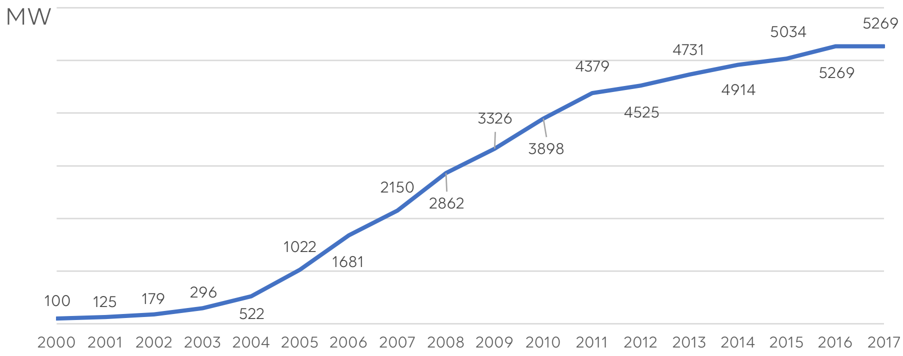


FIGURE4. INSTALLED WIND POWER CAPACITY, PORTUGAL.

Source: compiled by the author using data from ENERDATA

Three major operators dominate the wind energy market: ENEOP2, EDP Renováveis and Iberwind, who account for 45% of the total installed wind power capacity (Peña et al., 2017). In addition to these large operators, there are several hundred small renewable energy producers, the majority of which are part of the Portuguese Renewable Energy Association (APREN). The Omniflow scheme (see box 1) demonstrates the potential technological innovation of these small businesses, and is beginning to spread throughout Portugal and beyond.

According to APREN estimates (2018), renewable sources for electricity generation represented 1.8% of national GDP in 2017. **The technology which has contributed the most to this statistic is wind energy, due to the existence of a value chain that includes the production of industrial components as well as a range of R&D services. The sector accounts for 55,000 jobs, and there are 400 researchers working in this field.**

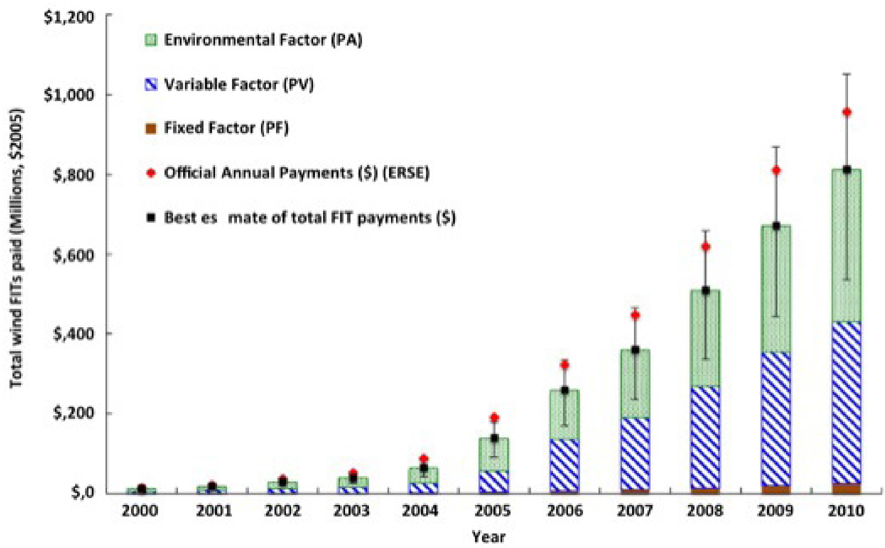


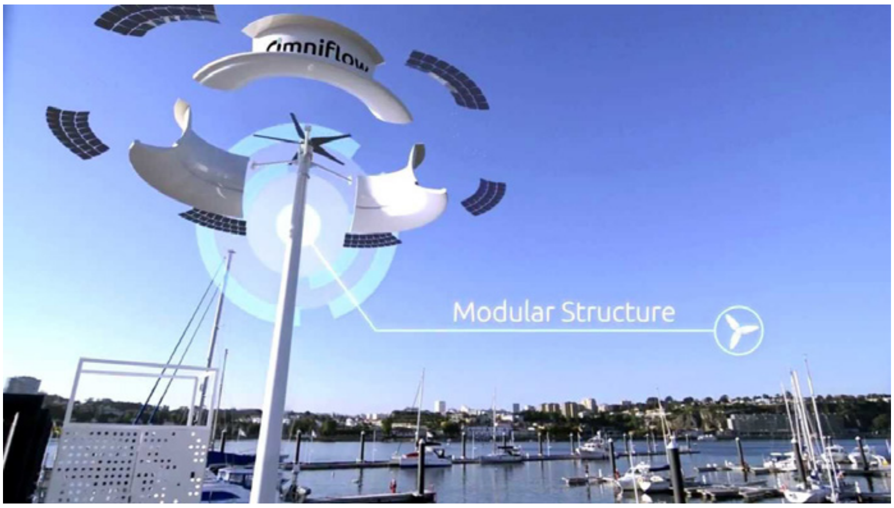
FIGURE 5. REMUNERATION PAID TO WIND ENERGY PRODUCERS

Source: Peña et al., 2017.

Omniflow, an innovative technology which combines wind and solar energy

Omniflow technology combines a vertical axis wind turbine with photovoltaic solar panels. This innovation was developed by a small Portuguese company which subsequently received financial support from the EU.

This technology has several innovative aspects: modular wing-shaped blades are integrated into a circular device which rests on a mast of varying size depending on the specific need. At its centre there is a mobile vertical axis which captures and accelerates wind coming from all directions, while the air above the turbine combines with the air coming directly from the turbine in an ascending cyclonic vortex. To complete the device, the surface is covered with solar cells. By combining these two energy sources, this hybrid technology increases total electricity generation and reduces storage needs thanks to the way solar and wind energy complement each other. As an energy source, the sun is usually more stable, but the turbine compensates for production losses in winter, as solar PV reaches peak production in summer while wind power experiences peak production in winter and can operate at night.



This start-up targets households as well as commercial buildings, and advises potential customers on the best solution for the site in question. It also offers a model that is suited to smart street lighting (Smart Street Lighting - Omnilight).

Source: Isento G. (10/11/2015) Omniflow é um gerador urbano com energia solar e eólica, publico.pt

TEXT BOX 1

• SOLAR PV TAKES OFF • The cost of solar PV has dropped significantly over the past few years, along with the price of storing electricity in batteries. In a sunny country such as Portugal, solar energy is a very appealing source of power to help balance the country's already impressive supply of hydraulic and wind energy. Portugal has invested in solar energy to take advantage of this potential, combining favourable conditions with technological progress and the government's stable regulatory framework. Recent investments have shown that Portugal can continue to play an active role in the deployment of renewable energies.

26 July 2018 marked the inauguration of a new solar facility in Ourique, Alentejo, in South-East Portugal. The *Ourika* plant has been operating since June, following 11 months of construction and 35 million euros of investment. **It is one of the largest solar power plants in Europe. Its 142,000 solar panels produce 80 GWh of energy per year, which is enough to power 23,000 households. In addition to its size, this power plant is the first on the Iberian Peninsula to be connected to the main power grid without a guaranteed tariff or other public subsidies.**

The Portuguese Minister of the Environment recently announced the planned instalment of 31 new power stations in Portugal before 2021, which represents an additional production capacity of more than 1,000 MW. The total value of the projects has been estimated to be around 800 million euros. In 2021, the country will be able to triple its installed solar PV capacity from the current 572 MW to nearly 1,600 MW. The government even hopes to increase solar energy production sixfold before 2025.

A floating solar power plant in a hydroelectric dam

The company *EDP-Renovaveis*, which is associated with a French start-up, is testing a technology that is one of its kind in Europe: combining a hydroelectric dam and a floating solar power plant. The Alto *Rabagão* model, located in the north of the country, is small in size: 840 solar PV modules occupy a surface area half the size of a football pitch, submerged in a pool of water that is eight thousand times larger. With 220 kilowatts of power, they can only power around one hundred homes. But the test, which was launched in late 2016, at a cost of 450,000 euros, shows promise (Le Monde, 31/08/2018).

There are several advantages to installing panels in an aquatic environment: it cools the cells, which would increase their efficiency by 4 to 10%, and there is no need to use land or build additional power lines. Furthermore, the floating power station reduces evaporation from the reservoir and slows the growth of algae, according to those in charge of the EDPR projects.
If the test is successful, it will be followed by a project on a larger scale with 20 megawatts (MW). EDPR intends to develop the process on a larger Portuguese dam called Alqueva, which is located in Alentejo, in the south of the country, and to eventually export it to Brazil, where the energy company has a strong presence.

Photo: Rui Oliveira / Global Imagens

TEXT BOX 2

3 • THE CHALLENGES OF INTEGRATING A GROWING SHARE OF INTERMITTENT ENERGIES

The Iberian Peninsula is home to vast wind and solar resources, but it remains relatively isolated from the rest of Europe, which hinders the injection of renewable electricity into central European networks. Several projects are in progress with the aim of reversing this situation. At the same time, integrating intermittent energies creates new challenges for transport and distribution network operators. With this in mind, smart grids are being developed in several of the country's cities.

• THE PORTUGAL - SPAIN - FRANCE INTERCONNECTION • In March 2018, Portugal produced more electricity from renewable energies than it actually needed. This marked the first time in the 21st century that the amount of electricity generated exceeded consumption. However, the lack of energy connections with the rest of Europe remained a stumbling block. Without a properly connected electricity network or a well-developed storage system, some of this intermittent energy would be wasted. This is why interconnections are vital for EU energy union projects in order to create a proper internal energy market, because they would enable surplus electricity to be transferred from one EU member state to another, depending on production and demand.

At the end of 2014, there were nine lines connecting Portugal and Spain: six were 400 kV and three were 220 kV, which meant there was a maximum exchange capacity of 2,800 MW from Portugal to Spain and 2,200 MW from Spain to Portugal. Despite this level of interconnection, sometimes there is still heavy traffic congestion between the two countries. Several investment projects are underway with the aim of remedying this issue, including two new 400 kV connections.

Furthermore, the EU has set the target of increasing the electricity interconnection capacity to 10% of the installed capacity in each country by 2020, and to 15% by 2030. In order to achieve this, special efforts need to be made to connect the Iberian Peninsula and integrate intermittent energies effectively. The completion of the planned interconnection projects between Portugal, Spain and France will help to increase electricity trading. Portugal and Spain will be in a position to export surplus renewable energy, particularly wind and hydraulic energy. Conversely, when wind energy generation is low or when hydroelectric resources are limited, more electricity from France could flow into the region.

In June 2015, the European Commission, France, Portugal and Spain signed a Memorandum of Understanding **for the creation of a High Level Group concerning interconnections for the South-Western region of Europe. Several projects are currently underway:**

• **Bay of Biscay line** Approved by the European Commission in January 2018, the project involves the installation of a 280 km long underwater line in the Capbreton Gulf (Landes). The French terrestrial portion will be entirely underground. This new line means that the interconnection capacity between the two countries will almost double from 2,800 to 5,000 MW. This will bring Spain closer to the interconnection target of 10% by 2025, the current level being 6%. This project received record EU funding of 578 million euros (Connecting Europe Facility-Energy).

-Santa Llogaia-Baixas Project (INELFE). The completion of the transformer in Arkale, Spain in June 2017 enabled full use of the Santa Llogaia-Baixas line between Spain and France, doubling the electricity interconnection capacity between the two countries, which rose from 1,400 to 2,800 MW. This line is 64.5 km long, with 33.5 km in France and 31 km in Spain. It connects the communes of Baixas in le Roussillon (France) and Santa Llogaia in Alt Empordà (Spain). The final route of the French portion was decided after 15 months of consultations with community representatives and local associations. One of the objectives of INELFE was to minimise the environmental impact of the interconnection, during both the design and implementation phases. The first step was to build the line underground and dig a utility tunnel to cross the Pyrenees. Although more costly, this solution helped to preserve, among other things, the forest tracks of the Albera mountain range[2].

• **Interconnection project between Spain and Portugal** (Ponte Lima - Vila Nova Famalicão - Recarei (Portugal) and Beariz - Fontefría (Spain)). This is a classic 400 kV aerial technology project which will connect Galicia with the Portuguese region of Minho, and will increase the exchange capacity between Spain and Portugal until it reaches the inter-governmental target of a 3.2 GW exchange capacity. The capacity will enable the full integration of the Iberian electricity market, as well as improving the management of renewable energy. The project is scheduled to be implemented in 2021. These projects, which are supported by the European Commission and the governments of Portugal, France and Spain, are an important step towards putting an end to the Iberian Peninsula's isolation from the rest of the European energy system.

• SMART GRIDS FOR SMART CITIES: EXAMPLE OF THE CITY OF ÉVORA • Évora is home to 56,596 inhabitants (2011), and is the capital of the Alentejo region, in south-central Portugal. It is the first city in the country to have tested certain smart grid technologies on a large scale through the *InovGrid* project. The *InovGrid project* has been developed by the energy company EDP in close

2 - *inelfe.eu/fr/projets/baixas-santa-llogaia*

collaboration with several organisations, including European research institutes and universities, industrial partners, local and national authorities, energy sector associations and regulators, the communities in question and other stakeholders. ***InovGrid* aims to transform the distribution network and provide a solution to a number of challenges in line with government policies: the need to increase energy efficiency, bring costs down, and to integrate intermittent energy producers as well as electric vehicles.**

An important component of *InovGrid* was the deployment of a smart grid infrastructure, which began in the municipality of Évora in 2011. The new infrastructure covers the whole of the city, reaching around 32,000 electricity consumers. Its main components are:

• smart boxes, installed in the homes of all low-voltage customers, which offer cutting-edge solutions such as real-time energy demand readings, load diagrams, voltage curves, etc.;

• distribution transformer controllers installed in each secondary substation, which act as data concentrators and as devices for local metering, supply quality monitoring and automation;

• a communication network based on powerline communication and radio service technologies, which connect computer housings and controllers to network headend systems;

• charging stations for electric vehicles;

• efficient street lighting systems, based on advanced control LED lighting.

Beyond implementing physical infrastructure, *InovCity* is seeking to improve communication between different stakeholders by offering various tools and services (displays, smartphone applications, etc.) and involving local authorities in a joint effort to improve energy efficiency.

The municipality of Évora has played an active role in this project, participating financially and allowing the first tests to be carried out in the city's public buildings. This project was guided by the city's 2012 action plan for sustainable energy[3] , which aimed to reduce GHG emissions by 20% by 2020.

The Évora project highlighted several benefits of smart grids, including: an improvement in energy efficiency (3.9% reduction in electricity consumption); an increase in service quality (detection and handling of faults, monitoring supply quality); reduced energy losses, resulting from a drop in demand and better management of the network; reduced fraud, improved integration capacities of distributed energy resources and electric vehicles.

Currently, the project is expanding to other Portuguese towns, including Guimarães, Lamego, Batalha/Marinha Grande, Alcochete, Algarve and São João Madeira, reaching in excess of 150,000 consumers by the end of 2014. Furthermore, as of 2015, all new establishments use digital boxes, making this technology standard in Portugal[4].

Brain-e, a social network for better electricity consumption

The Brain-e platform helps users reduce their energy consumption in a simple and interactive way. "The energy market is booming, yet there is a real lack of consumer awareness." This was the idea that brought about Brain-e, a smart platform for managing energy consumption. "Not many consumers know how much they are consuming, what they are consuming, what prices are being charged by the market or how to make savings," explains Luis Guerreiro, one of the young people involved in the project (publico.pt/2015/09/22).

Brain-e collects energy consumption information in digital format and presents information to users in a simple way. The platform provides consumers with suggestions on how to save energy, information on market prices and forecasts for energy consumption and production potential. Users can also cooperate with their friends and neighbours to manage their consumption across communities.

Simple actions can help to save energy; for example, washing clothes one hour later than usual or switching off certain appliances at night. This social network wants to help people change their daily energy consumption patterns by

3 - cm-evora.pt/pt/site viver/Habitar/ambiente/PublishingImages/Paginas/Evoracarbonozero/PAES_Evora2012.pdf

4 - http://www.gridinnovation-on-line.eu/articles/library/inovgrid-project---edp-distribuicao-portugal.kl providing consumers with information that will help them monitor their consumption. This project also seeks to forge energy management communities, which create incentives to jointly reduce the consumption of a certain location. Brain-e is free for users, who can save energy, save money and help to reduce CO_2 emissions. It is the result of work by a team of six entrepreneurs - four engineers, a social sciences researcher and a designer. The team has two important objectives at present: to launch a 1.0 version of the platform which can be tested by a limited number of users, and to find a commercial partner who is looking to break new ground in the services that they provide to their customers (publico.pt/2015/09/22). "The biggest hurdle will be the limited number of digital devices that are capable of reading energy consumption in Portugal. This is why we are looking at other markets at international level, where these devices are more commonplace", explains Luis Guerreiro.

Source: www.publico.pt/2015/09/22/p3/noticia/uma-rede-social-de-poupanca-de-energia-1824238

TEXT BOX 3

CONCLUSION

Portugal has been experiencing steady growth in the use of renewable energies for electricity generation in recent years. This transition is guided by proactive policies - European and, above all, national - but also by the actions of various operators, be it a long-established energy company or new innovative enterprises. In addition, actions by some cities such as Évora demonstrate the importance of the role played by local authorities. Despite this progress, the country still has a long way to go before it achieves a completely decarbonised electricity mix.

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The United States: towards a bottom-up climate leadership?

The American power sector reveals the importance of non-state actors. In June 2017, the federal government announced the exit of the United States from the Paris Agreement, casting strong doubts about the country's ability to continue the newly started decarbonisation of its economy. However, governors, mayors and CEOs of American companies reacted immediately. A few hours after the announcement from Trump's government, an unprecedented coalition of now more than 2700 States, cities and companies joined behind the Paris Agreement under the slogan "We Are Still In". How do these initiatives translate into concrete action at the level of States, cities and companies? Will they be sufficient to ensure a deep decarbonisation pathway of the American power sector? In order to provide answers, we will conduct a three-part analysis of the recent evolution of CO_2 emissions in the United States' electrical sector and the role of different non-state actors.

Head editor • **GERMÁN BERSALLI** • *Associate Researcher, Univ. Grenoble Alpes, CNRS, INRA, Grenoble INP, GAEL*

CONTENTS

1 • THE HUGE CHALLENGE OF DECARBONISING THE AMERICAN ELECTRICAL SYSTEM

The United States' electrical system is a complex generation, transmission and distribution network providing nearly 4000 terawatt-hours of electrical power generated by approximately 7000 power plants (spread over more than a million kilometres of high-voltage transmission lines and more than 10 million kilometres of low-voltage distribution lines) with nearly 160 million residential, commercial and industrial customers.

In a system that has long been based on fossil fuels, a deep decarbonisation pathway leading to zero emissions by 2050 represents a daunting challenge for all stakeholders and requires proactive policies at various levels.

• EMISSIONS FROM THE ELECTRICITY SECTOR CONTINUE TO FALL • The United States remain among the ten most emitting countries per capita on the planet with 15.7tCO_2/person in 2016. Considering the total CO_2 emissions of the energy sector, it is the second largest emitter after China with 5073MtCO_2 in 2017. 34% of this total corresponds to the electrical sector.

After reaching a peak in 2007, CO_2 emissions from public heat and power generation are decreasing, and they are currently at the lowest level since 1990. They decreased by 3.7% in 2017, confirming their downward trend from previous years (Figure 1). This is mainly due to the gradual decline in carbon intensity of the American power mix (CO_2/kilowatt-hour). The partial substitution of coal for natural gas and the increase in the share of non-carbon sources have thus led to a decrease in the carbon intensity of electricity generation.

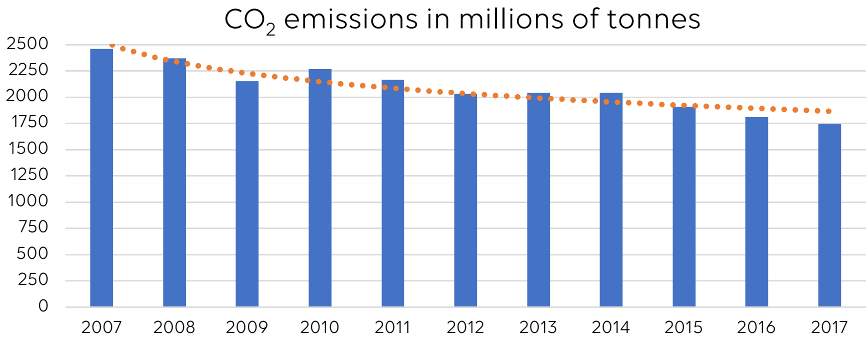

FIGURE 1. CO2 EMISSIONS FROM PUBLIC ELECTRICITY AND HEAT PRODUCTION

Source:: Compiled by the author using data from ENERDATA

Based on the 2018 analysis of the *Energy Information Administration (EIA) named "U.S. Energy-Related Carbon Dioxide Emissions*", **two fundamental factors have contributed to reducing the carbon intensity of electricity generation since 2005: replacing coal-fired production with combined cycle natural gas production, which consumes less and is more efficient, and deploying renewable energy, in particular wind and solar energy.** According to EIA, the first factor explains 61% of the improvement in carbon intensity while the renewable energies account for the remaining 39%. As for the production of nuclear energy, it practically has not changed between 2005 and 2017.

Total electricity production decreased slightly between 2005 and 2017. Over this period, electricity generation from fossil fuels decreased by approximately 14% and non-carbon power generation increased by 33%.

The electricity consumption of the United States, which decreased by 2% in 2017, has remained relatively stable over the past decade with only minor variations due to climatic factors. Despite GDP growth of almost 22% between 2005 and 2017, electricity consumption has barely increased by 2.7%, showing the powerful effect of improving energy efficiency. Nevertheless, various forward-looking models (EIA, 2018) show that electricity demand is expected to rise again in the coming years, as the electrification of the economy – including transportation – continues.

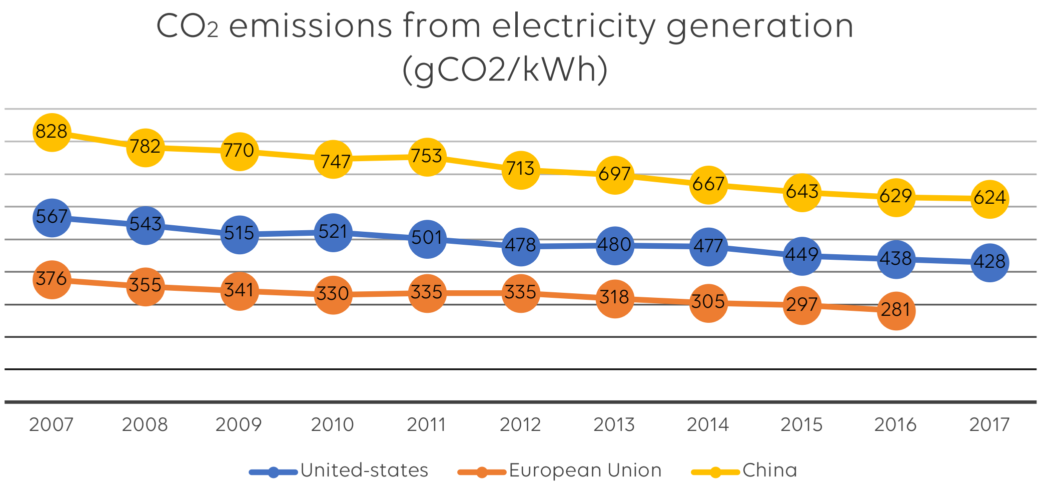

FIGURE 2. CARBON INTENSITY OF THE POWER MIX

Source: Compiled by the author using data from ENERDATA

This reinforces the need for further decarbonisation of electricity generation. Figure 2 above shows the decrease in carbon intensity of the American power mix that, however, still remains well above the average of other developed regions such as the EU and Canada. Will the current political and economic situation of the United States make it possible to continue or even accelerate the decarbonisation of the electrical sector? The change in energy policy proposed by the new conservative government threatens the continuation of decarbonisation; however, many coal plants were closed in the past year.

• THE DECLINE OF COAL CONTINUES THANKS TO THE RISE OF NATURAL GAS AND RENEWABLE ENERGY • Despite the US President's statement that he wants to end the "war on coal", industry experts are planning to continue plant closures. The number of US coal-fired power stations remains huge: according to EIA, a capacity of approximately 246GW was still active in July 2018, but it seems increasingly susceptible to decrease. The shutdowns announced for the 2018-2024 period – a total of 36.7GW – amount to approximately 15% of the current total (Feaster, 2018).

EIA forecasts that natural gas will account for 35% of electricity generation in 2018 and 2019, an increase from 28% five years ago. The share of renewable energy other than hydropower – mainly wind and solar – is also expected to increase to 10% in 2018 and nearly 11% in 2019. On the other hand, the share of coal is expected to fall to 27% in 2019 from 39% in 2014 (Feaster, 2018).

This trend seems to continue in this direction. On the one hand, the level of investment in renewable energy remains strong and costs continue to fall. On the other hand, the increase in domestic gas production is expected to keep a relatively low and stable price in the near future.

The age of the plants also becomes a significant factor for the US coal industry. Most of the country's coal-fired power plants were built in the 1960s, 1970s and 1980s, and many of these units are nearing the end of their "normal" end of life. S&P Global's data shows that in 2017, two-thirds of coal shipments went to power plants that were at least 38 years old and nearly 15% went to power plants that were at least 55 years old[1] .

1 - S&P Global, Coal's 'Aging-Out' Problem, Jan. 30, 2018 (coal deliveries from Nov. 1, 2016 to Oct. 31, 2017)

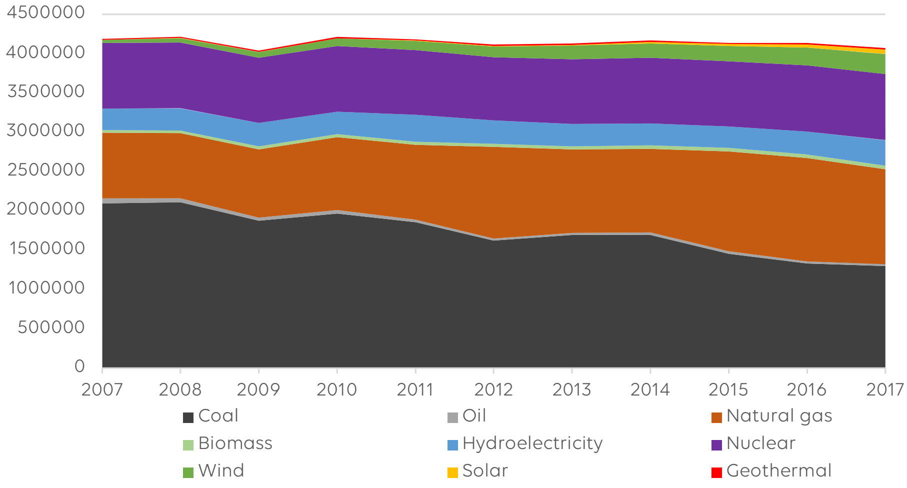

FIGURE 3. ELECTRICITY PRODUCTION PER SOURCE OF ENERGY (GWH/Y)

Source: Compiled by the author using data from ENERDATA

In contrast, much of the US natural gas capacity has been built since 2000, and most wind and solar facilities are less than ten years old[2]. A significant number of new gas, wind and solar power plants come into operation each year while few new coal-fired power plants have been commissioned in the last five years, and few (if any) are likely to be built in the future (Feaster, 2018).

Moreover, coal has serious competitive disadvantages compared to renewable energy and natural gas. In regions of the country where renewable energy and natural gas are abundant, even newer coal plants are closed. For example, power plant no. 5 of Sandow in Texas (600MW, commissioned in 2010) was retired in January 2018, just months after the announcement of its closure (Feaster, 2018).

Gas plants have a technical advantage over coal plants. They can generally respond quickly to fluctuations in demand and increase or decrease their production throughout the day. This allows them to integrate well with wind and solar power to meet the daily demand cycle while remaining economically competitive (Feaster, 2018). In contrast, coal-fired power plants are more efficient when operating continuously. Their operating and maintenance costs increase when they are cycled[3] and stopped for long periods.

In addition to this technical and economic disadvantage, coal-fired power plants are suffering the consequences of heavier regulations principally at the State level and the pressure of various environmental groups such as the Sierra Club.

In March 2018, the private electricity utility First Energy asked the Trump administration to intervene in order to keep coal and nuclear power stations under strain. So far, the government has taken no action to keep power stations open, but the administration was considering using executive power under the national security legislation to stop the wave of closures. However, no formal plan has been submitted.

The American Coalition for Clean Coal Electricity (ACCCE) also predicts that by 2020, at least 26,000MW of coal-fired power plants will be phased out. This association considers most of these closures to be driven by the policies of the Environmental Protection Agency (EPA) imposed under the Obama administration. The ACCCE supported the efforts of the Trump administration to lower EPA regulations and find ways to prevent the closure of coal-fired power plants.

Overall, these trends indicate that the power generation sector has entered a transition that is justified by economic and environmental principles. Coal infrastructure is aging and inflexible; the cost of renewable energy continues to decrease; private electricity utilities adopt decentralised power generation as they modernise their systems; and natural gas offers more flexibility by being less polluting than coal (Feaster, 2018).

At the same time, a fairly impressive number of innovations continue to emerge, particularly

2 - EIA, "Most coal plants in the United States were built before 1990," Today In Energy, April 17, 2017 3 - C'est-à-dire quand elles fonctionnent à différents niveaux de production tout au long de la journée, ou de façon saisonnière

in the field of electricity storage technology. In this context, some analyses show that if the costs of wind and solar energy and storage continue to fall, renewable energy will soon become more competitive not only in comparison to coal but also to natural gas. This has already been seen in some places such as Western Colorado (Cleantechnica, 2018)

2 • THE MOMENTUM OF CITIES AND STATES IS OPPOSED TO THE WITHDRAWAL OF THE FEDERAL GOVERNMENT

While the federal government is turning its back on climate policies, all the attention is focused on cities, States, businesses, universities and other relevant actors. A recent analysis suggests that if fully implemented, the objectives of registered and quantified non-state actors could approach the commitment made by the United States in the Paris Agreement, leading to a reduction in emissions of 17 to 24% in 2025 compared to 2005 levels. 22 States, 550 cities, and 900 companies in the United States have made climate change commitments, and the 50 States have adopted at least one policy likely to reduce emissions (Climate Action Tracker, 2018).

• A HIGHLY INADEQUATE FEDERAL CLIMATE POLICY • The American climate policy is currently considered highly insufficient to lead the country towards a deep decarbonisation pathway of its economy (Climate Action Tracker, 2018), as it was strongly shaken by the Trump administration in 2018. If the proposed actions become fully implemented, the projections of GHG emissions for the year 2030 could increase up to 400MtCO_2eq compared to the levels projected at the end of 2015. That is almost as much as the total of the emissions of the State of California in 2016. The federal government has proposed to replace the Clean Power Plan (CPP) to freeze vehicle efficiency standards after 2020 and not to apply standards to limit the extremely high emissions of hydrofluorocarbons (HFC). The administration also weakened standards for methane leakage from oil and gas production (Climate Action Tracker, 2018).

The *Clean Power Plan* issued by the Obama administration under the Clean Air Act was aimed at reducing emissions from the electricity sector by 32% by 2030 compared to 2005 levels by setting targets for each individual State. The successful implementation of the CPP would have been an important step in strengthening American climate action. However, in August 2018, the EPA proposed to replace the CPP with the Affordable Clean Energy (ACE) Rule (EIA, 2018) limiting the scope of the plan to reduce greenhouse gas emissions by setting more flexible rules for coal-fired power plants and allowing States to set their own standards (EPA, 2018). This is a significant departure from the CPP, which required all States to meet emission standards and is likely to result in emissions of up to 81MtCO_2eq/yr in 2025 and 212MtCO_2eq/yr in 2030 (Climate Action Tracker, 2018).

The federal government has played a fairly strong role in the diffusion of biofuels, but its role has been much weaker with respect to electric renewable energies. **Renewable electricity in the United States has been largely driven by State incentive policies, among other things, supported by federal tax incentives. In many respects, States as well as local governments and regional organisations have been more ambitious than the federal government.**

• STATES PAVE THE WAY TO RENEWABLE ENERGY AND ENERGY EFFICIENCY • At the sub-national level, 29 States have implemented Renewable Portfolio Standards (RPS) and nine have set voluntary targets (America's Pledge, 2017). Other incentives have also been put in place such as the net billing system or subsidised credits for renewable energy projects. The RPS are fairly flexible policy instruments that require electricity providers to obtain a minimum percentage of their energy from renewable energy sources by a certain date. Each State sets a quota (usually a percentage of renewable energy) and companies choose to fulfil their mandate using a combination of different sources (wind, solar, biomass, geothermal or other renewable sources). Some RPS specify the combination of technologies while others leave it to the market.

The first RPS was established in 1983; however, the majority of States adopted or strengthened their standards after 2000 (IEA/IRENA, 2018). The compulsory quota is usually accompanied by an element of economic flexibility: a system of tradable renewable certificates ("green certificates"). Electricity suppliers fulfil their obligation by producing renewable electricity themselves or by buying surplus certificates from other producers.

States have the power to individually dictate environmental protection policies, and this past year, many have strengthened some climate and energy standards. In recent months, State congresses have proposed hundreds of bills on clean energy production, reduction of GHG emissions, and regulations and measures for the protection of the environment. Many are also looking for ways to tax carbon emissions, encourage solar energy installations and demand general advancements in renewable energy technology (Green Gazette, 2017).

The scientific organisation Union of Concerned Scientists (UCS) recently proposed and applied a method that examines the evolution of clean energies across the country. By examining 12 parameters including the creation of clean energy jobs, the progress of renewable energy, and the reduction of power plant pollution, the report identifies the States that are making the most progress towards a sustainable future.

The UCS analysis clearly identifies leaders among the 50 US States:

- **California** paves the way for clean energy. The Golden State leads in the adoption of electric vehicles and is in the top five on six other indicators: residential solar capacity per household, energy savings, clean energy jobs, standard targets for renewable energy, the ability of companies to buy renewable energy and the targets for reducing carbon emissions (see Text box 1 below).
- **Vermont**, in second place, is the State that ranks first in terms of jobs in the clean energy sector and in its targets for reducing carbon emissions. It is also among the first in terms of energy savings, adopting electric vehicles and energy efficiency policies.
- **Massachusetts**, in third place, has the strongest energy efficiency regulation and ranks among the top five in terms of residential solar capacity per household, energy savings, clean energy jobs and emission reduction targets.

However, other bills oppose the transition to clean energy. Proposed legislation could put an end to the net billing system for "prosumers" (who produce and consume their own energy) of solar energy, which are gaining popularity in Indiana and Missouri. Wyoming lawmakers have considered penalising large-scale wind and solar producers. Most importantly, many States do not have laws to achieve their GHG reduction targets.

It also seems important to stress that some States that are less favourable to climate action and fossil fuel issues, such as Texas, are making remarkable progress in the field of renewable energies. If California is the champion of solar energy, then Texas in the champion of wind energy. This southern State has one of the most open and competitive electricity markets in the country and currently has the largest installed capacity of wind energy in the United States, with 22GW. Due to its low marginal cost, this type of energy has priority over the Texas electricity system, and in some months, it has already supplied a quarter of the electricity consumed in the State. For example, other more expensive sources of production such as coal are being pushed out of the market.

Despite a few exceptions, it is clear that it is the States more than the federal government that lead the decarbonisation of the electricity sector through two main principles: promoting renewable energy and improving energy efficiency.

The State of California: A sustainable energy policy.

California has adopted an aggressive programme to promote renewable energy. The centrepiece of the programme is the Renewable Portfolio Standard system introduced in 2002, which requires an increase in the percentage of State electricity sales from renewable sources each year (Ballotpedia, 2018). This percentage should reach 33% by 2020 and 50% by

2030. Other statutory tools to support this effort include a feed-in tariff for small-scale renewable electricity producers. In addition, the government introduced a net metering system in 1996 that allows customers who produce their own renewable electricity to sell a portion to the grid.

California also has the most ambitious legislation on climate change in the country. The 2006 Global Warming Solutions Act (known as AB 32) requires the State to reduce its GHG emissions to 1990 levels by 2020. AB 32 assigns the California Air Resources Board (CARB) the task of choosing the statutory and policy tools to achieve this target. CARB has chosen to implement a cap-and-trade programme. The programme caps all GHG emissions and then reduces the overall emissions limit annually until the 2020 target is achieved. In 2014, California tied its cap-and-trade system to Quebec's cap-and-trade system, creating a broader emissions trading market that should help reduce the costs (Dernbach, 2018).

In 2016, the California parliament passed a law setting a 40% GHG emissions reduction target relative to 1990 levels by 2030, leading to the need to adapt the cap-and-trade system to satisfy the new target.

The cap-and-trade programme is only part of California's overall plan to achieve the "technologically achievable" and "cost-effective" emission reductions that AB 32 requires. California also limits the carbon intensity of new long-term power supply contracts so that the supplier cannot produce more than a combined cycle natural gas power plant that emits approximately half of the emissions from a coal plan.

TEXT BOX 1

• INCREASINGLY COMMITTED CITIES • Many US cities have made a public commitment to reduce carbon emissions and combat climate change through initiatives such as the Covenant of Mayors, We Are Still In, or by developing their own climate action plans.

At least 80 US cities, under the coordination of the influential progressive NGO Sierra Club, have committed to achieving 100% renewable electricity production in the coming decades. In the United States, six cities – **Aspen, Burlington, Georgetown, Greensburg, Rock Port and Kodiak Island** – have already achieved their targets. These six cities now generate 100% of the energy used in their communities from clean, non-polluting and renewable sources.

As American cities join the quest for clean and sustainable energy, some are struggling against private electricity utilities that are sometimes resistant to change. Others have a municipal electricity utility or collaborate with their suppliers to move towards cleaner energy sources. As a result, some communities are separating themselves from these investor-owned businesses, joining forces to get their own energy sources through **Community Choice Aggregation (CCA)** programmes.

CCAs allow communities to bypass investor-owned electricity providers by joining together to buy their own wholesale energy and gain greater control over their energy options as a result. Thanks to CCA, decisions regarding electricity supply, tariffs and incentives are made at the local level. The 18 operational CCAs in California already represent many regions and cities in the State, and another nine are expected to be launched in the near future (Sierra Club, 2018). This is the case of **Santa Barbara** among others, which is in the process of creating a CCA in partnership with other neighbouring municipalities. This Californian city is committed to achieving at least 50% renewable electricity for the entire city by 2030. Further north, **San Francisco** and **San Jose** pioneered the creation of CCA, each with a target of 100% renewable energy over a decade ago.

In August 2017, the Orlando (Florida) city council unanimously passed a resolution to ensure the transition to 100% clean energy in municipal operations by 2030 and in the entire city by 2050. Led by Mayor Buddy Dyer – a strong supporter of the Sierra Club 100% clean energy movement – the Orlando resolution was supported by a broad and diverse coalition of local organisations including the League of Women Voters, IDEAS for Us and NAACP, as well as the Sierra Club. The coalition is currently working to secure the commitment to close the last two coal-fired power companies from the city's utility and replace them with renewable sources.

A 100% clean energy target is ambitious for all cities, but perhaps even more so for a long-standing coal industry capital like **St. Louis** (Missouri), home to two of the largest coal companies in the country. However, following the withdrawal of the Trump administration from the Paris Agreement, Lewis Reed – Chairman of the St. Louis council – urged his city to take charge of its future. In October 2017, the St. Louis council unanimously approved the commitment to switch to 100% clean and renewable energy by 2035. Its supporters have a long-term vision for the city focused on creating green jobs, clean air and a better quality of life for all residents. The city has set a deadline in December 2018 for developing its Clean Energy Transition Programme and has gathered a committee of stakeholders to this end.

These are a few examples of the many commitments made by US cities in 2017 and 2018. A follow-up of these commitments will make it possible to define their implementation and their real impact in the decarbonisation pathways of these cities.

3 • THE ROLE OF BUSINESSES AND CITIZENS' INITIATIVES

Just as in other countries, the electricity markets in the United States are in turmoil. Traditional businesses in the sector, whether private, public or mixed, face a dual threat. On the one hand, we see the arrival of new players from other economic sectors, often world giants. On the other hand, the large number of innovations in power generation and storage technologies enables increasingly decentralised production in which consumers and new forms of organisation play a more important role.

• COMPANIES INTEGRATE THE CLIMATE DIMENSION INTO THEIR STRATEGIES • As part of the **Global Climate Action Summit** held in September 2018 in San Francisco, 21 leading companies submitted the ***Step Up Declaration***. It is a new alliance dedicated to harnessing the power of emerging technologies and the fourth industrial revolution to help reduce GHG emissions in all economic sectors and ensure a positive climate change for 2020. Collectively, these organisations cover a wide range of sectors that can significantly reduce GHG emissions in buildings, data centres, the finance sector, telecommunications, transportation, etc. They include the following companies: Akamai Technologies, Arm, Autodesk, Bloomberg, BT, Cisco Systems, Ericsson, HP, Hewlett Packard Enterprise, Lyft, Nokia, Salesforce, Supermicro, Symantec, Tech Mahindra, Uber, Vigilent, VMware, WeWork, Workday and Zoox.

The Step Up Declaration was developed with the leadership of Salesforce, a leading California-based cloud computing company. The Declaration focuses on the transformative power of the fourth industrial revolution, which comprises artificial intelligence, cloud computing and the Internet of Things.

Are the oil giants joining the transition?

European oil companies have started to invest heavily in renewable energy – for example, solar energy at Total or off-shore wind at the Norwegian company Statoil, which has recently changed its name to Equinor. However, American oil companies are currently far less active. One of the provided reasons is the even lower profitability of renewable energy projects compared to oil and gas projects.

Nevertheless, American oil giants are taking a few steps towards non-carbon energies. ExxonMobil is interested in biofuels and is devoting a growing portion of its R&D budget to alternative energy sources[4]. This company invests approximately $1 billion per year into basic and applied research on low-carbon technologies. This oil supergiant is particularly focused on synthetic biology.

It hopes to prove the commercial feasibility of deploying genetically modified algae in large open-air operations capable of producing the equivalent of 10,000 barrels of renewable crude oil per day from sunlight and industrial CO_2. If the company's trial succeeds, this modular design could evolve to much higher levels. ExxonMobil is also developing genetically modified microbes together with the country's largest biodiesel producer Renewable Energy Group, which could produce biodiesel from residual biomass (i.e. without the use of food crops such as maize). Other projects include fuel cells that capture and consume CO_2 to produce electricity and new technologies for the manufacture of plastics emitting 50% less CO_2[5].

Chevron holds interests in solar, wind and geothermal generation facilities that can power approximately 113,000 US households each year. This seems modest, but it represents the first steps of a possible renewable energy development strategy for this company with a strong presence on the west coast of the United States. Chevron has also invested in next-generation renewable fuels with little success, but it still sees a bright future for renewable diesel. The company has tested various mixing ratios (with low-oil diesel) of 6 to 20% for some terminals in California.

TEXT BOX 2

With respect to electricity generation, private electric utilities provide 38.7% of the total production in the United States, other producers account for 39.9% of the total production, municipal utilities 10%, federal agencies 6.4% and electric cooperatives 5% (Klass, 2017).

Some of these companies are making progress in their decarbonisation efforts. This is the case of NRG Energy, an American company producing and distributing energy present in 11 States. Starting in 2009, NRG launched an initiative to become a green energy producer in the United States and began investing in clean energy projects. These include onshore and offshore wind energy, solar thermal energy, PV solar installations and the conversion of some of their traditional coal-fired power plants to biomass. At the end of 2010, NRG launched the "EVgo" network – one of the first networks of charging stations for electric cars. The company had set itself a target of halving its total emissions by 2030 compared to 2014 levels. It has already managed to reduce its emissions by almost 20 million tonnes, meaning that the target will be achieved well before 2030. **Climate action has helped NRG bring innovative solutions to the market, meet customers' current needs, and anticipate their future needs while making the company stronger and more efficient.** It also attracts and retains the best talent in the industry and provides excellent returns for shareholders, said one of the company's leaders (Greenbiz, 2018).

APPLE and TESLA enter the energy market

A number of established companies with a recognised brand in various sectors appear to be ready to compete in electric markets that have for long been dominated by traditional energy companies.

Among these new arrivals is Apple, who has quietly created a subsidiary called Apple Energy LLC and has applied to the Federal Energy Regulatory Commission (FERC) for a licence to sell electricity directly to retail consumers.

According to specialised press, Apple's strategy is due to several reasons (Sioshansi, 2017). First, Apple uses 93% of renewable energies in all its activities and its target is to quickly reach 100%. The company has contracts with solar

4 - tps://www.eniday.com/en/sparks_en/oil-majors-invest-renewable-energy/
5 - https://www.fool.com/investing/2018/06/04/big-oil-is-investing-billions-in-renewable-energy.aspx

developers around the world for a capacity of 521MW, making it one of the world's largest consumers of solar energy. In addition, it invests in net-zero energy buildings including its new headquarters in Cupertino, California.
Second, the company is in a position to generate surplus renewable energy most of the time, especially on cool, sunny days in the spring when there is no air conditioning. The surplus energy can be resold to the grid at wholesale prices, or even better, to other customers at current retail rates, which tend to be two to three times higher.
Third, some analysts speculate on the possibility of Apple resuming its plans for developing electric cars – an area in which it has been working quietly for some time. Having excess renewable energy to power electric vehicle batteries can open up new markets at a time when the mobile phone market appears to be saturated.
Finally, it counts on the value of its Apple brand. Its customers seem likely to buy any goods or services that boast the famous logo including electricity, especially if it is 100% renewable.
In mid-November 2016, Tesla shareholders at a special meeting approved the acquisition of SolarCity for $2.6 billion. This means that Tesla can move forward with the integrated solar roof and residential battery system announced in October 2016. The company predicted that the cost of solar electricity with storage via batteries will be lower than electricity retail rates in many places. If the company succeeds in combining the two products, it can use the same tools to shake the automotive and electrical industries by bringing together electric mobility, PV solar panels and storage. Affluent customers who can afford a high-end electric vehicle may wish to produce some of their electricity on their roof, and may want to store some of it in batteries for later use (Sioshansi, 2017).

TEXT BOX 3

• THE ENERGY DEMOCRACY MOVEMENT • Energy democracy is both a new concept and an emerging social movement that links the change in energy infrastructure to the possibilities of profound political, economic and social change. The term continues to spread in the context of climate justice struggles, driven by unions, academic communities and political parties. This concept is increasingly used in the United States to demand and justify the integration of policies linking social justice and economic equity to transitions to renewable energy (Burke & Stephens, 2017).
Energy democracy is born of citizen movements that fight against climate and economic crises, resist the expansion of fossil fuels, and seek a transition to renewable energies. Since 2012, various groups[6] and organisations in the United States and Europe have explicitly adopted the term "energy democracy" as the central theme of the energy and climate change discourse. In 2012 in the United States, the Cornell University's Global Labour Institute hosted an international round table of trade unionists who used energy democracy to discuss the struggle for the energy transition, which gave rise to a new organisation – the Trade Unions for Energy Democracy.

This transition path is characterised by a strong presence of actors who have lost confidence in existing governance systems, by the emergence of new guiding principles, beliefs and practices, the coexistence of multiple innovations and widespread experimentation, and a shift to more local or regional systems and decentralised technologies and management structures. These include energy co-ops, Community Choice Aggregation programmes (see 2.3 above), net metering systems and Community Benefit Agreements (Burke & Stephens, 2017).

6 - Community Power Network, Local Clean Energy Alliance, Trade Unions for Energy Democracy, Institute for Local Self Reliance, Center for Social Inclusion, Climate Justice Alliance, Rosa Luxemburg Foundation, Alternative Information and Development Centre, Public Services International, Emerald Cities Collaborative, Energy Democracy Alliance of New York, entre autres.

CONCLUSION

An analysis of the registered and quantified commitments of sub-national and non-state actors in the United States (America's Pledge, 2018; Climate Action Tracker, 2018) suggests that if implemented, these commitments could lead to a reduction in emissions of 17 to 24% in 2025 compared to 2005 levels.

While the federal government has significantly changed its climate policy – including the decision to leave the Paris Agreement –, the US climate leadership remains alive and well. It is a new kind of bottom-up leadership driven by the conviction of citizens, the leadership of cities and States as well as driven by the innovation capacity of its companies, making it possible not only to take concrete action now but also to lay the foundations for a future partnership with the federal government. In the coming years, the continuation of the decrease in CO_2 emissions from the American power sector will tell whether the dynamics of the Federated States will be stronger than the federal desire to revive coal contrary to recent economic developments.

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Fugitive emissions: a blind spot in the fight against climate change

The category of fugitive emissions covers a vast number of poorly controlled emissions: accidental, diffuse or unproductive. Fugitive emissions represent a significant proportion of anthropogenic greenhouse gas emissions and their assessment, let alone reduction, is still in its infancy. Often overlooked by climate policies and institutional mechanisms, actions in this area rely primarily on the emitters themselves, pushed by civil society and local stakeholders.

Main autor • **THIBAULT LACONDE** • *Consultant, Energie & Développement*

CONTENTS

1 • FUGITIVE EMISSIONS: DEFINITION AND EVOLUTION

The nature of fugitive emissions makes them difficult to assess but their level is significant - around 5% of global emissions - and has probably increased in recent years.

• DEFINITION(S) • The IPCC defines fugitive emissions as "emissions [of greenhouse gases] that are not produced intentionally by a stack or vent" and stipulates that they may "include leaks from industrial plants and pipelines" (IPCC, 2006). A previous definition provides more detail on potential sources of fugitive emissions: "they may be caused by the production, processing, transmission, storage and use of fuels and include combustion emissions only if they do not meet production needs (e.g. natural gas flaring at gas and oil production facilities) "(IPCC, 1996).
This definition may vary from one sector to another. In the fossil fuel sector, fugitive emissions are sometimes broadly defined as any emissions unrelated to the end use of the fuel. In air pollution, a fugitive emission can be defined as the "release of pollutants into the free atmosphere after they have escaped an attempt to capture them with a hood, seal or any other means for ensuring the capture and retention of these pollutants". They therefore contrast with channelled emissions (CITEPA, 1999).

Accordingly, there is no stable and universal definition of fugitive emissions. In practice, they generally include accidental emissions (pipeline breakage, coal seam fire, etc.), leaks and diffuse escapes (defective valves or seals, migration of gas to the surface near wells or mines, emissions from abandoned wells, etc.) and unintentional but non-productive discharges (mine ventilation, flaring, degassing, etc.). Many phenomena are therefore involved in a category that is primarily negative: fugitive emissions are ultimately emissions related to human activities that do not fit into any other category.

• AVAILABLE DATA ON FUGITIVE EMISSIONS • Their very nature makes fugitive emissions difficult to quantify. There is no comprehensive global data, but it is possible to assess their significance and evolution by combining national inventories and secondary data.

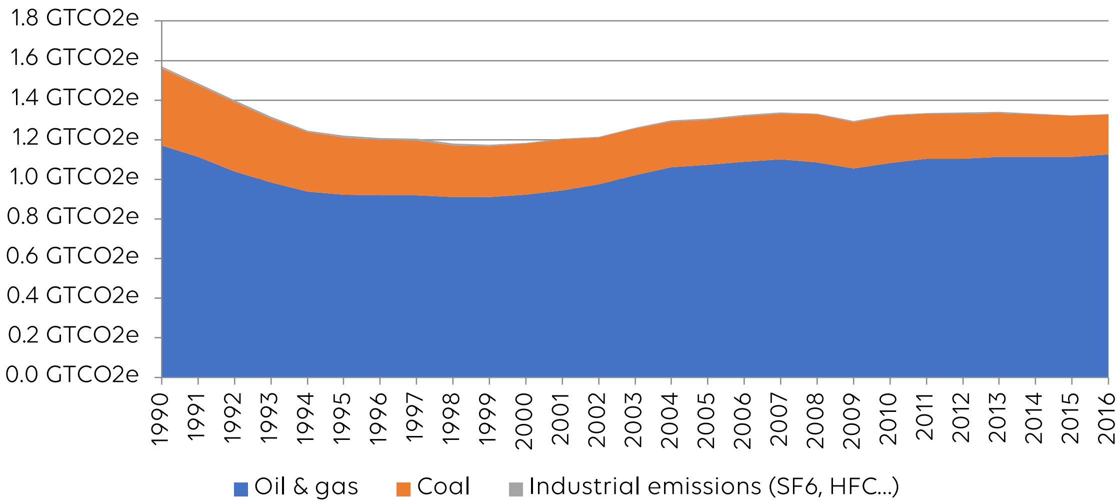

FIGURE 1. FUGITIVE EMISSIONS (ANNEX I COUNTRIES)

Under the United Nations Framework Convention on Climate Change, industrialised countries ("Annex I countries") regularly report fugitive emissions. These inventories show stable emissions since the mid-2000s after a decline in the early 1990s and a rebound around 2000. **In 2016, fugitive emissions reported by industrialised countries were 1.33 billion tonnes CO_2 equivalent compared to 1.57 in 1990, about 85% of which were from the hydrocarbons sector, 15% from coal and a fraction from industry (UNFCCC GHG data).**

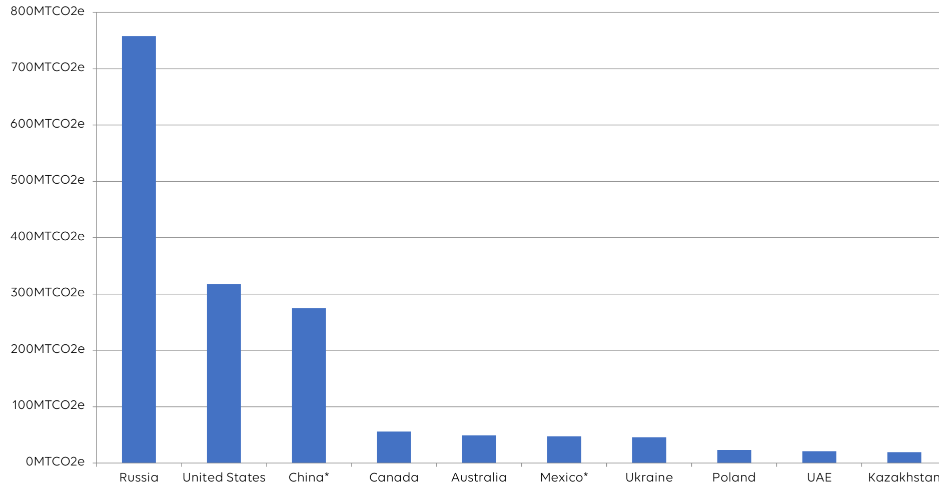

FIGURE 2. FUGITIVE EMISSIONS FOR SELECTED COUNTRIES UNFCCC GHG DATA EXCEPT *ENERDATA)

Outside Annex I countries, fugitive emission data are generally partial and dated: 276MTCO$_2$e for China (2005, CH4 only), 58MTCO$_2$e for Africa (2000, CH4 only), 47MTCO$_2$e for Mexico (2006, CH4 only), 21MTCO$_2$e for the UAE, etc. (Enerdata)

These data, although incomplete and partly obsolete, show that fugitive emissions account for a significant share of global greenhouse gas emissions: at least 2GTCO$_2$e i.e. 5% of the total. It also shows a correlation between countries with high emissions and those with a large oil, gas or coal industry.

While fugitive emissions can occur in any activities handling greenhouse gases - refrigeration (HFCs, CFCs), electricity (SF6), health (N2O), etc. - they occur mainly during the extraction, transport, storage and processing of fossil fuels and largely consist of CH4 (methane or "natural gas").

• A PRESUMPTION OF INCREASE • The orders of magnitude mentioned above must however be taken with caution. In fact, since the mid-2000s, there has been an unexplained increase in the concentration of methane in the atmosphere. This could indicate that fugitive emissions of this gas have been underestimated: the simultaneous increase of the ethane concentration seems to indicate that the oil and gas industry is responsible but the isotopic signature of the methane points to a natural origin (rice fields, swamps, livestock, degradation of natural or agricultural plant waste, etc.). Recent work has suggested a solution to this paradox and tends to confirm the responsibility of hydrocarbon production, which would be responsible for 50 to 75% of the observed increase (Worden, 2017).

Although this hypothesis remains controversial, it is corroborated by measurements carried out near the hydrocarbon production sites. These have found unusually high levels of methane (Zavala-Araiza, 2015): fugitive emissions reported by the US oil and gas sector could be under-estimated by 60% (Alvarez, 2018).

2 • IMPROVING MEASUREMENT AND REPORTING

The evaluation of fugitive emissions is an issue for the climate but also a political and economic one.

This is particularly the case for the gas industry. At equivalent energy, gas combustion produces about half as much carbon dioxide as coal and 30% less than petroleum products. However, at equivalent amounts, methane contributes much more to global warming than carbon dioxide, so this advantage can be rapidly offset by higher fugitive emissions. In the United States, for example, the shift from coal to gas in electricity production represents a gain for the climate only if the upstream leakage rate of plants is less than 3%. The conversion of liquid fuel to gas for commercial vehicles (trucks, buses, etc.) represents a gain if the leakage rate is less than 1% (WRI, 2013). Some studies suggest that fugitive emissions may exceed 4% (Pétron, 2014) or even 7.9% for unconventional gas

(Howarth, 2011). **These assessments cast doubt on the climate advantage attributed to gas compared to other fossil fuels, and therefore the investments made in this energy.**

• ISSUES AND SOURCES OF UNCERTAINTY • In addition to the lack of a clear definition, the evaluation of these emissions raises several practical and methodological problems. The first of them is detection. The emissions may actually be unintentional (leaks and losses from the gas network for example) or they may occur a long time after the end of an activity (emissions related to abandoned wells and mines, for example). Furthermore, the main gas involved is methane which, in its natural state, is invisible and odourless.

Independent producers in the United States

Since fugitive emissions are often diffuse, the collection of information is also problematic. This is particularly the case when the emitting activities are fragmented with many small players.

This is the situation in the oil and gas sector in the United States. Due to an original mining right that allows landowners to exploit the geological resources found on their land without authorisation or concession, oil and gas production in the United States is dominated by small and medium-sized enterprises. Accordingly, the United States has 9,000 independent producers (i.e. producing less than 5 million dollars of hydrocarbons a year or refining fewer than 75,000 barrels a day). These companies, with an average of 12 employees, drill 95% of wells and produce 54% of US oil and 85% of the gas.

This situation makes the estimation of fugitive emissions more complex and limits the means that companies can assign to measuring and reducing them.

Source : Independant petroléum association of America

TEXT BOX 1

A second problem is related to the conversion of these emissions into carbon equivalent. Fugitive emissions are largely composed of methane, a gas whose lifetime in the atmosphere and ability to intercept infrared radiation differs from that of carbon dioxide. To express the climate impact of these emissions in a single unit, their 100-year global warming potential (GWP) is calculated, i.e. the additional energy that they will send back to the Earth's surface in a century compared to that resent by a tonne of carbon dioxide. This equivalence makes it possible to estimate how many tonnes of CO_2 are "worth" one tonne of CH4. However, this figure has been revised steadily since the 1990s: The IPCC's second report puts it at 21, i.e. one tonne of methane would have the same effect on the climate as 21 tonnes of CO_2 - a figure that is still often referred to, while the fourth IPCC report puts it at 25 and the fifth at 28 (Greenhouse gas protocol, 2016). **All other things being equal, these revaluations mechanically increase the role of fugitive emissions.**

• ACADEMIC, ASSOCIATIVE AND INDUSTRIAL INITIATIVES • Significant work is still needed to arrive at a reliable evaluation of fugitive emissions both at the macro level and at the level of the facilities responsible for the emissions. Researchers, non-governmental organisations and manufacturers are mobilising to reduce these uncertainties and the resulting climate and economic risks.

Studies Initiated by the Environmental Defense Fund

The American NGO, the Environmental Defense Fund, has initiated a large-scale research programme to assess and locate fugitive emissions in the US gas supply chain. This programme, covering 16 independent projects, involved 140 researchers and experts from 40 universities or research centres (NOAA Earth System Research Laboratory, Stanford, Harvard, University of Texas ...) and 50 companies.

It led to more than thirty scientific publications between 2013 and 2018. A summary of this work was published in Science (Alvarez, 2018). It evaluates leaks during the extraction, transmission, storage and processing of gas to be 2.3% of US production, or 60% more than the inventory produced by the EPA, the federal environmental protection agency, based on the declarations of the companies concerned. It also shows large disparities between different sites and suggests that faster detection of leaks would reduce them significantly and cheaply, with existing technologies.

Source : www.edf.org/climate/methane-studies

TEXT BOX 2

Research and development projects are also under way to bring solutions for faster detection of diffuse emissions to the market. This is the case, for example, of the GaSes optical imaging project, developed by the Spanish company SENSIA and supported by the European Union as part of the H2020 programme.

3 • MAJOR SOURCES OF FUGITIVE EMISSIONS, SOLUTIONS AND INITIATIVES

Even if the data are incomplete, it is possible to identify some activities that contribute significantly to fugitive emissions: gas flaring, the hydrocarbon logistics chain and the coal supply chain.

• FLARING OF NATURAL GAS • Gas flaring involves burning gas without using the heat produced. This operation makes it easy to get rid of combustible gases from oil extraction or refining but releases carbon dioxide. By convention, flaring-related emissions are considered fugitive emissions. Last year, 140.57 billion cubic metres of gas were flared, equivalent to 3% of worldwide natural gas production. **This practice decreased in 2017 for the first time since 2010: gas flaring volume dropped by around 5% despite an increase in world oil production of 0.5% (World Bank, 2018)**. Flaring, however, remains responsible for the emission of 300 million tonnes of CO_2 per year.

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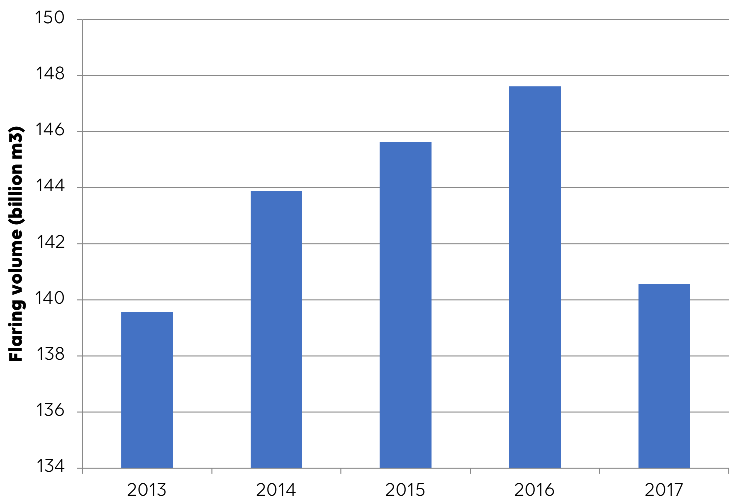

FIGURE 3. ANNUAL VOLUME OF GAS FLARED IN THE WORLD (WORLD BANK)

Source : Banque Mondiale

Origin of Flaring and Solutions

In general, oil deposits also contain methane. This "associated gas" must be separated from liquid hydrocarbons before they are processed. This gas has long been considered an embarrassing by-product of oil production that was rejected or burned. It was only in the second half of the 20th century that large-scale use of natural gas began, but even today it is sometimes cheaper to burn gas than to send it to a buyer, especially when the production site is distant from the consumption areas.

The range of solutions available for gas carriage has expanded. In addition to the construction of a gas pipeline, it is possible to compress the gas to reduce its volume, to liquefy it or to solidify it to make it easier to transport. Formerly marginal, this process has largely developed over the past 10 years, especially under the impulse of American companies - Chevron, Cheniere, Dominion, etc. - seeking new export markets. However, it requires particularly expensive infrastructure that takes a long time to implement.

There are other solutions for avoiding flaring even when gas cannot be transported cheaply, if at all. Note the following, in particular:

- The reinjection of gas in wells - this option can be used to increase the pressure in the tank and make it easier to recover the oil but also to conserve the gas so that it can be extracted again later, if required. Established in Kazakhstan in 2000, reinjection has prevented the discharge of 49 million tonnes of carbon dioxide and in Iran 31 million cubic metres per day are reinjected into tanks. This solution, however, is profitable only if the amount of gas involved is low.
- Generating electricity by burning the gas in a turbine rather than a flare.
- The production of methanol (which is used to produce other petrochemicals such as ethylene or propylene) or ammonia. This method is widespread in Persian Gulf countries.

Source : Soltanieh, 2016

TEXT BOX 3

Despite this progress, flaring remains common, especially in countries that do not have a market or infrastructure for the sale of gas. Its use is therefore often linked to the development and stability of the region: in Yemen, for example, the volume of gas flared per barrel of oil produced has increased four-fold between 2013 and 2017, while in Syria it has increased ten-fold (World Bank).

To limit this practice, the World Bank has launched a "Zero routine flaring" initiative that is mobilising oil tankers and governments to eliminate flaring in the normal operation of facilities by 2030.

Reduction of flaring at ENI

Some companies have committed to achieving this result more quickly: e.g. ENI. In 2007, the Italian company committed to gradually reducing flaring with a view to eliminating it completely in 2025. Two billion dollars were invested in this scheme, which has already reduced the volume of flaring gas by 75%. Additionally, since 2010, new projects developed by Eni no longer use flaring under normal operating conditions.

ENI has achieved this firstly by recovering the associated gas by coordination with the governments of the countries involved. This recovery in electricity generation or in local gas distribution is also used to improve the access of local populations to a modern energy. If recovery is not possible, Eni re-injects the gas into its wells.

The M'Boundi project (Republic of the Congo) is an example of this process: in March 2014, Eni completed the installation of two compression plants to enable the majority of the associated gas to be transported to a 300MW power plant belonging to CEC (Congo Electric Power Plant), with the surplus gas reinjected into wells. This project required an investment of 300 million dollars and is recovering 3 million cubic metres of gas per day.

Source : ENI

TEXT BOX 4

Flaring also has consequences for the local environment (air pollution, noise, etc.), which is why communities are mobilising to end the practice, often with the support of NGOs. In 2015, for example, Nigerian representatives of the Egi communities participated in Total's general assembly to demand the cessation of flaring in the Niger Delta and to testify to the environmental and social problems caused by the exploitation of hydrocarbons. They were supported by the NGO Friends of the Earth (Novethic, 2015). In 2017, Total Exploration and Production Nigeria signed 2 agreements with the Egi community to improve the living conditions of those living near its facilities.

• UPSTREAM GAS AND OIL• In addition to flaring, the hydrocarbon sector is responsible for fugitive emissions of methane at all stages of its activity:
• Wells: methane is normally piped and recovered through the well casing but some can escape into the atmosphere through the soil in the area around the boreholes (Kang, 2014). These diffuse discharges can last a decade after the end of operations (Boothroyd, 2016),
• During gas transportation and storage: defective sealing of valves and fittings, breaks and leaks, intentional or uncontrolled degassing, etc.
• During the processing of petroleum products: a refinery has tens of thousands of valves that can leak small amounts of greenhouse gases or other pollutants.

The Aliso Canyon accident in 2015-2016

The Aliso Canyon gas storage facility, near to Porter Ranch, is operated by SoCalGas, the leading natural gas distributor in Southern California. It has 114 wells with capacity for 2.4 billion cubic metres of gas, equivalent to 15 million barrels of oil. This storage facility is the second largest in the United States and supplies gas to 11 million homes and 16 thermal power stations in the Los Angeles area.
On 23 October, 2015, site employees found a massive leak in the tank: every day about 1,000 tonnes of gas were escaping into the atmosphere. After many unsuccessful attempts, the leak was finally found and sealed on 13 February 2016.
During these four months, 97,100 tonnes of methane and 7,300 tonnes of ethane were discharged - the equivalent of the greenhouse gas emissions of 200,000 Americans for one year. The disaster resulted in the evacuation of 2,000 households located near the site. The estimated cost was $665 million. This accident drew attention to the vulnerability of US gas infrastructures to methane leaks. Most fugitive methane emissions are, however, much less spectacular - and therefore much more difficult to identify and remedy.

Source : Conley et Al, 2016

TEXT BOX 5

The solutions available for reducing these fugitive emissions depend on their source but in all cases require the mobilisation of companies involved in the hydrocarbon logistics chain. Apart from the major leaks and those that represent a risk to staff, it is not always economically profitable to reduce fugitive emissions: indeed, to detect leaks, to determine their source and correct them requires investments which may be much higher than the cost of the lost gas.

Local regulation and the actions of communities and NGOs can play an important role in encouraging businesses to respond to low-volume leaks. For example, BP has installed a leak detection and repair system on more than 80,000 valves at its refinery in Whiting, Indiana, but it needed the company to be bound by an agreement with the American justice system at the end of a procedure initiated by 3 American states (Indiana vs. BP, 2001). More recently, on 23 March, 2017, California adopted a new regulation on methane emissions in the hydrocarbon sector, to come into effect between 2018 and 2020, expected to reduce the state's emissions by 1.4 CO_2mteq per year, in particular by establishing quarterly monitoring of fugitive emissions and by imposing repair timescales when leaks occur.

The challenge of gas distribution networks

As operators of gas distribution networks enjoy a natural monopoly, they do not always have an economic incentive to reduce losses. In the absence of competition, tariffs are generally set by a regulator, often on the "Cost +" model: the remuneration received by the operator is based on the operating cost of the activity, valued based on previous years, plus a margin. In this system, gas lost during transmission and distribution is absorbed in the historical operating costs. As a result, the operator does not suffer losses from fugitive emissions and there is no incentive to invest to reduce them. Local authorities often play a role in the management of the distribution network: they can own it (as in France), set rates (this is generally the case at state level in the United States), be on boards of directors, etc. They can use this role to encourage network operators to combat leaks, thereby helping to reduce their fugitive emissions even when the gas industry is not directly present on their territory.

Source : Hausman, 2016

TEXT BOX 6

Cooperation between companies, researchers and public bodies at sub-national level is particularly necessary in the United States, where the election of Donald Trump in 2016 led to federal regulation being undermined and the commitments of the previous administration being abandoned. There are initiatives in this direction (Konschnik, 2018).

At world level, the objective of the Oil and Gas Methane Partnership, under the auspices of the Climate and Clean Air Coalition, is to encourage oil tankers to take voluntary action. Ten of the largest oil companies on the planet, including Royal Dutch Shell, Total and BP, as well as Mexico's PEMEX and Thailand's PPT, have ratified its guiding principles for reducing methane emissions in the gas industry.

• THE COAL SECTOR • After hydrocarbons, the next sector causing fugitive emissions is coal: like oil reservoirs, coal seams generally contain methane that can escape into the atmosphere when the resource is exploited.

Coal-related fugitive emissions mainly occur:

• During coal mining: the fracturing of the ore releases trapped methane. In an open cast mine, the gas occurs directly in the atmosphere. When the mine is underground, the methane spreads in the tunnels before being evacuated by the ventilation system. The concentration of methane in the ventilated air outside mines is usually a few tenths of a percent, while the risk of explosion ("firedamp") starts from a few percent.

• During the transportation and storage of coal: the gas still present in the ore is released into the atmosphere
• Following decommissioning: methane can continue to escape through cracks and wells created during operation. In the United States, for example, there are several thousand abandoned mines, including 400 identified as discharging significant quantities of methane (EPA, 2017).

According to the available inventories, most emissions occur during ore extraction: ventilated methane alone accounts for half of the sector's fugitive emissions (EPA).

The gas associated with coal can be recovered and used as natural gas for electricity generation, vehicle fuel or in petrochemical processes. It can also be used in mining: to dry ores, heat tunnels, etc. The reduction of fugitive emissions in the coal sector can thus be a profitable operation: in Europe, coal degassing would yield €1.8 - €2.2 per tonne of CO_2 equivalent avoided (Ecofys, 2009). However, these emissions are often neglected: in the ETS framework, the European carbon market, for example, they are not included in calculations of the carbon footprint of coal producers.

The Global Methane Initiative, a public-private partnership launched in 2004 to reduce methane emissions, identified nearly 200 projects in the coal sector in 2016 (Global Methane, 2016). Among the most recent are the installation of a 1MW gas turbine (with the option to extend to 6MW) in the Fuhong underground mine in China or gas recovery and use for the production of steam, heat and electricity at the Severnaya mine in Russia.

Degasification of the Khe Cham Coal Mine (Vietnam)

Located in the northeastern province of Quang Ninh, the Khe Cham coal mine is operated by a subsidiary of the public conglomerate Vinacomin (Vietnam National Coal and Mineral Industries Group) and produces 1.5 million tonnes of coal per year.

The Khe Cham coalfield is one of the richest in methane in the country. These fugitive emissions pose safety problems: in 2009, a firedamp fire killed 11 miners.

In 2012, a drainage system was put in place, which reduced the methane concentration in the mine atmosphere by 0.2 to 0.6 points. This meant that the mine was no longer forced to suspend operations due to the abnormal presence of methane (compared to an average of 20 hours per month of interruption before its installation). Ventilation costs have also been reduced by a third and output efficiency has improved. Finally, the collected methane can be used to supply a gas turbine and partly cover the electricity needs of the mine.

FIGURE 4. STATION DE DRAINAGE DE MÉTHANE À KHE CHAM

Source : Global Methane

TEXT BOX 7

As emissions continue beyond end of operations, site remediation and the attention of local authorities can also help to reduce emissions.

CONCLUSION

Despite a significant contribution, fugitive emissions are one of the blind spots in combating climate change. Much work remains to be done for better evaluation and reduction of fugitive emissions. The available information suggests that the extraction and, to a lesser extent the processing and transportation, of fossil fuels is the main source of fugitive emissions. Responsibility for their reduction therefore rests first and foremost in the oil, gas and coal companies, assisted - sometimes spurred - by other actors: researchers, local authorities and local communities, NGOs.

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Carbon capture and sequestration: a solution that is struggling to materialise

Carbon capture and sequestration (CCS) prevents the release of greenhouse gases into the atmosphere by recovering carbon dioxide at the emitting facilities and then storing it or using it, possibly after transport. CCS could quickly reduce greenhouse gas emissions from power generation and industry without the need to reduce fossil fuel consumption. The technical feasibility of this solution has been demonstrated by pilot projects including Petra Nova which started in 2017. However, CCS struggles to get deployed: only 5 projects are underway in the world. We ask what the possible reasons for this reluctance may be.

Main autor • **THIBAULT LACONDE** • *Consultant, Energie & Développement*

CONTENTS

1 • CCS: MIRACLE OR MIRAGE

Carbon capture and sequestration is a set of techniques for recovering carbon dioxide from large emitting plants (thermal power plants, steel plants, etc.) and storing it sustainably to prevent its release into the atmosphere.

Unlike most mitigation techniques, **CCS could reduce emissions without the need to reduce fossil fuel consumption and thus without disrupting our consumption patterns or the structure of our economies. It also has the advantage of potentially allowing it to be implemented a posteriori in an existing industrial tool.**

• THE FUNCTIONING OF CCS • CCS comprises three main steps:

• Capture: separating carbon dioxide from other gaseous effluents at the chimney outlet or modifying industrial processes to release pure CO_2

• Sequestration: sustainably storing the recovered carbon dioxide to stop it reaching the atmosphere

• Transport: transporting carbon dioxide from the capture point to the storage point

Each of these steps can involve multiple technologies – sometimes with varying levels of maturity, costs, and environmental impacts.

The first step of CCS is capturing carbon dioxide at the output of thermal power plants or industrial facilities. The difficulty of this step comes from the fact that the effluents are not composed of pure carbon dioxide: similarly to ambient air, they contain approximately 2/3 nitrogen and various impurities. It is therefore necessary to separate carbon dioxide from other gases or to modify industrial processes to produce only CO_2.

There are three types of technologies for this:

• Post-combustion: carbon dioxide is separated from other gases and recovered directly from the exhaust fumes – allowing use on existing equipment without major modification

• Oxy-combustion: the installation is modified so that the combustion of fossil fuels is carried out in pure oxygen and thus produces only water vapor (easy to precipitate) and carbon dioxide

• Pre-combustion: this process consists in extracting carbon before combustion This can be done by producing carbon monoxide from the fuel (for example by steam reforming or incomplete oxidation) which reacts with water vapor to form carbon dioxide and dihydrogen (this is referred to as "shift-conversion"). Then, hydrogen is burned, producing only water vapor.

Atmospheric capture and CCS

Atmospheric capture consists in removing CO_2 not at the output of emitting facilities but directly from the atmosphere. This emerging sector is different from CCS because it does not only reduce emissions, it creates "negative emissions". It is experiencing a growing interest that has been stimulated in particular by the objective of net zero emissions stipulated by the Paris Agreement.

Atmospheric capture often relies on all or some of the technologies developed for CCS. For example, biomass + CCS (or "Bioenergy + CCS", BECCS) consists in using photosynthesis to remove CO_2 from the atmosphere and then burning the biomass produced and recovering and sequestering the CO_2: this technique therefore uses the whole chain of CCS. Direct air capture uses a technological process to extract CO_2 from ambient air where it is much less concentrated than in factory fumes (approximately 0.04% vs. 30%) before sequestering it: in this case, only the transport and the sequestration are common with CCS..

Source : center for carbon removal

TEXT BOX 1

The captured carbon dioxide then must be stored safely and sustainably to prevent it from entering the atmosphere. The solution most often considered is geological sequestration: CO_2 is injected into depleted oil or gas reservoirs into unusable coal seams or deep saline aquifers. **In practice, however, the captured CO_2** is rather used than stored – it is sold, which improves the profitability of the process but can also decrease its positive impact on the climate. **The valuation may consist of:**

• Injecting CO_2 into a hydrocarbon reservoir during operation: as the petrol or gas is being extracted, the pressure in the reservoir drops, and the injection of CO_2 (or other gases) can make it possible to increase it and increase production – this is referred to as enhanced oil recovery or EOR

• Using CO_2 as a raw material in chemical, industrial or agricultural processes, for example as a solvent, refrigerant or dissolved in sparkling beverages

• Using energy to convert CO_2 into liquid or gaseous fuel through photosynthesis (e.g. by producing microalgae used for biomass production) or by methanation.

It is not always possible to use the dioxide at the place of capture and it is rarely possible to store it there. An intermediate step therefore consists in transporting the gas. This transport can be done by gas pipelines, but also by truck, train or boat.

• CCS TODAY IN THE WORLD • Carbon transport and sequestration – usually by EOR – has been carried out on a small scale for several decades. These first experiments have almost all taken place within petrochemical processes already producing concentrated CO_2 without the necessity to modify the emitting installation. For example, this is the case of the purification of natural gas (Terrell Natural in the United States in operation since 1972, Sleipner in Norway since 1996, etc.) or the production of nitrogen fertilisers (Enid Fertilizer in the United States since 1982).

Carbon capture from facilities that do not produce pure carbon dioxide is a more recent occurrence. For example, there are many demonstrators in electricity generation but only two large-scale projects are currently in operation: Boundary Dam in Canada (commissioned in 2014) and Petra Nova in the United States (commissioned in 2017).

Boundary Dam

Boundary Dam is a coal power plant operated by Sask Power in the Canadian state of Saskatchewan. Its unit 3 has been equipped to capture the emitted carbon dioxide: up to 90% of the CO_2 produced during combustion, i.e. approximately 50,000 tonnes per month, which is captured by absorption using a chemical solvent. The CO_2 is sold and transported via a pipeline to the Weyburn oil field where it is pumped into wells to increase production. At the beginning of 2018, Boundary Dam 3 exceeded the threshold of 2 million tonnes of captured CO_2.

The project cost $1.35 billion Canadian dollars (€945 million). It is approximately 5 times more than a coal power station without CCS which would have cost €150 to 200 million at equivalent power. An overconsumption of energy of 25% is also added to these investments. In addition to its net capacity of 110 MW, the plant produces 29 MW which only serve to fuel the energy-intensive process of carbon capture. Despite these costs, the project demonstrated the technical feasibility of post-combustion CCS on an industrial scale.

Source : www.saskpower.com

TEXT BOX 2

Excluding small demonstrators and pilots, 17 carbon capture and storage projects are currently in operation around the world, preventing the release of just over 31 million tonnes of CO_2 annually. Five additional projects are under construction and another fifteen are in various stages of development (Global CCS Institute, 2018).

There have also been several costly failures in carbon capture such as the FutureGen projects or the Kemper County project in the United States and ZeroGen in Australia.

The technical feasibility of capturing and sequestering carbon has therefore been established, but projects likely to significantly reduce emissions are rare and difficult to materialise. We may ask how to explain these difficulties and what role do non-state actors play in the development or instead in the resistances to CCS.

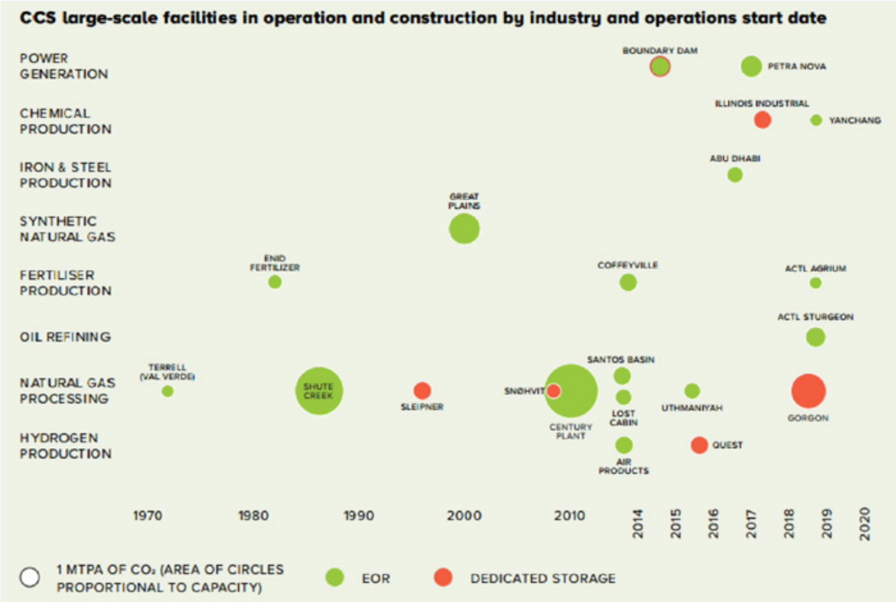

FIGURE 1. CCS PROJECTS ON AN INDUSTRIAL SCALE BY DATE OF COMMISSIONING, SECTOR AND THE QUANTITY SEQUESTERED (GLOBAL CCS INSTITUTE, 2018)

2 • COMPANIES: AN ENTHUSIASM WITHOUT A BUSINESS MODE

Carbon capture is attracting the interest of many economic players, especially those who depend on fossil fuels because its large-scale deployment would reduce emissions without jeopardising their activity. Coal industry, tankers, fossil electricity producers, heavy industries, etc. therefore support the development of this sector; however, like the Lacq pilot project (France) launched by Total, these experiments rarely lead to large-scale implementation.

One of the major causes of this reluctance is that carbon capture does not have economic rationality these days (Kapetaki, 2017).

• INSUFFICIENT CARBON PRICE TO MOVE BEYOND PILOT PROJECTS •

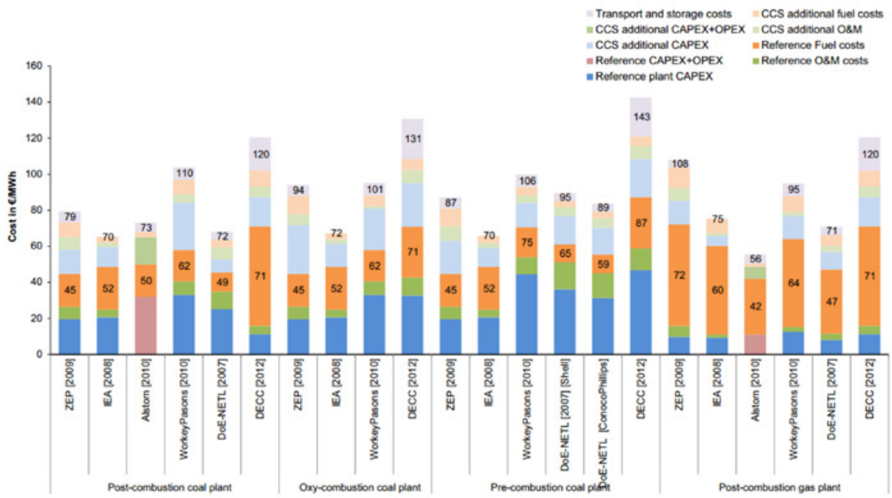

FIGURE 2. ADDITIONAL COST (LCOE) OF CARBON CAPTURE AND SEQUESTRATION PER MEGAWATT HOUR PRODUCED BY VARIOUS STUDIES

(Renner, 2014)

These projects are expensive and significantly decrease the performance of the facilities on which they are conducted. According to the considered studies and technologies, carbon capture and sequestration in a thermal power plant would increase the cost of electricity from €56 to €143 per megawatt. In Europe the price of electricity is around €40/MWh – it would therefore mean at least a doubling of the wholesale price.

Under these conditions, it would necessitate a price of carbon of €115 per tonne in Europe for thermal power plants with CCS to become the most profitable option. For comparison, the price of European carbon credits has been fluctuating between €4 and €20 per tonne of CO_2 since the creation of the European carbon market. In China, the tipping point is lower: a carbon price of €45 per tonne would be enough to make CCS profitable in the electricity sector. This threshold could be reached by 2030 (Renner, 2014), but the Chinese carbon market pilots currently place the price per tonne of CO_2 between €0.13 and €15.5.

Where it exists, **the price of carbon is therefore too low and often too volatile to justify the development of carbon capture and sequestration.** Companies have no incentive to go beyond pilot projects.

The new US carbon capture tax credit

In the United States, the 2018 budget has created a strong incentive for carbon sequestration: geological sequestration of one tonne of CO_2 gives the right to a tax credit of $50. The other uses of CO_2 are accompanied by a tax credit of $35 per tonne. This system applies both to CO_2 captured from energy or industrial installations and CO_2 removed directly from the atmosphere. It may not be sufficient to allow carbon capture and sequestration to become profitable, but this system should help many projects come closer to it.

This tax credit is also original by the variety of support that it gets, bringing together both climato-septic and environmental activists, Republicans and Democrats, coal producers, unions and NGOs.

Source : MIT Technology review

TEXT BOX 3

• THE REGULATORY WAY • In the absence of economic rationality, regulators may be tempted to impose carbon capture and sequestration on companies. The first example of this strategy can be found in Australia in the case of the Gorgon and Wheatstone gas projects: the Western Australian Government authorised the construction of these facilities by Chevron provided that 80% of the CO_2 removed from the gas is captured and sequestered.

This initiative replaces the carbon price: the Western Australia compulsory compensation scheme was abolished in 2011 when Australia created a carbon tax, but this tax was in turn abolished in 2014 by Tony Abbott's government. Chevron no longer has any financial incentive to reduce its emissions.

As part of the deal, Chevron invested $2.5 billion (out of a total investment of $88 billion) to capture 4 million tonnes of CO_2 per year. The sequestration will take place in a reservoir located 50 km from the coast and 2 km below the surface in the Isle of Barrow nature reserve.

However, the regulatory approach shows some limitations: the Gorgon site has been operating since March 2016, but carbon capture and sequestration is still not operational and it will ultimately only address 40% of emissions. This delay was not foreseen by the agreement whose application is therefore included. Two investigations were initiated by the local environmental protection agency.

The European Union has taken a more flexible approach: the 2009 CCS Directive does not require carbon capture and sequestration, but a feasibility study is required for new thermal power plants above 300 MW. When transposing this directive, some member states including France and Great

Britain decided to allow only CCS-ready projects, meaning projects fulfilling the conditions (space, access, etc.) allowing them to be retrofitted for carbon capture.

3 • A DIVIDED CIVIL SOCIETY

Another obstacle for carbon capture and sequestration projects is its image in civil society: this sector is little known and often leads to a rejection response.

• NGOS AND THE ACADEMIC WORLD• Some researchers see carbon capture as a "Faustian pact" (Spreng, 2007) that can lead to a technological impasse and hinder the development of low-carbon technologies such as renewable energy.

The Yanchang project – illustration of the CCS paradoxes

Yanchang in the coal-producing areas of northern China is to host the first industrial-scale carbon capture and sequestration system in Asia. The project is led by Yanshan Petroleum, a company owned by the provincial government of Shaanxi and the 4th largest petrol producer in China. It is to be opened in 2018 and avoid the discharge of 410,000 tonnes of CO_2 per year.

Yanchang illustrates the paradoxes of carbon capture: just like 4 out of 8 Chinese CCS projects, it is intended to capture emissions from coal liquefaction plants. The installation of these systems at the plant level does not eliminate emissions either upstream (for example fugitive emissions of methane during coal mining) or downstream (during fuel combustion). The process also consumes a large amount of water (6 to 13 tonnes of water per tonne of fuel). In addition, the catchment site and the storage site are separated by 140 km, and the transport is done by truck: more than 20,000 round trips will be needed each year. Finally, the captured CO_2 is sequestered in the Qiaojiawa oil field where it can stimulate the production of hydrocarbons.

The carbon capture and sequestration carbon is therefore part of a value chain emitting a lot of greenhouse gases which it helps to perpetuate.

Source : Financial times

TEXT BOX 4

This opposition was reinforced around the year 2010 when it became clear that CCS projects were facing many difficulties – delays, extra costs, abandonment, etc. (Markuson, 2012). This period also corresponds to a decrease in the resources allocated to research: in Europe, public and private investment in research into carbon capture and sequestration peaked in 2010 (Fiorini, 2016). In the United States, the Carbon Sequestration Initiative research programme into CCS at MIT closed in June 2016 after 16 years of existence.

In a similar fashion, some NGOs are radically opposed to carbon capture. Greenpeace believes that CCS is a dangerous waste of time, "Greenpeace opposes CCS as a dangerous distraction from the safe, secure 100 percent renewable energy future we all want." ***This position is however far from consensus: other organisations fight in favour of CCS (Bellona, ZERO, etc.), even WWF has sometimes cautiously supported this solution (WWF-UK in 2014: "Demonstrating carbon capture and storage is an urgent priority ... but the Government shouldn't plan significant investments in new fossil fuel plants today on the assumption that CCS technology will be available at an affordable cost in the future to capture emissions when we simply don't know that yet."***

• LOCAL COMMUNITIES • Carbon sequestration with its risk of leakage and induced earthquakes is worrying riverside communities. Their mobilisation has slowed or even prevented carbon capture and sequestration projects and pushed some governments to abandon on-shore sequestration in favour of more expensive off-shore sequestration.

This is what happened to the CCS project proposed by Shell in Barendrecht (The Netherlands). This project was to start in 2011 and provide storage for 10 million tonnes of CO_2 within 25 years. It was abandoned in 2010 due to opposition from the local population. Following this failure, the Dutch government decided that all CO_2 storage projects should be done at sea. Similar movements took place in Germany (Beeskow, Brandenburg) and in the United States (Greensville, Ohio and Long Beach, California).

The acceptance of carbon capture and sequestration projects by the local population is therefore a major challenge in the development of this sector. The topic has been the subject of numerous studies and scientific publications. As is often the case for emerging technologies, the first factor of acceptability is the perception of benefits, in this case the continued use of fossil fuels (L'Orange Seigo, 2014). As a result, populations heavily dependent on fossil fuels are more favourable to carbon capture and sequestration projects, even when they are otherwise hostile to emission reduction efforts. For example, in the coal state of Indiana, 80% of respondents support carbon capture and sequestration. However, this does not prevent the NIMBY effect ("not in my backyard"): 20% of respondents favourable to CCS change their minds if the project is close to their community (Krause, 2013).

The used technologies and especially the source of CO_2 are other factors likely to affect public opinion. A German study shows that CCS, which is on average perceived as relatively neutral, is supported more when it is conducted on biomass plants or industrial facilities than when it is conducted on coal plants. The mode of transport and storage also have an influence: using enhanced hydrocarbon recovery, for example, is better perceived than injecting into saline formations (Dütschke, 2016).

4 • COMMUNITIES: UNDECIDED ARBITERS

Carbon sequestration means storing a dangerous substance for an indefinite amount of time. This practice, and to a lesser extent carbon transport, has a significant territorial footprint, making communities crucial stakeholders.

For example, the 2009 European Directive on CCS provoked resistance in Germany, where the federal states challenged the sites selected for carbon sequestration. As a result of this move, the German CCS Act recognised the role of federal states by granting them a veto over carbon sequestration projects – **an unprecedented prerogative in German environmental law that does not generally give the right of scrutiny over infrastructure projects to local authorities.**

More generally, experience shows that the interest of communities can vary significantly depending on the selected technology and the equipment to be installed on their territory. In particular, they seem reluctant to accept the storage of carbon dioxide, especially when it is not associated with the construction of a new thermal power plant or with value-production (such as the production of hydrocarbons).

The implementation of the FutureGen project in the United States

FutureGen was announced in 2003, and it was conceived as the leading figure in Bush administration's "clean coal" agenda. The project was meant to demonstrate carbon dioxide capture and sequestration in a single location, bringing together the entire technology chain in a purpose-built state-of-the-art facility. This ambitious project had a budget of $1.5 billion, of which 74% was funded by the federal government.

Implementing the project was the subject of a two-year competitive process. Seven states applied for it and 12 sites were selected. The first selection round led to four finalists – two in Illinois and two in Texas. Both states have invested in the process including mobilising the general public to ensure project recognition and acceptability. In January 2008, Mattoon, Illinois was chosen as the site for FutureGen.

In mid-2009, the consortium in charge of FutureGen acquired the land in Mattoon. Laying the foundation stone of the new plant was planned for 2010. In August 2010, the project – now called FutureGen 2.0 – was restructured by cancelling the construction of the new power plant to instead retrofit an existing facility located 280 kilometres from Mattoon. In this way, Mattoon would have provided only the geological carbon storage site which led the community to withdraw support for the project. The search for a new site delayed the project for another year and was eventually abandoned in 2015.

Source : Markusson, 2011

TEXT BOX 5

CONCLUSION

Carbon capture and sequestration is an attractive option for reducing greenhouse gas emissions and could even help remove carbon dioxide from the atmosphere. A decisive advantage of CCS is that its technological feasibility has been proven and that it has been implemented on projects dating back several decades. Its main fault is that it is still too expensive and too uncertain to truly mobilise the economic actors. The reluctance of local authorities and the cautiousness of communities often complicate projects and obscure the prospects of a technology that, for the time being, remains an uncertain deus ex-machina.

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