

# What future equilibrium for the supply and demand of energy?

## Foreword

Dr. Fatih Birol, executive director, International Energy Agency

## Introduction: What future equilibrium for the supply and demand of energy in the transition toward a carbon-neutral world?

Dominique Auverlot, Ministry of Environmental Transition and Solidarity (MTES), and Richard Lavergne, Conseil Général de l'Économie

## Final consumption of energy: New uses, new behavior patterns in France and the world

### Application by 2050 of the energy transition and carbon neutrality to the demand for energy in France

Laurent Michel, general director of Energy and Climate, Ministry of Environmental Transition and Solidarity (DGEC/MTES), and Quentin Deslot, engineer from the Corps des Ponts, des Eaux et des Forêts (DGEC/MTES)

In its Climate Plan of July 2017, France made the commitment to raise its ambitions to the goal of carbon neutrality by 2050. This implies thoroughly overhauling the country's energy system, which will have to eliminate nearly all fossil fuels. The shares of the biomass and renewable sources of energy for heating and electricity will increase in the energy mix. To eliminate carbon in this mix, the consumption of energy will have to be halved; and systematic efforts, made to improve energy efficiency, modify individuals' behaviors and reorganize society for a more sober consumption of energy. We must bear in mind that carbon neutrality at the national level implies working on the country's whole carbon footprint, making the most effective decisions and accompanying the most vulnerable households and firms during this transition. This long-term goal cannot be spared more vigorous actions in the short and middle run.

### Trends in electricity consumption in France?

Thomas Veyrenc, director of Stratégie et Prospective, Réseau de Transport d'Électricité (RTE)

Predictions and futurological studies of electricity consumption have recurrently aroused controversies about France's power stations. These stations produce a supply of electricity that is highly decarbonized and will even more so, thanks to nuclear power, once the last coal-fueled power stations are shut down in 2022, as announced. This makes electricity an obvious vector for reaching our

climate objectives. Nuclear power theoretically provides a ground for programs that would use electricity for new industries and purposes (e.g., "mobility"). Nonetheless, a successful energy transition entails a general effort on energy consumption, in particular the effort to find ways to save energy, including electricity. The priority to be established between these two orientations, the weighting of the effects, upwards or downwards, that each implies on different time scales, the consequences for power stations (in particular, the place of nuclear power) and the energy sector's overall structure are topics of lively debates. These debates are reflected in the work done since 2017 by RTE, the transmission system operator, to thoroughly revise scenarios for France's electricity sector.

### Possible trends in the uses of electricity from the perspectives of carbon neutrality in France and of the respect of the Paris Agreement worldwide

Jean-Michel Cayla and Donia Peerhossani, analysts at the Direction of Strategy, Électricité de France (EdF)

Following the Paris Agreement, France set the objective of reaching carbon neutrality by 2050. When applied optimally, the strategy for electrifying the uses of energy in buildings, transportation and industry would enable the country to achieve carbon neutrality fast at a lesser cost by 2050 with a moderate increase in electricity consumption. Underlying this strategy is a supply of electricity already relatively carbon-free and an existing, competitive technology that allows for reducing the electricity bill for households. Robust in the face of uncertainty, this strategy will yield its first major results by 2030.

### The transformation of electricity systems: Will the consumer be a winner?

Dominique Jamme, Commission de Régulation de l'Énergie (CRE)

Everywhere in the world, electricity systems are undergoing deep changes stemming from the massive lowering of the prices of energy from renewable sources and of batteries. In France, the existing supply of nuclear energy is competitive, but uncertainty about the new generation of reactors and, too, the recent competitiveness of renewables suggest that we should gradually decrease the share of nuclear power in the electricity mix while increasing that of renewables. To adapt to these trends, electricity grids will increasingly use new means of "decentralized flexibility": storage, demand-side management, supply-side peakshaving, renewables, electric vehicles. Downstream on the grid, the profusion of innovations and of services (such as those now offered thanks to smart electricity meters) provides consumers with new opportunities for taking charge of

their consumption. The major challenge will be to obtain the commitment from as many consumers as possible while keeping the system simple and efficient for everyone.

### **Demand as a lever of decarbonization: Visions, disparities and limits**

**Nadia Maïzi**, Center of Applied Mathematics, MINES ParisTech, PSL Research University

By exploring differing scenarios, the fundamentals are assessed that underlie alternative visions of the future that share the same objectives of reducing greenhouse gas emissions. The distinction is made between scenarios based on a technological creed whereby adjustments in the supply of energy should enable us to cope with climate events and the scenarios that see societal factors (lifestyles and behaviors) as the best means for actually bifurcating toward a low-carbon world. This choice of narratives corresponds to a shift from an all-electric world toward a world of “sobriety”. In conclusion, it is argued that a reconciliation of these two positions is indispensable for settling the climate issue.

### **Major issues: The transformation of transportation and sustainable mobility**

**Didier Houssin**, IFPEN

Transportation has to cope with deep changes. An ever increasing demand for moving freight and people must be taken into account along with environmental constraints, both local (pollution and air quality) and global (transportation at the origin of a quarter of CO<sub>2</sub> emissions worldwide). This sector is still highly dependent (90%) on fuels produced from petroleum. Many of its segments (transportation by motor vehicles, trucks, ships, airplanes, etc.) have to be reoriented transformed so as to help develop low-carbon techniques (biofuels, gas, electric or hydrogen vehicles). Decarbonizing transportation for “sustainable mobility” is a major issue that calls for devoting thought not just to engines and fuels but also to the management of traffic and the infrastructure. It will even require modifying human behaviors if relevant solutions are to be proposed for the future.

### **Carbon neutrality: Opportunities and risks for French industry**

**Michel Guilbaud**, general director, MEDEF

France is among the first countries in the world to adopt legislation for reaching carbon neutrality by 2050. This very ambitious goal fits in with programs, both global (the Paris Agreement, the IPCC report on limiting global warming to +1.5°C by 2100) and European (the roadmap for a low-carbon economy). For France, now a stride ahead, the key issue is to tap the potential in all sectors and increase the country’s ability to develop low-carbon solutions and forms of technology and place them on the world market. This implies major, even radical, changes in our economic and social model, an acceptance by consumers of a thoroughgoing modification of their lifestyles, an anticipation of the impact on jobs and skills, and fair conditions for competition.

### **Heating and air-conditioning: Issues and opportunities in France, Europe and the world**

**Thibaut Abergel and Maxine Jordan**, International Energy Agency (IEA)

Heating and air-conditioning account for nearly 70% of the energy consumed by housing and buildings in France, and nearly 40% in the world. These energy-intensive needs are the source of many an environmental and economic problem and of our dependency on fossil fuels. A major issue is to design industrial innovations for reducing by nearly 90% greenhouse gas emissions worldwide by 2050. Home improvements on a vast scale, the rollout of efficient, low-carbon appliances, and flexibility are the key to a responsible, economically viable environmental transition.

### **Balancing the demand for energy and the protection of a capital asset, our forests**

**Pascal Yvon**, Carbon Forest

Extracting resources from forests has always been a threat to nature, landscapes and biological diversity. Wood (probably mankind’s first source of energy, after the sun) yields little energy. Representing 4% of the energy produced in France, it should be reserved for consumption near points of production. Its potential is so low that the future of our forests should not be brought down to a discussion of wood as a source of energy. Wood is not suited for energy! To ensure a supply of wood while conserving this natural capital, the right solution is “multifunctionality”: biodiversity, soil conservation, carbon capture and storage in the ground and biomass, the efficient management of the water supply, and the production of lumber (and, thereafter, of wood for heating). This managerial model already exists and is perfectly feasible.

### **What supply of energy for a carbon-neutral environment?**

#### **The prospects for energy systems and hydrocarbons in a carbon-neutral world**

**Claude Mandil**, former executive director of the International Energy Agency (IEA)

Carbon neutrality by 2050, an essential condition for limiting the increase of the average temperature worldwide to 1.5°C in the long run, is an extraordinarily ambitious objective, since certain uses of fossil fuels seem durable and inevitable. All available means and methods will have to be put to use: efficiency and sobriety, electrification, the development of both renewable energy sources and nuclear power, and carbon sequestration (the only technology capable of yielding negative emissions). A start should be made with the least expensive solutions, since some attractive solutions are, in fact, financial sinkholes. The consequences for big industrial groups in France are analyzed. For instance, Électricité de France (EdF) has to find the break-even point for nuclear power, and automakers must cope with Asian competition in the technology for electric vehicles.

### Breakthrough technology for energy?

Hervé Bercegol, Sophie Didierjean, Mathieu Étienne, François Kalaydjian, Jean Le Bideau, Fabrice Lemoine, Guy Maisonnier, Gaël Maranzana, Fabrice Patisson and Abdelilah Slaoui, Alliance ANCRE

The climate question forces us to step on the accelerator of innovations in energy technology and low-carbon techniques. The massive introduction of energy from renewable, intermittent sources necessitates procedures for durably storing electricity at a low cost; and it also entails using versatile, decarbonized energy vectors, such as hydrogen produced by electrolysis. Farther along, we must move far away from fossil fuels in transportation and the chemical industry, and toward the capture and sequestration of CO<sub>2</sub> (part of which could be reused as a raw material) or toward carbon-neutral processes in industries (e.g., iron and steel) that emit huge quantities of greenhouse gases. Finally, the “co-conversion” of hydrogen and carbon dioxide into fuel and other useful molecules depends on technological breakthroughs in synthetic biology, photocatalysis and electrosynthesis.

### The prospects for developing nuclear power in France and the world: Which technology?

Jean-Guy Devezeaux de Lavergne, director of the Economic Institute, Commissariat à l'Énergie Atomique et aux Énergies Alternatives (CEA) & president of the Section Technique Économie, SFEN

Nuclear power's contribution to decarbonization in the world amounts to a little less than 10%. This represents a sizable market, probably the equivalent of more than a thousand nuclear reactors to be built by 2050. Reactors in this new generation will, in part, be small or medium-sized, and mostly have cooling systems that use ordinary water. Nuclear energy is, therefore, a solution for decarbonization alongside renewables. In France, an economic optimum would be to maximize the length of use of current reactors and thus postpone replacing them. This strategy has serious, negative industrial consequences, since it is hard to reconstitute a supply chain. The rationale that turns out to be the best during the current phase is to lower the costs of third-generation reactors (in comparison with the cost of prototypes and the first reactors in the series) and start replacing the fleet right away by using the EPR2 reactors designed by Framatome.

### The place of nuclear energy in a carbon-neutral world

Dominique Finon, CNRS, CIRED

For many people, nuclear power is condemned to extinction worldwide given the economic success of renewable sources of energy – a success story that contrasts with the setbacks experienced by the nuclear industry. A *reductio ad absurdum* argument demonstrates that decarbonizing the world's electricity supply by using only renewables without nuclear power would encounter insurmountable physical and economic obstructions, as reflected in the scenarios that, recently reviewed by the IPCC, seek to stave off the increase in greenhouse gas emissions worldwide.

What is yet to be found are the solutions for raising the economic value of new nuclear reactors (and of all forms of technology that do not emit greenhouse gases) by creating a “carbon rent” (which does not exist) while reducing its incompatibility with financial capitalism – what has already been largely done for renewables.

### France needs natural gas to achieve carbon neutrality

Thierry Trouvé, GRTgaz

The French energy system is to change radically and have a “net zero carbon footprint” in 2050. For the gas industry, this means lower demand and the replacement of natural gas with gases from renewable sources, as prescribed by the nation's low-carbon strategy. To avoid underestimating the optimal volume of renewable gases, this strategy should have taken account of the systemic interactions between forms of energy and the practical constraints on users. Furthermore, several scenarios should have been evoked; the effects of international trade, taken into account; and the analysis, broadened beyond the field of energy (to agriculture, wastes...). This would have shown that assigning more importance to gases from renewable sources (eventually imported) with a faster short-term development than foreseen by the strategy opens a way for reaching carbon neutrality in 2050 that would be less costly and less coercive for users and, too, more robust for coping with the unforeseen.

### Gas: An asset or liability in the quest for carbon neutrality?

Jean-Pierre Hauet, president of the Comité Scientifique d'Équilibre des Énergies

Natural gas has played a key role in our country's economic development. Current installations, in particular the pipeline grid, are an asset of considerable worth. However the new orientations in France's energy policy toward achieving carbon neutrality by 2050 raise a major problem for the gas industry. France differs significantly from several other countries, where gas seems to be a favorite replacement for coal, especially for generating electricity. This is not so in France, given the development of nuclear power and, soon, of energy from renewable sources. Gas, a form of energy that adds little to pollution, is not carbon-free and is, therefore, inconsistent with the achievement of carbon neutrality – in particular in housing and the service sector, which represent 65% of the end-use gas market. Great Britain, after the Netherlands, has announced that gas heating will not be allowed in new buildings after 2025. The French gas industry has to reinvent its business model, a question now being debated. It is necessary to set the level of decarbonized resources (“renewable gases”) that can be used under acceptable economic conditions and to identify the sectors that will have access to them. Reaching carbon neutrality by 2050 is an excessively forceful goal. Energy is a long-run issue: the infrastructure has to have the time to adapt and to find solutions that can be rolled out during the second half of the century, in particular hydrogen and the capture, storage and use of CO<sub>2</sub>.

## What future demand-supply equilibrium for energy?

Patrick Pouyanné, Total

A major challenge for the 21<sup>st</sup> century: how to make demographic growth consistent with a reduction of greenhouse gas emissions? As many people as possible have to have an affordable supply of energy while the emissions from this energy are being reduced. A complex equation to solve: energy for more people but with less carbon. What does it imply for a big gas and oil company like Total?

## Future of Oil in a Low-Carbon World

T.J. Wojnar Jr, Vice President, Corporate Strategic Planning, Exxon Mobil Corporation

Our world faces a dual challenge: meeting growing demand for energy while reducing environmental impacts, including the risks of climate change. This is a global issue that requires the collaboration of governments, industries, consumers and other stakeholders.

From reducing the environmental impact of our operations, to developing advanced products that help our customers reduce their emissions, ExxonMobil is committed to doing our part. We are investing in next-generation technologies such as carbon capture and storage and advanced biofuels from algae. We have been vocal in our support for the Paris Agreement, an important framework for addressing the risks of climate change.

Each year we produce an *Outlook for Energy*, our view of energy demand and supply through 2040. We use the *Outlook* to help inform our long-term business strategies and investment plans. The below highlights some of the key takeaways from our most recent *Outlook*, and the actions we are taking as the world shifts toward a lower-carbon energy system.

## Determinants of trends in energy production from the perspective of sustainability

Marc Jedliczka, Hespul et négaWatt, and Yves Maignac, WISE-Paris et négaWatt

It would be presumptuous, given the inertia and hoped-for breakthroughs, to predict how the energy system will evolve by such a far-off horizon as 2050. However it seems evident, given ever stronger long-term requirements and the constant progress made in response to them, to foresee how this evolution should be oriented in order to be sustainable.

## Freed from fossil fuels by 2060 thanks to nuclear power

Élisabeth Huffer and Hervé Nifenecker, the association Sauvons le Climat

A rapid development of the production of nuclear energy up to 173 EJ/year (4,152 Mtoe, 47,921 TW-h) by 2060 and then to 605 EJ/year (14,520 Mtoe, 167,585 TW-h) by 2110, would limit the average increase of global warming on the earth's surface to 1.5°C more than during the preindustrial era, while reducing the quantity of CO<sub>2</sub> to be stored from 800 Gt (under the original MESSAGE-Efficiency scenario)

to 275 Gt (under the scenario used in this article) and doubling the total primary energy available between 2015 and 2110.

## The challenges for making Europe carbon-free

Marc-Antoine Eyl-Mazzega, Energy Center, IFRI

The generation of electricity by coal-fueled power stations represents 19% of European electricity and 18% of CO<sub>2</sub> emissions by the energy sector. With approximately 200 coal-fueled power stations in the European Union and 128 mines in operation, this sector provides about 237,000 jobs, 185,000 of them in the mines. By the end of 2025, the equivalent of 30 GW of this production capacity should be shut down and then 70 GW more by 2030, respectively 20% and 50% of the production capacity of installations in 2019. This exit from coal power, which will start in the coming years, is a necessity for the climate, but it is also a major challenge with social, economic, financial and systemic dimensions. Its successful implementation on the European scale is far from certain. It requires strong commitments and broad consultations among all stakeholders, in particular the EU, its member states, regions and firms.

## What prospects for energy suppliers in Europe?

Nicolas Goldberg and Sébastien Méraud, Columbus Consulting

Energy suppliers move in a complex market in Europe. Given the EU's regulatory framework, which has constantly backed market liberalization, they face intense, diversified competition. Given their business model, structurally subject to high costs, they also face a systemic risk of shrinking margins due to price fluctuations and their customers' increasing bargaining power. In this context with its competitive and financial pressures, they could use the next five years to explore several possibilities: how to differentiate their offers of energy-related services, how to use digital technology to make customers loyal and optimize commercial costs, how to limit bottlenecks in the supply chain and how to stimulate growth by diversifying their activities.

## What place for the biomass as a source of energy in a carbon-neutral France?

Claire Tutenuit and David Laurent, Entreprises pour l'Environnement (EpE)

Since climate change forces us to reduce or even eventually stop the consumption of fossil fuels, all branches of the economy (in particular energy) are hoping to secure their future production chain with a supply of renewable raw materials coming from the biomass. However the biomass does not have an unlimited yield. How can it help satisfy energy needs? The answer, in part, is drawn from the recently released study *ZEN 2050* by the association Entreprises pour l'Environnement. To explore the feasibility of carbon neutrality in France by 2050, this study balances the absorption by carbon sinks (from 60 to 100 Mt of CO<sub>2</sub> equivalents) with a stiff reduction in emissions (from 480 to 100 Mt of CO<sub>2</sub> equivalents).

The biomass will play a key role in the energy system, but several points of rivalry and synergy between the uses and services related to it exist: the food supply for people and animals, biodiversity, the capture of CO<sub>2</sub>, soil amelioration, new materials... For instance, enlarging the capacity of carbon sinks implies expanding woodlands, limiting or even stopping the compacting of the soil due to human activities, and managing farmlands and farming practices so as to increase the carbon contained in the soil. Furthermore, soil management could significantly increase the quantity of the biomass available for energy purposes, a quantity that currently limits the supply of energy. In conclusion, the study advises public authorities to set up a new governance for the use of the soil, land and biomass that takes into account various uses and services.

## The long-term equilibrium of supply and demand, or the geopolitics of energy on the road toward carbon neutrality

### The geopolitics of energy in 2050

Olivier Appert, advisor at the Energy Center, IFRI

For a century now, the access to energy has fueled geopolitical conflicts between nation-states. These conflicts will persist during the energy transition, while new parties will be entering the game. A new dimension in the geopolitics of energy is the access to critical metals and to the technology indispensable for this transition.

### A carbon-free world – What is Russia's response?

Tatiana Mitrova, PhD, Director, Energy Center, SKOLKOVO Business School, and Yuriy Melnikov, Senior analyst, Energy Centre, Moscow School of Management SKOLKOVO

The article reviews the impact of decarbonization and the global Energy Transition on Russia, analyzing Russia's position in relation to climate change and decarbonization agenda. Unlike some European countries, Russia has not yet made decarbonization of the energy sector a strategic priority. This is partially explained by the fact that there is a degree of skepticism among the stakeholders in relation to global climate change. Ranking fourth in the world in terms of primary energy consumption and the volume of carbon dioxide emissions, Russia continues to rely on fossil fuels, while its GDP energy intensity remains high amid relatively low energy prices and high capital costs. The share of RES in the energy mix (solar and wind power) is negligible and is not projected to rise above 1% by 2040. However, there is no denying that the Russian energy sector is beginning to feel the impact of increasing global competition, growing technological isolation due

to sanctions and ongoing financial difficulties. Quite apart from the impact of global climate change agenda, these factors present Russia with the necessity to produce a new development strategy for its energy sector, which has been and remains crucial for its economy.

### National Oil Companies of the Future

Valérie Marcel, Chatham House

Will national oil companies (NOCs) be the champions of the energy transition and invest in clean energy? That is not a commonly asked question. Because NOCs are designed to produce and sell fossil fuels, their potential contribution in the area of renewables, cleaner energy and energy efficiency standards is often underappreciated. This article reviews NOC incentives to invest in the clean energy space and asks whether they are the right vehicles to lead the energy transition in their countries.

### Strategies and policies for energy transitions: Between cooperation and fragmentation

Jean-Eudes Moncomble, Conseil Français de l'Énergie

Deep thought must be given to the determinants used in energy scenarios. Among critical points of uncertainty are the degree of international cooperation and the equilibrium between market operations and public policies – two very important means of leverage for managing energy. Fragmented or cooperative worlds thus appear in which energy systems will meet in different ways the objective of sustainability. A focus on the World Energy Council's scenarios...

### Will China and India remain the world's workshop on a planet struggling with climate change? A technological and demographic interpretation of energy issues

Joël Ruet, economist at the CNRS (CEPN Paris 13 & CRG École Polytechnique) and president of the Bridge Tank

The industrialization of China and India can be interpreted as a diffusion of technology that the abundance of funding for infrastructures and "technological massification" has accelerated. The "demographic dividend" tends to speed up the effects of adopting a new technology. However these two countries are undergoing energy transitions toward the sustainability of their necessarily complex ecosystems, which involve several sorts of energy. Attention is drawn to the principal factors in this modernization-transition. Energy technology is, for these two countries, a sure way not just to remain the world's workshop but also to obtain the option to evolve beyond being a mere workshop.

*Issue editors: Dominique Auverlot and Richard Lavergne*