Presentation of the *Sounding Board* Results

Study on strategic perspectives of energy

May 2018

I. Objectives, process and method of presentation of the results

1) Objectives

a) Background

The energy sector is undergoing major upheavals in Europe and around the world as a result of two real revolutions. On the one hand, the energy transition changes the landscape of electricity generation and modifies the generation mix. The need to reduce CO2 emissions leads to limiting the share of fossil fuels, while the consequences of the Fukushima accident weigh on the economic fundamentals of nuclear production. At the same time, intermittent renewables, as well as energy storage technologies, are seeing their production costs drop dramatically. On the other hand, the digital revolution is transforming all the components of the energy sector. The multiplication of available data, thanks in particular to the roll-out of smart meters, goes hand in hand with the exponential development of the processing capacity of this data. The ways to operate and maintain networks, the understanding of consumer behavior and expectations, and the ability to control equipment intelligently, are profoundly altered.

These major developments create a particularly uncertain future and challenge the functioning of the energy markets.

In this context, the objective of this study was to analyze, in Europe and worldwide, the changes taking place in the energy sector to better know and anticipate foreseeable medium and long-term changes.

A first phase of this work has resulted in highlighting a dozen “theses” describing what could be a long-term energy future. More than 80 qualified individuals from the energy sector – French, European, and from around the world – were asked to share their personal opinion on the probability that these theses come true, by 2030 and 2050.

b) List of theses

Theme	Thesis statement
1. Final energy demand	Even if final energy demand will increase globally, driven by the increase of demand in developing countries, it will strongly decrease in Europe and in France, including for natural gas. In Europe and in France, power demand will decrease or at most increase slightly despite important substitutions of end uses towards this energy.
2. Power system	**a. [Low-carbon power systems]** Worldwide**,** new power generation capacities will mostly be renewable. In developed countries, very low-carbon power systems (>80% of carbon-free power production) will emerge by 2050 at the latest.
	b. [Competitiveness of renewables] These low-carbon power systems will be competitive (compared to fossil-fuel systems) in interconnected areas as in non-interconnected areas.
	c. [Electricity storage] Electricity storage, especially with electric vehicle batteries, will play a key role in enabling the proper functioning of low-carbon power systems with a high penetration of variable renewable energy.

	d. [Market Design] In this context, the price on wholesale markets will not be used as a relevant long-term investment price signal (it will remain used only for the dispatching optimization).
	e. [Price signals and long-term contracts] The market design has to be adapted to introduce or reintroduce price signals or long-term contracts.
3. Power networks	**a. [Impact for operators]** The energy transition will have a major impact on the balance of the power network, leading both to a significant need for networks and a decrease of their utilization rate (linked to self-consumption and, for the transmission network, to decentralized production).
	b. [Transmission/generation optimization] The shift to a high integration of renewable capacities will lead to an entire redesign of the power systems and networks, requiring a holistic approach so as to optimize system-wide investments in production capacities and transmission networks.
	c. [Transmission networks] From the transmission network's point of view, apparent demand will strongly decrease (due to decentralized production), but the need for interconnections will increase to make use of the reduction in intermittency associated with generating renewable energy on a wider geographical area.
	d. [Network balancing] Flexibility requirements will increase and will be mostly met through decentralized tools (storage, demand response, electric vehicle batteries, decentralized production) requiring the aggregation of numerous points; the distribution system operator will then become responsible for the active management of the network and the organization of local flexibility markets.
	e. [TSO/DSO coordination] The coordination between TSOs and DSOs in the operation and optimization of flexibility sources (global optimization vs local optimization) will become a critical issue.
	f. [Micro-grids / Impact on networks] Micro-grids, which will enable neighborhoods to locally source their power supply, will grow and be profitable in places where the economic and regulatory conditions make their development possible. Except in specific cases (isolated systems, lack of reliable networks), these micro-grids will still be connected to the main network.
4. Gas systems	In Europe, gas infrastructures will continue to play an important role thanks to various drivers: a shift towards "green" gas, the growth of its use in the transportation sector, a still important contribution of gas to meet winter peak demand in addition to low-carbon electricity.
5. Hydrogen	A hydrogen economy will emerge in developed countries, providing a relevant answer to needs specific to some parts of the transportation sector, but mostly to the decarbonization of gas and electricity systems.
6. Consumers / Suppliers	**a. [Residential / SMEs]** For their electricity supply, consumers will have various alternative solutions to the "typical" energy supplier. For residential customers and SMEs, the number of self-producers will increase, to reach several millions in all the main European countries.
	b. [Large companies] For larger companies, long-term power purchase agreements signed directly with renewable energy producers will spread on a large scale in all developed countries.

2) Approach

a) Panel interview

As part of this *Sounding Board*, more than 80 French and international experts were invited to comment on 16 theses describing what could be a long-term energy future. Specifically, three responses were requested for each thesis:

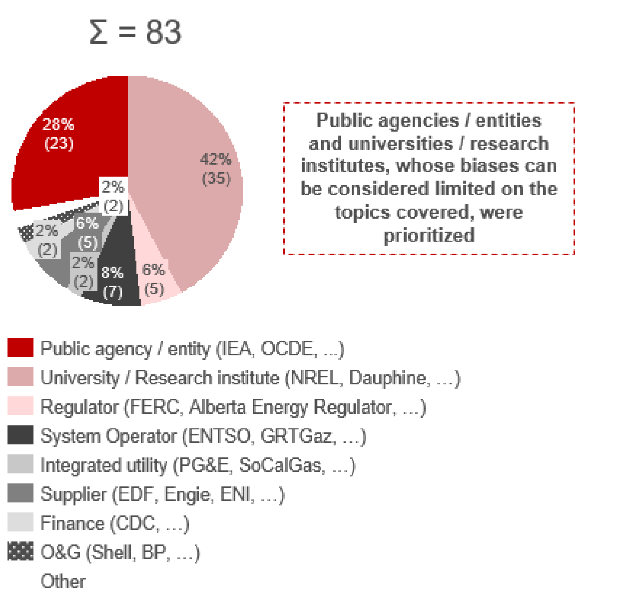
- the probability of occurrence of this thesis by 2030,
- the probability of occurrence of this thesis by 2050,
- any possible comment relating to the realization of the thesis (conditions of realization, justification of the answer given...).

Each answer given in terms of probability of occurrence concerns the realization of the whole of the thesis, as it is proposed, and not only a part.

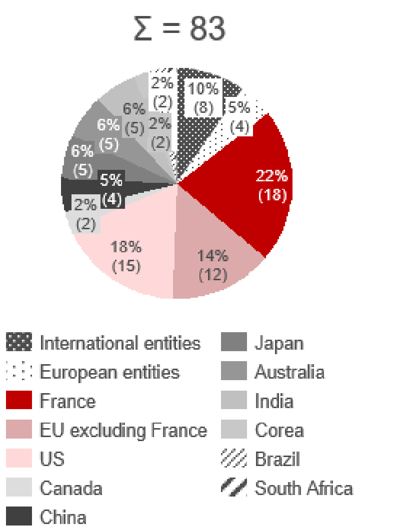
The aggregated results are then reported while maintaining the confidentiality of the individual answers of the experts: the theses are evaluated statistically, and the comments are quoted in both a verbatim and anonymous manner.

The surveyed experts were selected to represent all geographical areas. French respondents represent about 20% of the panel surveyed, as do American respondents. The rest of the panel is divided between: 25% respondents in the Asia-Pacific zone, 15% from Europeans outside France, 15% from international or European entities, and 5% from other countries.
A significant diversity of players in the sector is represented, but the academic or institutional profiles, which in principle have a more limited bias with regards to the issues addressed, have been deliberately targeted as a priority. They represent about 70% of respondents.

Breakdown of participants by category



Geographical breakdown of participants



b) Method of presentation of the results

The results of the *Sounding Board* can be summarized by grouping the respondents of all nationalities into three categories, for each thesis and each deadline:

- The “Convinced”, having opted for the “Probable” and “Certain” answers
- The “Undecided”, corresponding to the central answer “Plausible”
- The “Not convinced”, having opted for “Impossible” and “Unlikely” responses

The results are first presented this way in paragraph II, along with the key messages emerging from the detailed analysis.

Paragraph III details the analysis of the panel's responses. For each thesis, the statistical results are provided:

- for the whole panel (all nationalities combined), for the European panel only, and for the panel outside Europe,
- in the detail of the five probability options selectable by the experts (without aggregating "Certain" and "Probable" on the one hand, and "Unlikely" and "Impossible" on the other hand as in the summary).

The analyses are presented, describing the consensus or uncertainties emerging from the answers, as well as the arguments put forward in the comments to justify, specify or argue the choices of the experts. Where appropriate, additional analyses by geographical area – more precise than at the Europe/non-Europe level – are also carried out.
Finally, a verbatim selection is highlighted for each thesis. This selection is made from the most in-depth and/or representative comments of the arguments put forward by the panel, whether these arguments are in favor of the thesis or intended to express reservations or underline conditions of achievement.

II. Summary of results

1) Key messages

a) Consensus emerges from experts' answers on several issues

A large majority of the panel is convinced:

- **of the major role of transport and heat electrification in the evolution of final energy demand, both for all energy products (due to lower demand for petroleum products) and for electricity (due to the offsetting of energy efficiency efforts),**
- **of the appearance, in the long term (2050), of decarbonated electrical systems with more than 80% or renewable generation, and the competitiveness of these systems compared to fossil fuels (including in interconnected areas),**
- **of the need in this context of a market design overhaul to introduce long-term signals,**
- **of the need in the medium and long term for better coordination between TSOs and DSOs on the one hand, and between the development of generation facilities and networks on the other, in order to optimize the development of future electrical systems and to develop new sources of flexibility,**
- **of the need to develop interconnections for the integration of renewable generation.**

On the other hand, the majority of the panel interviewed seems unconvinced, even in the long term, of the development of an economy in which hydrogen plays a significant role in the future energy mix: this thesis is the only one to gather a majority of negative opinions by 2030, and a majority of respondents are undecided (which translates into a majority of "Plausible" opinions) by 2050.

b) Some other issues divide opinions

The opinions expressed are particularly divided on two important points:

- **The decline in network energy consumption (gas and especially electricity) in Europe: opinions differ in particular, in the case of electricity, on the compensation effects between energy efficiency efforts and the electrification of final energy uses.**
- **The long-term role of the gas system and its infrastructure in the energy mix: while the fact that the gas infrastructure will continue to play an important role by 2050 gathers a majority of positive opinions, uncertainties emerge, with a percentage of unconvinced or undecided respondents totaling 45%, compared to only 28% by 2030.**

2) Summary of statistical results

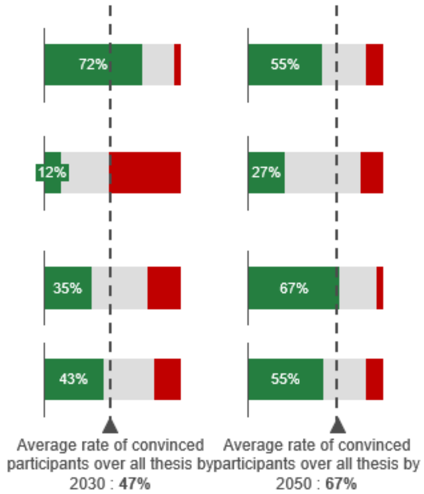
Legend : Convinced ("Likely" & "Certain") | Undecided ("Plausible") | Not convinced ("Unlikely" & "Impossible")

Thesis		Aggregated results 2030 (convinced)	Aggregated results 2050 (convinced)
1. Final energy demand	Even if final energy demand will increase globally, driven by the increase of demand in developing countries, it will strongly decrease in Europe and in France, including for natural gas. In Europe and in France, power demand will decrease or at most increase slightly despite important substitutions of end uses towards this energy.	43%	63%
2. Power system	**[a. Low carbon power systems]** Worldwide, new power generation capacities will mostly be renewable. In developed countries, very low-carbon power systems (>80% of carbon-free power production) will emerge by 2050 at the latest.	39%	76%
	[b. Renewables competitivity] These low-carbon power systems will be competitive (compared to fossil-fuel systems) in interconnected areas as in non-interconnected areas.	56%	85%
	[c. Electricity storage] Electricity storage, especially with electric vehicle batteries, will play a key role in enabling the proper functioning of low-carbon power systems with a high penetration of variable renewable energy.	43%	72%
	[d. Market Design] In this context, the price on wholesale markets will not be used as a relevant long-term investment price signal (it will remain used only for the dispatching optimization).	36%	53%
	[e. Price signals and long-term contracts] The market design has to be adapted to introduce or reintroduce price signals or long-term contracts.	64%	79%
3. Power networks	**[a. Impact for operators]** The energy transition will have a major impact on the balance of the power network, leading both to a significant need for networks and a decrease of their utilization rate (linked to self-consumption and, for the transmission network, to decentralized production).	46%	66%
	[b. Transmission/generation optimization] The shift to a high integration of renewable capacities will lead to an entire redesign of the power systems and networks, requiring a holistic approach so as to optimize system-wide investments in production capacities and transmission networks.	55%	72%
	[c. Transmission networks] From the transmission network's point of view, apparent demand will strongly decrease (due to decentralized production), but the need for interconnections will increase to make use of the reduction in intermittency associated with generating renewable energy on a wider geographical area.	57%	77%
	[d. Network balancing] Flexibility requirements will increase and will be mostly met through decentralized tools (storage, demand response, electric vehicle batteries, decentralized production) requiring the aggregation of numerous points; the distribution system operator will then become responsible for the active management of the network and the organization of local flexibility markets.	46%	70%
	[e. Transmission and distribution system operators' coordination] The coordination between TSOs and DSOs in the operation and optimization of flexibility sources (global optimization vs local optimization) will become a critical issue.	68%	84%
	[f. Micro-grids / network impact] Micro-grids, which will enable neighborhoods to locally source their power supply, will grow and be profitable in places where the economic and regulatory conditions make their development possible. Except in specific cases (isolated systems, lack of reliable networks), these micro-grids will still be connected to the main network.	48%	70%

Average rate of convinced participants over all thesis by 2030 : **47%**

Average rate of convinced participants over all thesis by 2050 : **67%**

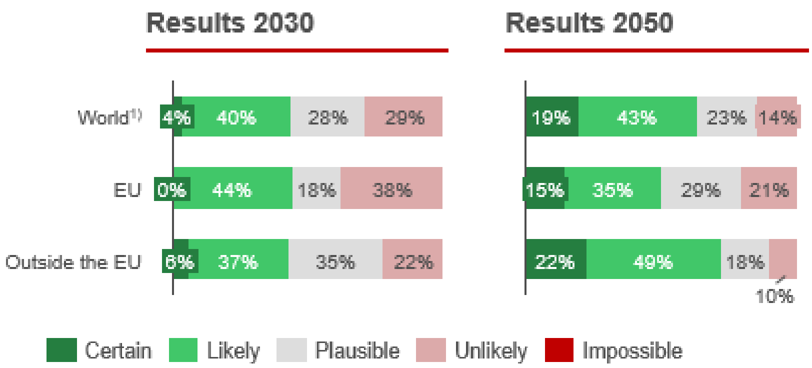
4. Gas systems	In Europe, gas infrastructures will continue to play an important role thanks to various drivers: a shift towards "green" gas, the growth of its use in the transportation sector, a still important contribution of gas to meet winter peak demand in addition to low-carbon electricity.
5. Hydrogen	A hydrogen economy will emerge in developed countries, providing a relevant answer to needs specific to some parts of the transportation sector, but mostly to the decarbonization of gas and electricity systems.
6. Consumers / Suppliers	**[a. Residential and SMEs]** For their electricity supply, consumers will have various alternative solutions to the "typical" energy supplier. For residential customers and SMEs, the number of self-producers will increase, to reach several millions in all the main European countries. **[b. Large companies]** For larger companies, long-term power purchase agreements signed directly with renewable energy producers will spread on a large scale in all developed countries.



III. Presentation of the detailed results

1) Final energy demand

Reminder of the thesis:
Even if final energy demand will increase globally, driven by the increase of demand in developing countries, it will strongly decrease in Europe and in France, including for natural gas. In Europe and in France, power demand will decrease or at most increase slightly despite important substitutions of end uses towards this energy.



1) « World » designates the entire panel of participants, all nationalities included

- **The interviewed panel gives mixed opinions on this thesis by 2030,** with less than 50% of positive opinions and nearly one third of negative opinions. **The doubts mentioned in the comments concern, first and foremost, the real impact of European energy efficiency policies**. Some argue that "normative scenarios tend to overestimate the ability of policies to induce large increases in energy efficiency", and that "most countries and the European Union have historically failed to put energy efficient policies in place". They are therefore skeptical of a sharp decline in total demand in this time frame. Others, on the other hand, rate this thesis as probable by 2030, thanks to "the combination of increased energy efficiency efforts, a stable population, and a decoupling of energy demand and economic growth".

- **By 2050, positive opinions are in the majority, reaching 60%, but still remain a minority among European respondents (while reaching 73% outside of Europe). The reservations put forward by the panel focus in particular on the decline or stagnation of electricity demand in Europe:**
    - There is a consensus on the decline in total final demand by this deadline, but the panel emphasizes that the electrification of transport and heat is key to achieving this trend in total demand (because it is essential to lower the demand for petroleum products), and that these substitutions will boost the demand for electricity.
    - In addition, the European panel has greater doubts than the rest of the world about the impact of energy efficiency efforts.
    - The combination of these effects leads part of the European panel to think that – in the case of electricity demand – "energy efficiency efforts will be offset in the longer term by a strong electrification of end uses (electric vehicles, heat pumps), due to the low carbon footprint of electricity production and the fall in the cost of renewable energy generation". The comments also suggest that while the electrification of transport is identified by the entire panel as a key trend for the evolution of total demand and demand for electricity, the electrification of heat is, on the other hand, predominantly of European concern.

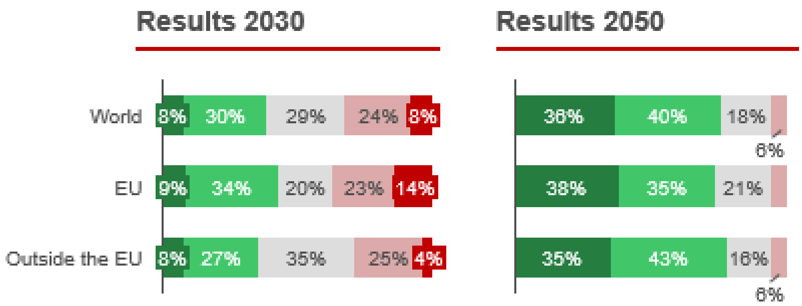
Extracts from comments:

- ***Verbatim* in favor of the thesis**:
    - *"The unsustainability of many of today's wasteful uses of energy – e.g. inefficient buildings, private autos, long-distance shipping, industrial agriculture and food waste – will become increasingly obvious and pressures to remedy them will become more compelling"*
    - *"Substitutions of end uses of energy towards electricity will not compensate the decrease in demand due to energy efficiency. This would cause electricity demand to decrease. A high proportion of electric vehicles by 2050 could cause demand to grow again between 2030 and 2050, but it would still remain below current levels."*
- **Expressed reservations:**
    - *"Normative scenarios tend to overrate the ability of policy makers to effectively induce strong increases in energy productivity. Important concerns are e.g. rebound effects and distributional issues limiting policymakers room for action."*
    - *"Total final demand will decrease. Demand of electricity will maybe not decrease because of electrification of space heating and transport".*
    - *"Concerning power demand: as the decarbonization of power is substantially easier than the decarbonization of other energy carriers, I think it likely that we see accelerating electrification, with resulting increases in electricity use."*
    - *"In the short term, demand may be driven down by the significant efforts that are being put into energy efficiency. However, energy efficiency efforts will be offset in the longer term by a strong electrification of end uses (electric vehicles, heat pumps), due to the low carbon footprint of electricity production and the fall in the cost of renewable energy generation"*

2) Power system

a) Low-carbon power systems

Reminder of the thesis:
Worldwide**,** new power generation capacities will mostly be renewable. In developed countries, very low-carbon power systems (>80% of carbon-free power production) will emerge by 2050 at the latest.



- **By 2030 opinions are still divided on this thesis**, with 40-45% positive opinions depending on geographical areas but with also more than a third of negative opinions and a percentage of "Impossible" opinions reaching 10% in Europe. 80% carbon-free electrical systems seem, indeed, difficult to achieve at this rather close deadline in the eyes of part of the panel, which explains the majority of the reservations expressed, and in particular the "Impossible" opinions. The comments highlight the cost of renewable energy, which has "dropped considerably and is now very competitive", but also its intermittency and costly integration into the network when reaching very high penetration. Moreover, "the political solutions implemented do not yet provide certainty that new fossil fuel capacities will not be built and connected to the network by 2030", in particular in developing countries that could continue to build them at massive rates to meet the increase in demand. In the short and medium term, part of the panel therefore questions the fact that the new capacities are "very highly renewable" in developing countries.
- **By 2050, however, a broad consensus emerges in favor of the thesis, with around 75% of positive opinions.** The importance of lower costs of storage solutions (particularly seasonal) is emphasized in the comments as a necessary step to reach around 80% of carbon-free generation without a high share of nuclear power, as well as the importance of CO2 prices. The potential roles of CCS and new nuclear technologies are also highlighted in a more limited number of comments.

Extracts from comments:

➢ ***Verbatim* in favor of the thesis:**

- *"As prices for renewable energy sources continue to decline worldwide, this category of generation will become the dominant form of new resources. Additionally, much progress has been made on the integration of variable renewable generation into the grid, both at the transmission and distribution grid levels. Further advances and price declines in energy storage technologies will accelerate this trend over the next 10 to 12 years."*
- *"The only significant countervailing force to this trend is the political power of the fossil fuel industry. Other factors - the economics, the technology, the increasing frequency and severity of extreme weather events and the needs of people most affected by greenhouse gas impacts - will create an accelerating trend toward renewable power generation."*
- *"The time period to 2030 is too short for a deep energy transformation that is required to shift towards deep decarbonization with more than 80% of carbon-free energy production even if penetration of renewable energy penetrates with higher rates compared to what we have*

seen so far. However, with more ambitious energy and climate policies this is likely to be achieved by 2050."

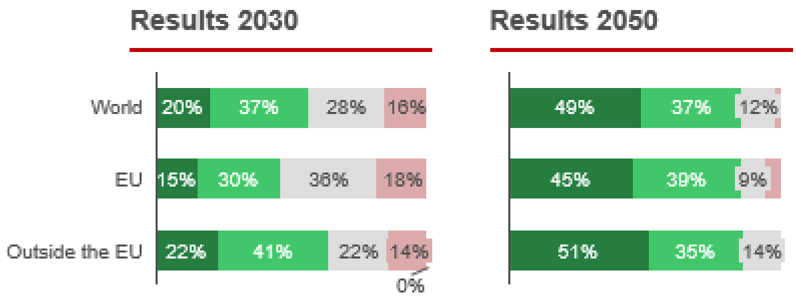
- *"Storage of power from low carbon systems is a key to achieving a percentage over 80."*

➢ **Expressed reservations:**

- *"These scenarios are technically very plausible, but the political realization is currently not yet there to give us certainty that fossil will not be built and locked in. Especially in the 2030 timeframe."*

b) Competitiveness of renewables

Reminder of the thesis:
These low-carbon power systems will be competitive (compared to fossil-fuel systems) in interconnected areas as in non-interconnected areas.



- **This thesis generates, as early as 2030, a majority of positive opinions** with some comments stressing that "grid parity has already been reached in certain zones". However, **uncertainties persist, especially among European respondents who register only ~45% positive opinions against more than 60% outside of Europe.** This gap between Europeans and non-Europeans can be attributed to the fact that European interconnected systems are very efficient, making it more difficult to envisage very highly competitive renewable-energy systems within such a short time frame. European respondents point out that even if the renewable LCOE is or will become competitive in the short-term compared to fossil fuels, "the complete service delivered" by renewable generation is very different, and that by 2030 the competitiveness of a very largely renewable electrical system is not obvious. This is especially true in the absence of high carbon taxation and in countries with abundant natural gas resources.
- **On the other hand, the consensus in favor of the thesis is very clear by 2050, in a homogenous way in Europe and in the rest of the world**, with high certainty rates (>40%). Conditions are mentioned, such as a "(high) market value of the CO2 externality", the further decline in the costs of renewable energy and the fall in storage costs. It is also stressed that achieving a 100% renewable system is more difficult than an 80% renewable system, and some comments consider that in an 80% renewable system – even by 2050 – a minority of fossil fuel generation capacity will remain as a back-up, to be only rarely used, and possibly to provide ancillary services.

Extracts from comments:

➢ ***Verbatim* in favor of the thesis:**

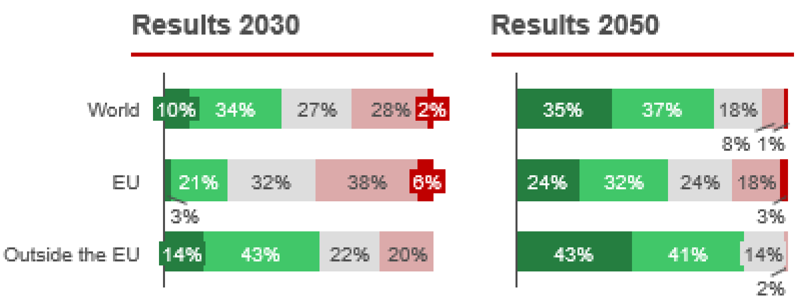
- *"They will be all the more competitive if political decision on a carbon tax come in support of this transition"*
- *"They would be cost competitive now, except for the fact that we've not been able to quantify in a compelling way some of the main benefits of low-carbon and the costs of high-carbon energy systems. For example, resilience is mentioned often in the power sector but thus far we don't have a good definition or a way to quantify its value. If low-carbon doesn't "pencil out" it's mainly because we don't have the right pencil."*
- *"They are already competitive, and as the penetration of renewables exceeds 50% in the next decade or so, even the need for additional energy storage and network strengthening will still see renewables as being more competitive."*

➢ **Expressed reservations:**

- *"The answer for 2030 will depend on the cost of battery storage and systems for maintaining reliability on a grid with high penetrations of non-dispatchable renewables. Clearly a solvable problem, hence its plausibility."*
- *"The answer depends on the structure of the system, but renewable energies do not provide a constant supply of energy, and can vary with conditions. Solar for example will not provide much energy during night-time. The improvement of battery technologies will be much more important for non-interconnected areas where the geographic sparseness makes for example recharging of electric car batteries more difficult owing simply to few recharging stations being available. However, these problems are known and many efforts are underway to manage the load in such situations. I anticipate by 2050 the core issues will have been resolved."*

c) Electricity storage

<u>Reminder of the thesis</u>:
Electricity storage, especially with electric vehicle batteries, will play a key role in enabling the proper functioning of low-carbon power systems with a high penetration of variable renewable energy.



- **Reservations are expressed by 2030, and are quite pronounced among European respondents; however, outside of Europe positive opinions are shown to reach more than 50%.** Technological progress and lower storage costs are noted, but some European respondents point out that intermittent renewable generation is unlikely to reach sufficient penetration rates by 2030 for large-scale storage to be required and play an essential role in the operation of the electrical system by that time.
- **By 2050 a consensus emerges which is particularly marked outside of Europe where more than 80% of respondents describe the realization of this thesis as probable or certain in the long-term**. The panel agrees that storage will play an "essential" role in a highly carbon-free and renewable system.

- **The battery stands out as the storage technology that will play the most prominent role,** although several respondents point out that other technologies will be needed to complement it. At both horizons, doubts are raised concerning the fact that batteries of EVs are necessarily the main source of storage, especially compared to stationary storage (large-scale on the grid or in homes). The comments highlight the "difficulty in synchronizing the demand for transport with that for network balancing". Some think that the EV fleet will only be used to make demand flexible, but that V2G will not massively develop and other storage solutions will be more competitive.

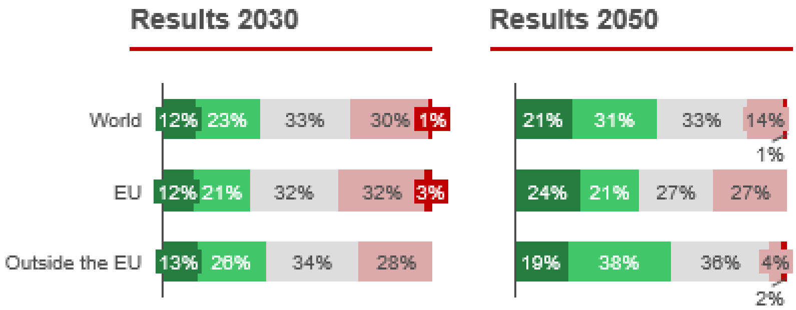
Extracts from comments:

- ***Verbatim* in favor of the thesis:**
  - *"Energy storage technology is already playing an important role in integrating high penetrations of renewable energy in areas like California and Hawaii, and this trend will continue."*
  - *"By around 2030, solid-state batteries will be available at reasonable costs, which will revolutionize EV batteries. Other types of advanced batteries will also become the norm by 2050."*
- **Expressed reservations:**
  - *"While the growth in EVs is driving significant reduction in battery prices, their use for grid support may be more limited. Stand-alone batteries, deployed behind the meter to provide customer benefits, are more likely to provide reliable grid services, including renewable integration."*
  - *"Demand response made possible by smart EV charging: in this case, I would say that yes, a mass development is very likely. However, I do not believe in a mass development of V2G. Finally, stationary storage should become competitive compared to other fossil-fuel sources of flexibility as of 2030"*
  - *"I would not limit this to electricity storage only. The use of thermal storage for buildings, for example, will greatly improve space conditioning of the buildings themselves while smoothing the impacts of variable renewables on the distribution and transmission systems."*
  - *"It does not seem that vehicle-to-grid could scale up to a system with >80% or 90% renewables, but it could contribute by "consuming at night". However, I do not see how we could do without a mass development of P2G (either for H2 or syngas)."*

d) Market design

Reminder of the thesis:

In this context, the price on wholesale markets will not be used as a relevant long-term investment price signal (it will remain used only for the dispatching optimization).



- **This panel expressed divided opinions by 2030 regarding this thesis,** in and outside of Europe, with less than 40% positive opinions. By that time, some respondents **point out the absence of a viable alternative** and think that the wholesale market price "will continue to guide the constitution of portfolios" and influence investments in generation capacity other than wind and solar.
- **Positive opinions are higher by 2050 but only reach a slight majority, reflecting a certain reluctance towards a thesis questioning the future of the wholesale market price as a reference signal for investment.** Many comments agree that its relevance in its current form will be challenged: since renewables are characterized by "a high capital intensity and a low operating cost, wholesale prices will no longer be relevant as an investment price signal"; however, opinions are divided on that topic, and even more so on possible alternatives. Capacity mechanisms and the value of flexibility are cited as investment signals for technologies with capacity value. The possible adoption by public authorities of other investment-support mechanisms, to ensure the proper functioning of the market and security of supply, could also contribute to the weakening of the role of wholesale market prices.

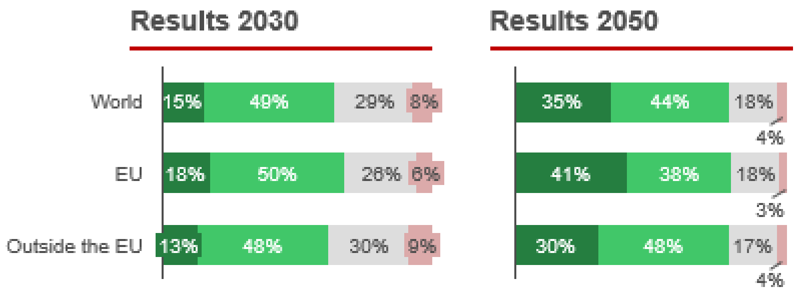
<u>**Extracts from comments**</u>**:**

- ***Verbatim* in favor of the thesis:**
- *"Taxation will be redesigned to make it possible to finance fixed costs in a system where variable costs of electricity generation will be very low. The marginal cost will be sufficient for dispatching but not to recover investments; we already have a capacity market, and the system will need to be improved"*
- *"The shift from energy as commodity to markets for energy services aligns with the shift to zero-marginal-cost power generation. End-users will increasingly customize their energy sources and uses with on-site equipment, making the grid the residual supply rather than the primary supply. Spot energy market revenues will continue to shrink. For the TSO, real-time balancing will be about procuring responsive services (e.g., frequency response and synthetic inertia) rather than spot energy transactions."*
- *"I expect that policymakers are too afraid of malfunctioning markets and wrong investor expectations to continue relying on an energy-only market for determining investments. The public reaction to a major blackout would be so negative that I think it likely policymakers will implement additional measures to ensure that the stability of power system is ensured, thus adding additional incentives to provoke investments and making the wholesale price less important for investment decisions"*
- **Expressed reservations:**
- *"It would be necessary that other signals than wholesale prices be used to justify investments. But it will be difficult to significantly change the market design by 2030. Carbon taxation could be a crucial parameter"*

> ➢ *"I believe the markets will not dismiss the role of the wholesale market price in their investment decisions, and that it will accordingly play a role in price formation. However, that role does have the potential to be quite different from the role it plays today. It is possible that it could become irrelevant in the future, but more likely that it becomes less relevant and complemented with other sources of price information that take more priority."*

e) Price signals and long-term contracts

Reminder of the thesis:
The market design has to be adapted to introduce or reintroduce price signals or long-term contracts.



- **Positive opinions are mostly expressed regarding this thesis, starting by 2030 and increasing by 2050.** In the long term, the consensus is highly marked, with nearly 80% of positive opinions reported. The comments agree on the **need for a redesign** to "quickly provide visibility to investors" without excessive government intervention or centralized planning.
- **A consensus, however, does not emerge from the comments on the solutions to implement.** Various elements of solutions are mentioned, which include:
  - capacity markets,
  - the generalization of long-term contracts for difference,
  - long-term PPAs (Power Purchase Agreements),
  - nodal prices or other forms of local price signals,
  - development of long-term market products liquidity.

<u>Extracts from comments</u>:

➢ ***Verbatim* in favor of the thesis:**

- *"Difficult to see how the power system can create appropriate incentives for investment and operation of flexibility options without stronger locational signals. Nodal pricing seems to be important element of this."*
- *"Schemes such as "contracts for differences", notably, could generalize".*

➢ **Expressed reservations:**

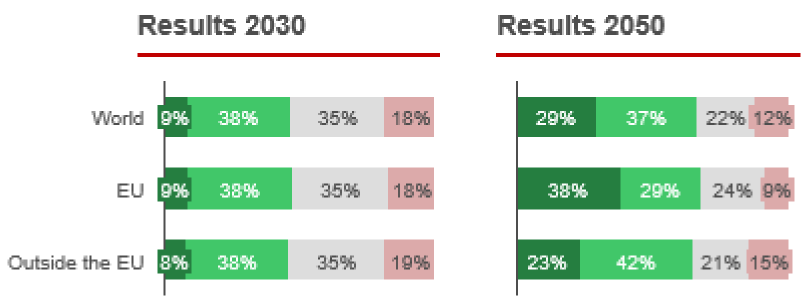
- *If such long-term contracts are implemented, a cost-benefit analysis for society and the whole electrical system which will host this new subsidized generation capacity will have to be carried out, taking into account the duration of this investment (i.e. its profitability for society) over its whole lifetime, as well as the future drops and changes in costs of other competing sources of generation. The capacity market already offers a first level of price signal over a longer term than the spot market. Tenders are also already a form of long-term contracts.*
- *"It is not clear that an alternative structure of power supply alters the importance of transparent pricing mechanisms, or the value of ensuring long-term supply contracts. It is*

possible that a poorly designed very-low carbon power generation system may have more difficulty in meeting peak load demand, and that this could encourage consumers to want to negotiate priority access, but such contracts already exist. Similar comments hold in relation to the length of contracts. Large-scale power users already have scope in cases to negotiate the length of terms of contracts. So it is not obvious what would 'need' to change. However, that aside, there is always value in regular appraisal of market mechanisms, to help avoid misuse of contracts."

3) Power networks

a) Impact for operators

<u>Reminder of the thesis</u>:
The energy transition will have a major impact on the balance of the power network, leading both to a significant need for networks and a decrease of their utilization rate (linked to self-consumption and, for the transmission network, to decentralized production).



- **This thesis generates uncertainties by 2030 within the panel, with less than 50% positive opinions and more than a third of respondents who are undecided.** The analysis of the comments reveals that the strongest trends anticipated for the transmission and distribution networks are influenced by local contexts of the respondents. A significant proportion of respondents, in particular in European countries whose energy transition is most advanced, agree on a growing need for transmission infrastructure, but are struggling to consider reducing the rate of use of these in the short-term: "With the accelerated development of wind and solar, […] the expansion of transmission networks is becoming increasingly important", and "VHV transmission networks will be increasingly used and increasingly valuable". American respondents, in particular from California, insist instead on "lower utilization rates in relation to self-consumption and self-generation, decentralization and micro-grids".
- **2050 sees a majority of positive opinions (~65%), with a slightly larger majority in Europe, where the volume effect of self-consumption on network utilization rates is considered to be higher by that time.** Some comments note that the role of storage could limit the need for network infrastructure: "distributed storage will allow, on the contrary, and particularly in countries that are modernizing, for the rejection of the current model of a strong and very dense network".

<u>Extracts from comments</u>:
- ➢ ***Verbatim* in favor of the thesis:**
  - *"With increasing deployment of wind and solar, large-area pooling and therefore transmission grid expansion becomes more important."*

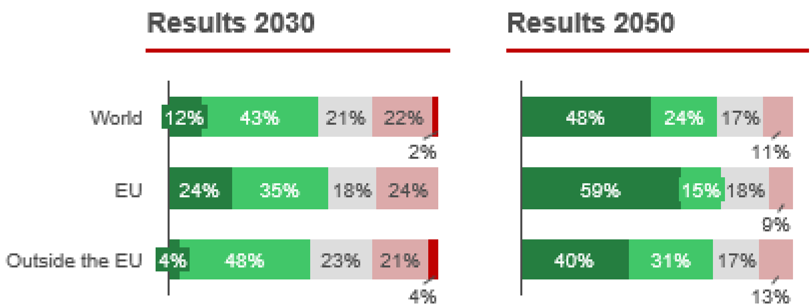
- *“The majority of renewable generation that is competitive in the market is still far away from the main areas of consumption, which requires extending networks. Although self-consumption will develop, it will in most cases not lead to full energy autonomy in interconnected areas.”*
- *“The distribution network will be most heavily impacted and will need to become “very smart”. A mass development of PV in urban areas will certainly lead to lower utilization rates than today. The development of local electricity transactions will create a new type of use. The configuration of the transmission network may change, but it will remain necessary for the transit of very local generation (wind, marine power etc), and for interconnections with neighboring countries. Whether or not networks will be significantly needed will depend on countries.”*

➢ **Expressed reservations:**

- *“I agree, there will be a significant impact on the grid as a result of more renewable resources, particularly due to distributed (decentralized) energy resources. In the short-term, there may be a need for new transmission to access areas with an abundance of renewable wind, solar, or geothermal resources. However, as distributed resources become more prevalent, there will be less need for transmission infrastructure. On the distribution network, energy storage will enable better management of the grid, allowing for more efficient utilization of the grid and reducing the need for capital upgrades. The grid will see more bi-directional flow with greater penetrations of distributed solar, and innovations such as transactive energy.”*

b) Transmission/generation optimization

Reminder of the thesis:
The shift to a high integration of renewable capacities will lead to an entire redesign of the power systems and networks, requiring a holistic approach so as to optimize system-wide investments in production capacities and transmission networks.



- **This thesis generates ~55% positive opinion by 2030 globally,** with the majority of the panel saying that “the operation of networks will probably require an optimization taking into account the whole system rather than a *Top-Down* approach based on generation capacity, as is currently the case”. Some reservations, however, are still formulated. Indeed, the thesis considers “a complete overhaul of electrical systems and networks”, and such a change seems exaggerated in the relatively short term (~10 ans) for many respondents. All are waiting for the issue of investment optimization between the transmission networks and generation to be addressed, but the networks will be redesigned on “a time scale probably longer than the politicians would like, because it would create major costs during a period of weak economic growth".

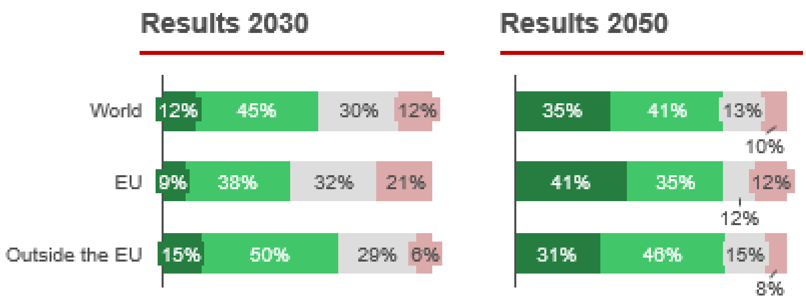
- **By 2050, a real consensus emerges, with a particularly high degree of certainty among the European panel (~60%).** The high percentage of certainty among the European panel can be attributed to the fact that some of the first countries to achieve high penetration rates of intermittent renewable generation, and to cope with significant costs related to network congestion and the development of new network capacity between renewable generation areas and consumption areas, are located in Europe. Some respondents go as far as stating that we must "really achieve an overall optimization which takes into account all the components of the system (dispatchable or non-dispatchable generation, all forms of storage, development of networks and interconnections, demand management) and at different levels (local, regional, national, and international)". Others are more measured and believe optimization will need to be realized on several levels, at transmission level but also at local distribution system level, with a coordination between transmission and distribution.

<u>Extracts from comments</u>:

- ***Verbatim* in favor of the thesis:**
  - *"While the grid will still balance centralized renewables with distributed energy resources in 2050, the operation of the grid is more likely to require optimizing from either end rather than top-down from the generation assets as is done today."*
- **Expressed reservations:**
  - *"My hesitation here is the observed tendency to under-estimate the potential of local, community-based power systems on the part of parties who like to build big infrastructure. An "entire redesign" should take a grid architecture approach, integrating system architecture with network control theory, with specific emphasis on coordination of T-D (or TSO-DSO) interface operations. Such an approach would reveal the immense value of a "layered" architecture whereby optimization of energy production, storage and use can occur at multiple levels from the individual end-use meter up through micro-grids of various scales."*

c) Transmission networks

<u>Reminder of the thesis</u>:
From the transmission network's point of view, apparent demand will strongly decrease (due to decentralized production), but the need for interconnections will increase to make use of the reduction in intermittency associated with generating renewable energy on a wider geographical area.



- **By 2030, opinions are already mostly positive globally, but do not yet reach 50% at the European level.** Comments indicate that, by that time, there is a **consensus on increasing interconnection requirements,** with respondents stating that "the development of interconnections over wider geographical areas to manage the variability of renewable generation will be particularly important in the next 10 to 20 years". Some reservations – which account for the minority of positive opinions in Europe – are formulated, however, by that time regarding the sharp decline in resulting demand for transmission networks, especially among respondents in countries already experiencing a high rate of penetration of renewables like Germany or Denmark, who believe that it is "difficult to anticipate a sharp reduction in the use of transmission networks".

- **By 2050, a consensus emerges with more than 75% of positive opinions from the entire panel,** with comments stressing that "agreements at the European level will be unavoidable". Some comments, however, mention the development of storage and the emergence of micro-grids, which could question the needs for interconnection.

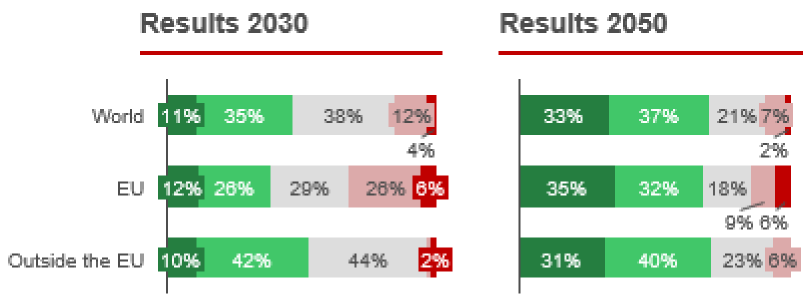
Extracts from comments:

- ***Verbatim* in favor of the thesis:**
  - *"Agreements at the European level will be unavoidable."*
  - *"The need for interconnection will increase. But the wider deployment of cost-effective stationary batteries will help optimize the regional operation."*
- **Expressed reservations:**
  - *"With electrification of multiple elements of demand and the broader spatial variation of production patterns it is difficult to anticipate large reduction of transmission use."*
  - *"Wider geographic interconnection to manage variability of renewable production will probably be most important in the next 1-2 decades, but could decline substantially after that with the rise of micro-grids, storage of various types and scales, and the increased capabilities of inverter-based facilities to provide instantaneous grid services."*
  - *"This will depend on Europe's use of combined cycle natural gas generators. If these plants are near retiring coal plants, the need for additional interconnections could decrease. If Europe pursues an "80% carbon-free" policy (no new natural gas), then there will likely be a need for more interconnections."*

d) Network balancing

Reminder of the thesis:

Flexibility requirements will increase and will be mostly met through decentralized tools (storage, demand response, electric vehicle batteries, decentralized production) requiring the aggregation of numerous points; the distribution system operator will then become responsible for the active management of the network and the organization of local flexibility markets.



- **Opinions are divided on the probability of this thesis becoming reality by 2030.** These doubts are essentially related to the scale of the change envisaged in the thesis: by that time, the analysis of the comments shows that it is easier to consider a mix of centralized and decentralized flexibility sources, and it is **unlikely that decentralized sources will be able to account for a majority of the increased flexibility requirements.**

- **By 2050, a majority of positive opinions are expressed regarding the thesis.** The fact that local flexibility sources will be able to meet a majority of the increased need for flexibility reaches a fairly clear consensus, but **many comments express reservations about the role of distribution system operators in this area**: "just because renewable energy generation and flexibility will be more and more local does not mean that the DSO must be in charge of organizing these markets (even though possible local constraints are to be taken into account", and these local markets could become "competitive" ground.

Extracts from comments:

➢ ***Verbatim* in favor of the thesis**:

- *"I see this as a feasible and highly desirable scenario, to have high-functioning DSOs as part of a layered grid architecture."*
- *"This is beginning to happen in California, where there are high penetrations of renewable and distributed energy resources."*

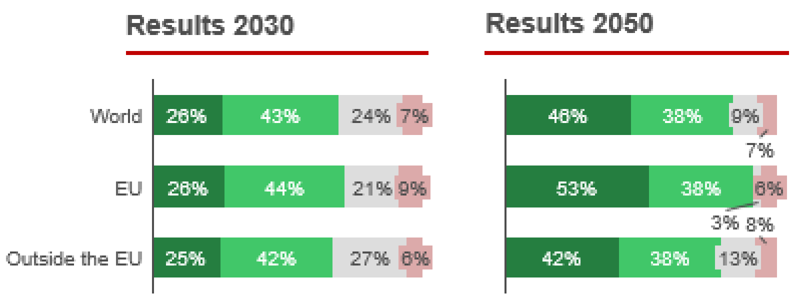
➢ **Expressed reservations:**

- *"Ok with active network operation. The organization of local flexibility markets could escape them if they do not take a serious look at "energy digitization" issues, which open the market for other types of players, such as the GAFA"*
- *"The realization will depend, however, on the willingness of the DSOs to grow into much bigger roles than they have today, and the willingness of the TSOs and regulators to let go of the desire for a fully-centralized energy market and system balancing function. It would mean, for example, that the TSO does not need to have visibility and control of assets on the distribution system, but instead deals only with the DSO at each T-D interface point. This would enhance qualities like resilience and cyber-security, but may be a major departure from current thinking by the TSOs."*
- *"I'm not certain that this will result in the distribution network operator becoming responsible for actively managing the grid, or coordinating and facilitating aggregators participation in flexible capacity markets at the wholesale level."*
- *"There will be a need for aggregation. It is not obvious that this should be part of the work of DSOs for economic aspects"*
- *"I believe this will be a competitive space, and there may be more players than just the distribution system operators."*

e) TSO/DSO coordination

Reminder of the thesis:

The coordination between TSOs and DSOs in the operation and optimization of flexibility sources (global optimization vs local optimization) will become a critical issue.



- **This thesis garnered a consensus by 2030, and the consensus is very clear by 2050 with more than 80% positive opinions, with 90% positive opinions within the European context.** The panel emphasizes that coordination between TSOs and DSOs is "absolutely necessary in order to maintain effective management for the consumer".
- The comments evoke, for some, a move towards "network integration" or the emergence of integrated players, equivalent to an American ISO, that would be "balancing managers of national and local networks" both at transmission and distribution levels.
- A few comments, in limited numbers, discuss the potential role of automation and Artificial Intelligence techniques in managing long-term sources of flexibility (2050 and beyond).

Extracts from comments:

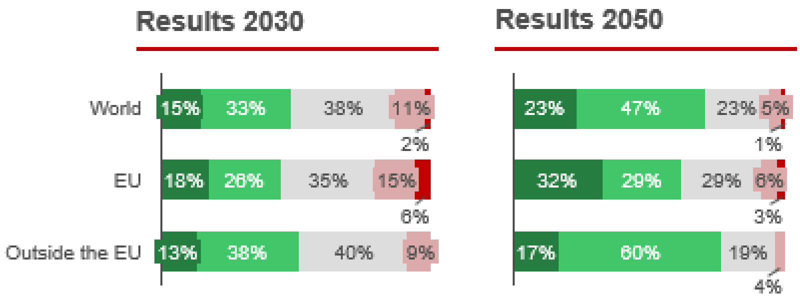
➢ ***Verbatim* in favor of the thesis:**
- "This coordination is absolutely necessary in order to maintain effective management for the consumer"
- *"This is an urgent topic for everyone who thinks about the future power grid with high degrees of decentralization and renewable generation. The layered grid architecture is probably a less familiar concept than global optimization, which most in the industry see as the natural evolution of today's wholesale markets. But as numbers and varieties of DER increase, the benefits of the layered architecture and the vulnerabilities of the centralized will become more apparent and quantifiable."*
- *"The issues of cooperation are likely to create room for strategic interaction and transaction costs that could generate inefficiencies. There will be more actors involved within the overall system, and this alone will require increased coordination effort."*

➢ **Expressed reservations:**
- *"Automation will make the distinction between these two entities unclear"*

f) Micro-grids/Impact on networks

Reminder of the thesis:

Micro-grids, which will enable neighborhoods to locally source their power supply, will grow and be profitable in places where the economic and regulatory conditions make their development possible. Except in specific cases (isolated systems, lack of reliable networks), these micro-grids will still be connected to the main network.



- **The panel reports uncertainties concerning the development of micro-grids by 2030, with positive opinions ranging from ~45% in Europe to ~50% in the rest of the world, and ~55% in the Asia-Pacific Region.** Comments converge on the fact that developing countries, or those where the quality of networks is lower, will be the preferred targets for micro-grids by 2030.
- **By 2050, opinions are mostly in favor of this thesis, regardless of the geographical area considered.** The consensus is marked outside Europe, and particularly **in the Asia-Pacific zone where ~80% of respondents believe that this thesis is probable or even certain by 2050.** The statement "where the economic and regulatory conditions permit" in the thesis is identified as essential and represents a "key uncertainty" in the development of micro-grids, especially in large, interconnected systems. In these systems, the panel believes that "the necessary solidarity between territories and regions and the guarantee of continuity of supply will be strong incentives to stay connected to the network", and that "as long as grid connection costs are reasonable, [micro-grids] will probably not exist in complete isolation in developed countries like France". It is emphasized that it is "the responsibility of regulators and DSOs to ensure that micro-grids have an interest in staying connected", and that "network access pricing will need to be reviewed".

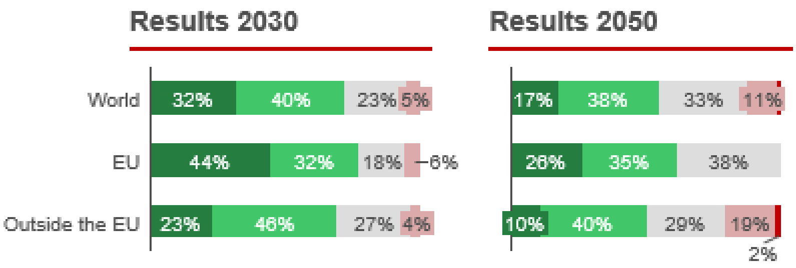
<u>Extracts from comments</u>:

- ***Verbatim* in favor of the thesis:**
  - *"If the economic / pricing signals are correct then a sensible design allowing for this is likely to be in everyone's interest."*
  - *"The necessary solidarity between territories and regions and the guarantee of continuity of supply will be strong incentives to stay connected to the network".*
  - *"The optionality around maintaining the connection to the network is clear for the owner. So long as connection costs are reasonable, they will likely not exist in isolation in developed countries like France."*
  - *""where the economic and regulatory conditions enable it" is the key"*
- **Expressed reservations:**
  - *"A couple of qualifications. First is that regulators and policy makers need to pay serious attention to the resilience value of MGs able to function in island mode, given the likely increase in the frequency and severity of extreme weather events, as well as their resistance to propagation of network disruptions. It should not be just the economically well-off areas that have MGs, but it should be a matter of public policy to expand this capability to all communities. Second, ideally MGs will operate in connected mode most of the time, and use island mode only when conditions require it. But each MG operator (even down to the level of the individual end user or "smart building") will make that decision based on the value and cost of staying connected. This is where it's up to the regulators and the DSOs to make the case for the value of staying connected, which will need to involve opportunities for MGs to earn energy revenues from providing grid services."*

- *"It's hard to imagine that the cost and reliability advantages of central power will be eclipsed by micro-grids in places that are already well-served by traditional grids. I see a bigger role for micro-grids in underdeveloped countries and other places with remote, isolated load centers that are not economic to extend conventional transmission service to."*

4) Gas systems

Reminder of the thesis:
In Europe, gas infrastructures will continue to play an important role thanks to various drivers: a shift towards "green" gas, the growth of its use in the transportation sector, a still important contribution of gas to meet winter peak demand in addition to low-carbon electricity.



- **The panel expresses a fairly strong consensus by 2030, contending that the role of the gas system, by this date, will serve as an** "important provider of flexibility", "crucial for the transition to a low-carbon system".
- **Uncertainties emerge, however, by 2050.** While opinions are still mostly positive, this majority is smaller, barely more than 50% worldwide, denoting shared opinions especially on the potential of making gas more "green" which is deemed a "real industrial challenge". One of the key arguments put forward by the European experts responding positively to this thesis is the possibility of achieving "100% of green gas" by 2050, which will allow gas to continue to play an important role in the CO2 emissions reduction targets. The role of gas infrastructure as a "means of storing surplus renewable generation via *Power to Gas"* is also emphasized. But other European and American respondents are considering a decline in gas, in a context where the volumes of biogas will be "insufficient for current infrastructures", and where this energy will become incompatible with complying with the objectives of CO2 emissions reduction.

Extracts from comments:

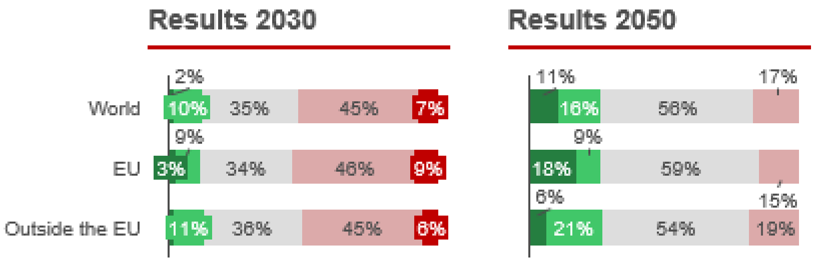
➢ ***Verbatim* in favor of the thesis:**
- *"In the near-term, gas will continue to play a vital role for the reasons stated."*
- *"Furthermore, gas infrastructure will offer a means of storing surplus renewable generation via Power to Gas technologies"*
- *"These infrastructures will be key for seasonal storage"*
- *"Provided that gas becomes more and more green, it will keep playing an important role"*

➢ **Expressed reservations:**
- *"However, geopolitical instability, energy security concerns and declining prices for renewable energy and energy storage will make fuel substitution more feasible. Ongoing, and by 2050, potentially accelerating concerns about the impacts of climate change will drive the transition away from gas, which produces significant GHG emissions in the production and shipment process."*

- *"To reach GHG emissions reduction targets, natural gas can no longer be used. Regarding biogas production, it will be insufficient for current infrastructures"*

5) Hydrogen

Reminder of the thesis:
A hydrogen economy will emerge in developed countries, providing a relevant answer to needs specific to some parts of the transportation sector, but mostly to the decarbonization of gas and electricity systems.



- **A majority of negative opinions are expressed regarding this thesis by 2030,** with more than 50% of "Not plausible" and "Impossible" responses at the global level by this deadline. **Respondents who believe that the realization of this thesis is impossible are in relatively high numbers**, especially with regard to other theses for which this option is rarely used. The costs of hydrogen solutions are referred to as "prohibitive", limiting its development in the short and medium-term.
- **By 2050, uncertainty prevails over negative opinions but positive opinions remain by far in the minority:** in all geographical areas, more than 50% of respondents consider the thesis "Plausible", and positive opinions increase but do not exceed 30% of the panel. Although respondents point to the potentially important role of hydrogen in a transition to a carbon-free energy system, the question of the competitiveness of technologies (production and infrastructure costs) persists in the long term, even though hydrogen could prove "complementary" to existing gas infrastructure, facilitating its adoption. Investment decisions in the coming decade will be significant for the long-term development of hydrogen technologies.
- It can be noted that Europe shows slightly more positive opinions than elsewhere, and more importantly that among the ~30% of positive opinions, nearly two thirds of respondents are certain of the realization of this thesis. **This is, therefore, a divisive subject on a European scale, the "certain" opinions being twice as numerous as the "probable" opinions, while the "plausible" opinions are clearly in the minority.**
- Comments can also be analyzed to identify differences between sectors. If an economy of electrolytic hydrogen for industry consumers is deemed "probable" in some comments, the emergence of the hydrogen fuel cell for mobility "inextricably depends on competition with batteries", and the result of this competition is uncertain. Finally, the methanation of hydrogen is considered as an "industrial wager" that can be envisaged by 2050 and beyond.

Extracts from comments:

➢ ***Verbatim* in favor of the thesis:**

- *"Even with drastic energy efficiency programs, renewable energy generation does not provide a complete solution to substitute all energy consumption. We have to bet on hydrogen, which* *could reach 20% of the energy mix by 2050 (part of which will have to come from imports, either of H2 from fossil fuel CCS, or of electrolytic H2 from countries with very low-cost renewable generation)"*

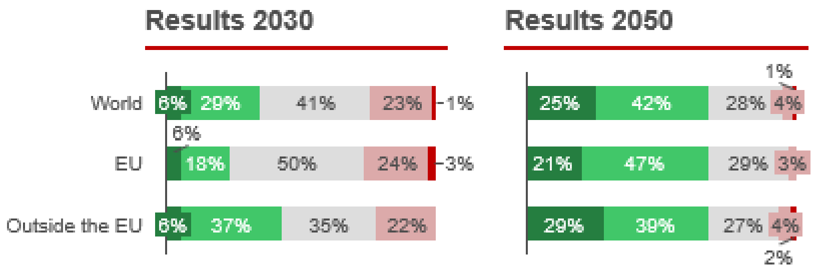
➢ **Expressed reservations:**

- *"The issue can only be answered by sector: an economy of electrolytic hydrogen for industry consumers is highly likely and could probably come fast (before 2030). An economy of electrolytic hydrogen for mobility inextricably depends on competition with batteries. The result is uncertain. Today batteries are ahead. An economy of hygroden for methanation (producing methane from hydrogen and CO2) is an industrial wager, which is only accessible in the long term (2050)."*
- *"It will take time for hydrogen to emerge as a significant resource for transportation and decarbonization of the grid. While promising, it continues to be "10-years down the road," as was promised in the mid-1990s. Unless significant technology improvements, resulting from significant government and private sector funding, the price will continue to be too high for the near to mid-term future."*
- *"The eventual significance of hydrogen energy by 2050 will depend to a great extent on public policy and investment decisions in the next 10-15 years."*
- *"Hydrogen could emerge, but likely will be limited in scope and scale. The energy economics of making it are simply too costly, with other cheaper alternatives available for all but the most critical applications depending on social preference (e.g., jet fuel substitute?). Too much alternative infrastructure needs to be built out to make it available as a common substitute."*

6) Consumers/Suppliers

a) Self-consumption

<u>Reminder of the thesis</u>:
For their electricity supply, consumers will have various alternative solutions to the "typical" energy supplier. For residential customers and SMEs, the number of self-producers will increase, to reach several millions in all the main European countries.
The consumer will be able to supply its power via « peer-to-peer » platforms (using for example blockchain technologies), enabling to select identified and localized assets for its energy supply and/or sell its own production surplus.



- **The panel is very divided on this thesis by 2030.** Doubts pertain to the fact that volumes such as those mentioned in the thesis (several million in each major European country) are achievable by this deadline. It can be noted, however, that – despite these volumes – few respondents think the thesis "impossible" by this deadline.

- **By 2050 the panel is much more confident in the probability of accomplishing this thesis, with nearly ~70% of positive opinions.** The development of self-consumption by this date is broadly agreed upon, however the comments emphasize that the scale of this development “inextricably depends on social appetite and costs”: the competitiveness of PV solar + storage solutions for the mass market will be a key factor, and the achievement of large volumes will require “processes relatively simple to grasp and great communication efforts” in the case of France.
- Moreover, **the generalization of P2P platforms, which would allow the consumer to choose energy from identified and localized production assets or sell his own surplus production, generates considerable uncertainties for the panel even in the long term.** Some comments raise the question of the associated model, for instance other players (such as GAFA or players already in the energy sector) acting as aggregators or intermediaries at a local scale, and stress that “P2P transactions will be complex and expensive”, offering negligible additional value compared to intermediated transactions.

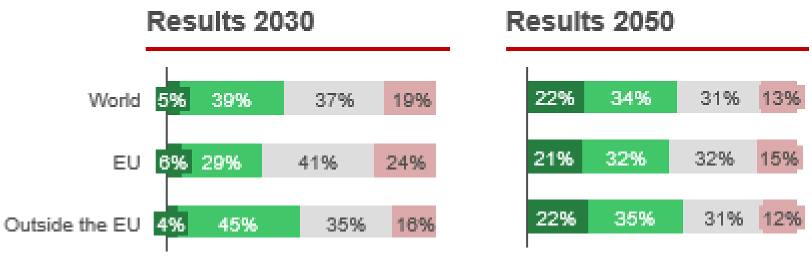
<u>Extracts from comments</u>:

- ***Verbatim* in favor of the thesis:**
  - *“It is highly likely that, by 2030, "for residential customers and SMEs, the number of self-producers will increase, to reach several millions in all the main European countries."”*
  - *“It is technologically feasible. It inextricably depends on social appetite and costs.”*
- **Expressed reservations:**
  - *“Regarding the statement "the consumer will be able to supply its power via “peer-to-peer” platforms (using for example blockchain technologies), enabling to select identified and localized assets for its energy supply and/or sell its own production surplus": this is unlikely by 2030; by 2050, this is plausible.”*
  - *“My personal opinion is that most consumers will want to deal with a “service provider that takes care of everything”. These “service providers” will implement the techniques to optimize the cost and availability of energy, while everything will remain very transparent for the end consumer. Only large industrial consumers will see a point in managing their supply themselves, without resorting to this type of “service provider””.*
  - *“I mostly agree with these statements, but have reservations about "peer-to-peer" and blockchain. I've had many conversations with proponents of both and have yet to hear a compelling value proposition for either. Having delved into the complexities of DSO-TSO operations with high DER, I think peer-to-peer energy transactions will be complex and costly to implement while offering negligible value over simpler transactions between end-users/self-producers and the community-based energy agency. Blockchain technology seems to be quite an energy hog, the subject of much techno-hype, and it's not clear how blockchain helps to ensure grid feasibility of delivering bilateral transactions. What makes more sense to me is local markets for energy and grid services operated by the DSO, and I don't see what blockchain has to offer in this arena.”*
  - *“These models will exist – but through the intermediation of powerful platforms, such as Google or Amazon”*

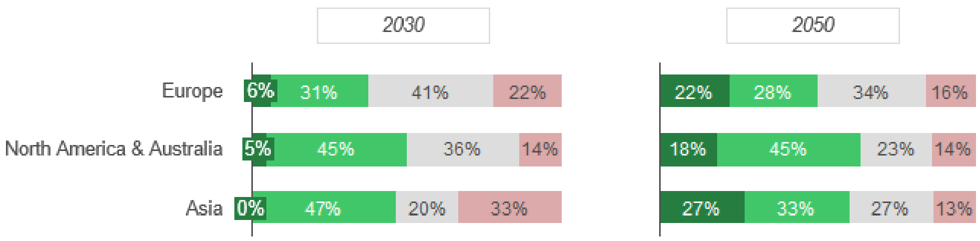
b) Corporate PPAs

Reminder of the thesis:

For larger companies, long-term power purchase agreements signed directly with renewable energy producers will spread on a large scale in all developed countries.



- **Uncertainties are expressed regarding the realization of this thesis by 2030, as well as by 2050, at which time the positive opinions are more numerous but barely exceed 50% worldwide.** This covers a certain geographical disparity in the opinions expressed: **in countries where corporate PPAs are already commonplace today, such as the United States and Australia, respondents are more confident**, with 50% of positive opinions among North American and Australian respondents by 2030, and just over 60% by 2050. The consensus is not particularly strong even in these countries, where it does not exceed two-thirds of respondents.



- Beyond the positive effect on public image of renewable energy supply, the advantages highlighted by positive opinions are the visibility and the financial security associated with PPAs for companies, in a context of digitization that drives up their electricity consumption, as well as the creation of an “environment of confidence for investments in new generation capacity”.
- But a number of obstacles to the “large-scale” development of PPAs are also mentioned, including:
  - the regulatory context, which is not favorable everywhere,
  - the fact that large companies need a supply guarantee, and that “renewable production will have to be associated with consumption or storage flexibility solutions in order to guarantee the delivery of stable quantities within the framework of long-term purchase contracts with large consumers”,
  - the fact that in a context of anticipated lower costs of renewable energy, companies might not wish to commit to a long-term tariff.

Extracts from comments:

➢ ***Verbatim* in favor of the thesis:**

- *“Security of supply and the need for mid- to long-term visibility are powerful drivers to seek these long-term contracts”*
- *“Long-term PPAs would create a confident investment environment in new energy supply and would reduce the cost of finance for new low carbon infrastructure.”*

- *"With digitization rapidly growing in most industries this will be a must for most large companies."*

➢ **Expressed reservations:**

- *"If you define such agreements to include distributed energy resource providers and aggregators, I agree. If you limit this definition to only large-scale renewable producers located on the bulk grid, I think this will be much more limited in practice."*
- *"Likely to certain: RE producers will be combined into carbon-free portfolios, which can then be managed at the wholesale level. Direct PPAs will almost certainly become too cumbersome; the portfolio approach will provide flexibility and less risk."*
- *"Options of procuring renewable energy economically will be expanded and long-term agreements will not be reasonable."*

IV. Appendix

1) Nominal list of the Sounding Board expert panel

Country	Category	Entity	Name
Australia	University/research	Melbourne Energy Institute, University of Melbourne	Susannah Powell
Australia	University/research	EEMG (energy economics and management group), School of Economics University of Queensland	John Foster
Australia	University/research	Australian National University - Energy Change Institute	Ken Baldwin
Australia	University/research	Australian National University - Energy Change Institute	Andrew Blakers
Australia	University/research	Institute for Energy Economics and Financial Analysis	Tim Buckley
Brazil	University/research	Energy and Environment Institute - University of Sao Paulo	Colombo Tassinari
Brazil	University/research	Institute of Economics (IE) of the UFRJ	Helder Queiroz Pinto Junior
Canada	University/research	Trottier Energy Institute	Normand Mousseau
Canada	Regulator	Alberta Energy Regulator	Mark Taylor
China	University/research	University of Tsinghua	Tianyu Qi
China	University/research	Rocky Mountain Institute (RMI)	Jon Creyts
China	University/research	The Hong Kong Polytechnic University	David Broadstock
China	TSO	State Grid Corporation of China	Xianzhang Lei
Denmark	Agency/public entity	Danish Energy Agency	Peter Bach
European Entities	TSO	ENTSO-E	Laurent Schmitt
European Entities	TSO	ENTSO-G	Jan Ingwersen
European Entities	Agency/public entity	European Commission	Tom Howes
European Entities	Agency/public entity	European Climate Foundation	Rebecca Collyer
France	University/research	Dauphine University – Center of Geopolitics of Energy and Raw Materials	Patrice GEOFFRON
France	University/research	Dauphine – Climate Economics Chair	Christian de Perthuis
France	University/research	Dauphine University - Center of Geopolitics of Energy and Raw Materials	Sophie MERITET
France	University/research	University of Montpellier	Jacques Percebois
France	Finance	Macquarie Infrastructure and Real Assets	Stephane Brimont
France	Supplier	EDF	Bernard Salha
France	Agency/public entity	ADEME	David Marchal
France	Supplier	Engie	Thierry Lepercq
France	Finance	CDC	Gautier Chatelus
France	TSO	GRTgaz	Olivier Aubert

France	Supplier	Direct Energie	Fabien Choné
France	University/research	Mines Paristech	MAYER Didier
France	Agency/public entity	AFHYPAC	Philippe Boucly
France	Supplier	Formerly EDF	Philippe Torrion
France	Supplier	ENI	NAIMA IDIR
France	Agency/public entity	Luciole	Natacha Hakwik
France	DSO	GRDF	Jean Lemaistre
France	Agency/public entity	SER	Jean-Louis Bal
Germany	University/research	Fraunhofer Institut	Georg Rosenfeld
Germany	TSO	Open Grid Europe	Daniel Muthmann
Germany	University/research	University of Köln	Marc Oliver Bettzüge
Germany	Agency/public entity	German Energy Agency (DENA)	Oliver Frank
Germany	University/research	German Institute for Economic Research (DIW)	Karsten Neuhoff
Germany	University/research	Potsdam Institute for Climate Impact Research	Robert Pietzcker
India	University/research	Department of Energy Science & Engineering, IIT Bombay	Rangan Banerjee
India	Agency/public entity	National Institution for Transforming India	Anil Jain
India	Agency/public entity	Department of science and technology, Indian Government	Vineet Saini
India	Other	Prayas Energy Group	Ashwin Gambhir
India	Agency/public entity	National Institution for Transforming India	Manoj Kumar Upadhyay
International Entities	Agency/public entity	IEA	Apostolos Petropoulos
International Entities	Agency/public entity	International Renewable Energy Agency (IRENA)	Dolf Gielen
International Entities	Agency/public entity	United Nations Environment Program	Mark Radka
International Entities	Agency/public entity	United Nations Framework Convention for Climate Change	Katia Simeonova
International Entities	O&G	BP	Paul Appleby
International Entities	O&G	Shell	Wim Thomas
International Entities	Agency/public entity	OECD	Rob Dellink
International Entities	University/research	Economic Research Institute for ASEAN and East Asia	Anbumozhi Venkatachalam
Italy	University/research	Universita Bocconi	Luigi de Paoli
Italy	Agency/public entity	Italian Association of Energy Economics	Vittorio d'Ermo
Japan	Agency/public entity	IEEJ (Institute of Energy Economics)	Ken Koyama
Japan	Regulator	Electricity and Gas Market Surveillance Commission	Tatsuya Shinkawa
Japan	University/research	Nagoya University of Commerce and Business Graduate School	Tatsuo Masuda
Japan	Agency/public entity	Renewable energy institute	Masaya Ishida

Japan	Agency/public entity	Japan Renewable Energy Foundation	Tomas Kåberger
Norway	University/research	Nordic Energy Research	Hans Jørgen Koch
South Africa	University/research	University of Cape Town, Energy Research Center	Harald Winkler
South Korea	University/research	Korea Energy Economics Institute	Yongduk Pak
South Korea	University/research	Korea Polytechnic University	Seung-Jin Kang
UK	Agency/public entity	Department for Business, Energy and Industrial Strategy, United Kingdom	James Steel
UK	University/research	Cambridge University	David Newbery
US	University/research	Stanford Precourt Institute for Energy	Dan Arvizu
US	Regulator	CPUC	Scott Murtishaw
US	Built-in utility	PG&E	Todd Strauss
US	Built-in utility	SoCalGas	George Minter
US	University/research	DoE / Argonne National Laboratory	Guenter Conzelmann
US	Regulator	FERC	Carl Pechman
US	ISO	Formerly CAISO	Lorenzo Kristov
US	Other	Stem	Jim Baak
US	University/research	Joint Institute for Strategic Energy Analysis (part of NREL)	Doug Arent
US	Agency/public entity	EIA	Christopher Namovicz
US	University/research	NREL (National Renewable Energy Laboratory)	Jaquelin Cochran
US	Agency/public entity	Center for Strategic and International Studies, United States	Guy Caruso
US	University/research	Howard H. Baker Jr. Center for Public Policy	Lorna Greening
US	Regulator	NARUC	Greg White
US	University/research	NREL (National Renewable Energy Laboratory)	David Hurlbut