PANORAMA 2014

a look at ...

# The energy scenarios put forward by the Ancre

The Alliance nationale de coordination de la recherche pour l'énergie (Ancre), France's National Alliance for Energy Research Coordination which is made up of all of the country's public bodies involved in energy, wanted to contribute to the discussions that began within the framework of the debate initiated in autumn 2012 and as part of preparations for the law on energy transition. It wanted to do this by shedding some light (sharing its own expertise in research, technological development and innovation) on the various barriers (mainly of a technological nature) that will need to be overcome in order to reach the ambitious targets for reducing greenhouse gas emissions. One of the aims was to assess the conditions required and the impacts of the various possible pathways for reaching this target. This approach sets out to shed light on options on the basis of efficiency criteria, both in terms of the energy policy and in terms of France's current economic and industrial situation.

## The broad lines of the Ancre's scenarios

The Ancre has selected a framework defined by several targets. These include reducing greenhouse gas emissions by a factor of 4 between now and 2050, the government assumption of reducing the share of nuclear energy in the electricity mix to 50% between now and 2025, increasing the share of renewable energies in the energy mix and increasing efforts to bring about more modest and efficient energy usage. The pathways put forward are based on an analysis of the determining factors (both global and by sector) of energy supply and demand, as well as of $CO_2$ emissions. They factor in leeway in terms of energy usage — including as far as transfers between energy vectors are concerned — and the developments that technological progress may give rise to.

Decarbonizing the energy system between now and 2050 implies bringing in some major structural changes. Doing so will need to involve controlling demand by promoting energy efficiency and by getting consumers (both households and companies) to modify their behaviour to a greater or lesser degree, by developing an appropriate energy supply and by managing energy networks and vectors as appropriately as possible.

With all of this in mind, the Ancre has developed three main scenarios and two alternative scenarios which give contrasting pictures of France's energy future between now and 2050 (Tab. 1).

### The "energy saving" scenario (SOB)

The pathway put forward in this scenario is based on three factors: extremely responsible behaviour on the part of consumers in relation to energy consumption; energy efficiency, including — in particular — major investment in renovating existing buildings and recovering unavoidable heat; developing variable renewable energies.

Assumptions about changes in people's behaviour that are taken into account in the SOB scenario relate to:

- the transport sector with a shift towards lower levels of mobility and a fall in car ownership rates, increased reliance on environmentally-friendly modes of transport, car-sharing, car-pooling, etc.;
- the construction sector with a slower increase in surface area, a greater proportion of collective housing, no rebound effect, a slowdown in the increase of specific electricity consumption, etc.

These changes in behaviour result in particular (but not exclusively) from the introduction of appropriate (pricing signals) or regulatory incentive schemes.

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### The "Decarbonization through electricity" scenario (ELE)

The pathway put forward in this scenario places the emphasis on the electricity vector and increasing efficiency for successfully bringing about the energy transition. In this scenario, decarbonization is brought about by energy efficiency, electricity derived from renewable sources (variable or dispatchable) and nuclear.

The main characteristic of this scenario is that highly decarbonized electricity develops as a vector and finds itself in use in other areas (manufacturing, car transport, hydrogen production, etc.), resulting in lower demand for fossil fuels.

### The "Diversified vectors" scenario (DIV)

The pathway put forward in this scenario involves significant usage of "new" vectors within the energy system, particularly at local level:

- making use of unavoidable heat sources (recovering low-temperature heat, heat from electricity power plants and renewable sources);
- incorporating bioenergy into conventional liquid or gas energy vectors;
- energy efficiency.

## Other scenarios

### The "Nuclear and Renewable energies" variant (ELEC-V)

A fourth scenario was subsequently developed in order to assess the consequences of an electricity mix that was closer to the current mix for nuclear energy, albeit with a significant increase in the share of variable renewable energies.

This scenario retains the fundamental assumptions underlying the "decarbonization through electricity" scenario, i.e. major efforts to increase energy efficiency and using the electricity vector to decarbonize new energy uses. Except that in this scenario, the share of nuclear energy in the electricity mix decreases by less and is still more than 50% in 2025. There is also a share of nuclear cogeneration integrated into this scenario. But enough space is created to significantly develop the share of variable renewable energies — compatible with European targets in this area.

### The "underlying" pathway (TEND)

A benchmark pathway has been developed for the purposes of comparison and assessment. This pathway serves as a means of illustrating how the energy system's trends would behave in France were the current trends to continue, taking the government's commitments in relation to energy and climate policies into account. It should be pointed out that this pathway has not therefore been developed on the basis of building stock remaining unchanged — it factors in recent trends, in terms of the rate at which renewable energies are being incorporated, for example.

Table 1

Changes in lifestyles depending on the scenarios

| | 2010 | 2030 | | | 2050 | | |
|---|---|---|---|---|---|---|---|
| Population (millions of inhabitants) | 62.8 | 68.5 | | | 72.3 | | |
| Scenario | | TEND | ELE/ DIV | SOB | TEND | ELE/ DIV | SOB |
| HOUSING | | | | | | | |
| $Mm^2$ | 2,539 | 3,063 | 3,063 | 2,957 | 3,559 | 3,559 | 3,377 |
| $m^2$/inhabitant | 40 | 45 | 45 | 43 | 49 | 49 | 47 |
| Share of collective housing (% housing units) | 43% | 44% | 44% | 46% | 45% | 45% | 49% |
| TERTIARY | | | | | | | |
| $m^2$/employment | 52 | 55 | 55 | 52 | 55 | 55 | 52 |
| MOBILITY | | | | | | | |
| Passenger traffic (excluding air) Gpkm | 971 | 1,088 | 1,088 | 980 | 1,219 | 1,219 | 976 |
| Number of private vehicles (millions of vehicles) | 31 | 37 | 36 | 32 | 43 | 39 | 17 |

*Sources: INSEE, Ancre forecasts*

## Methodology

The Ancre used the following process for its work: analysis and aggregation of changes in the energy needs of the various sectors; estimation of the impacts that these changes have on the energy sector (electricity generation, oil refining, gas and heating transport and distribution) and assessment of the resulting changes in the energy mix.

Factoring in the initial targets (successfully implementing the factor 4 project and reducing the share of nuclear energy in the energy mix to 50% by 2025) places constraints on the system and means making technological choices in order to both guarantee production and ensure that the overall system is balanced. The energy sector involves very long time frames — probably more than any other industry. And any changes to it —

even large-scale changes resulting from political decisions — only start to have any effect decades after they were implemented.

Global demand is supposed to break with the long-established trend that has seen per-capita energy consumption increase continually. This turnaround is the result of both the need to reduce our consumption of finite resources and the collective realization of the impact that our societies have on the environment. All the scenarios are based on varying degrees of emphasis placed on more modest energy consumption, production efficiency and more rational use of energy.

## Results of the scenarios

The Ancre set out to explore the various possible ways of successfully implementing the factor 4 project to reduce $CO_2$ emissions by 2050 by carrying out a comparative analysis of these three different scenarios. Two main results have emerged from our study:

- all three scenarios will result in the factor 4 project for reducing $CO_2$ emissions being successfully implemented. They operate several levers for this purpose: major investments for the efficiency and renewables options, and changes in people's behaviour. These scenarios involve technological breakthroughs which — by their very nature — have not yet come about;
- the scenarios will result in a 65 to 70% fall in total greenhouse gas emissions.

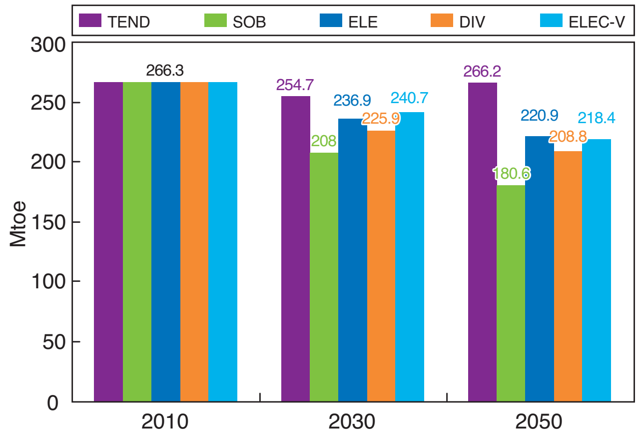
As far as the technological breakthroughs are concerned, the SOB scenario involves capturing and storing $CO_2$, the ELE scenario involves storing massive quantities of electricity and both the DIV and ELEC-V scenarios involve nuclear cogeneration.

## Primary energy consumption report

In the TEND benchmark scenario, the quantities of primary energy consumed remain more or less stable over time — drives to reduce energy consumption counterbalance the dynamic effects which have a tendency to drive it up, demographic change and economic growth in particular.

Primary consumption is significantly reduced in the SOB scenario (–32%) compared with 2010, and there is a clear distinction as far as primary energy is concerned between, this time, the DIV scenario and the other ELE and ELEC-V scenarios. While these two scenarios favour the electricity vector, the diversification sets great store by biomass (Fig. 1).

Fig. 1 – Primary energy consumption 2010-2050*




*Calculations for primary energy include consumption for non-energy uses, as well as international transport.

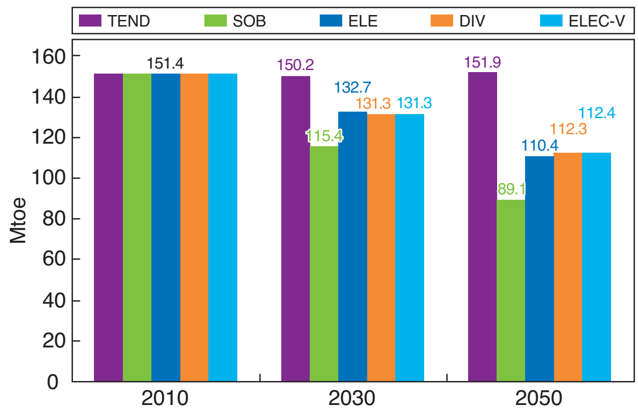
*Source: The Ancre's calculations*

## Final energy consumption report

Calculations for final energy are in "standard" format. This means that they include neither consumption for non-energy uses, nor international transport. Factoring them in would add approximately 20 Mtoe to final energy consumption. Using this "standard" format makes it easier to compare the Ancre's scenarios and those put forward during the French National Debate on Energy Transition.

As far as demand is concerned, only the SOB scenario is significantly different from the others in the final energy report, showing a significant decline compared with today (–41%). Although they all show a trend reversal, the ELE, DIV and ELEC-V scenarios show final energy demand of between 110 and 112 Mtoe. This –27% fall is, nevertheless, a result of considerable efforts on the part of consumers (Fig. 2).

Fig. 2 – Final energy consumption 2010-2050




*Source: The Ancre's calculations*

# The energy scenarios put forward by the Ancre

## Change in energy consumption in the residential-tertiary sectors

As far as the residential and tertiary sectors are concerned, the main differences between the various scenarios are the rate at which existing stock will be renovated and the energy performance of these renovations.

In the ELE and DIV scenarios, the annual rate at which housing units are renovated is increased to 350,000 per year (the average over the period), and the rate at which the building stock is renovated is increased to 15 Mm² in the tertiary sector, as opposed to the current situation where 100,000 housing units per year and 10 Mm² are renovated. In theory, the performance levels of thermal renovation projects could save 60% compared with the benchmark figure for existing building stock consumption. But factoring in a rebound effect will limit effective savings to 53%. Specific electricity consumption holds stable in the DIV scenario before falling slightly after 2030. In the ELE scenario, it continues to increase and then stabilizes.

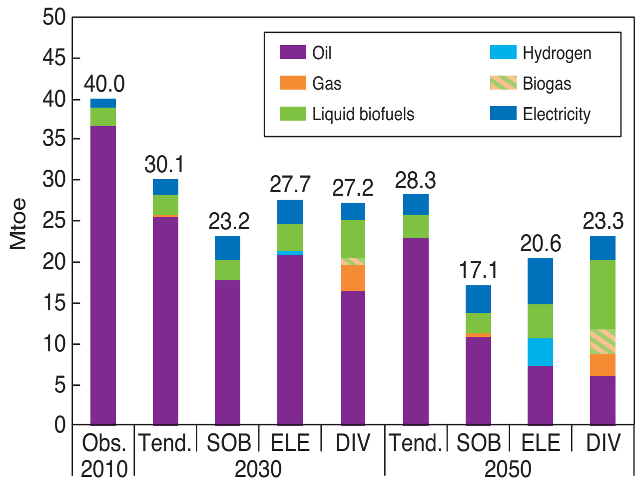
In the SOB scenario, significantly increased drives to renovate building stock result in 650,000 housing units/year being renovated in the residential sector and 25 Mm² in the tertiary sector. Thermal renovation can also save up to 70% of heating energy without any notable rebound effect. Similarly, electricity consumption is predicted to stabilize from 2015 onwards, before falling after 2030.

## Change in energy consumption in the transport sector

As far as the transport sector is concerned, the ways in which the various pathways put forward by the Ancre differ involve change in demand for mobility, the relative shares of different modes of transport and the preferred technologies and vectors.

The assumptions as far as changes in demand for mobility differ between the SOB scenario and the two other ELE and DIV scenarios. Trends that have been observed over the last ten years continue in the ELE and DIV scenarios. People's mobility, expressed in passenger-kilometres (pkm), increases by 25% between 2010 and 2050. This increase can mainly be attributed to population growth (72 million people in 2050). Over this same period, the transport of merchandise, expressed in tonne-kilometres (tkm) increases by 53% (Fig. 3).

Fig. 3 – Consumption in the transportation sector




*Source: The Ancre's calculations*

In the SOB scenario, significant changes in people's behaviour and in organizational modes are assumed. Individual mobility falls by 20% on average over the projected 40-year period. This results in the global volume of passenger-kilometres stabilizing — despite the increase in population. This reduction can be attributed to people adopting more environmentally-friendly modes of transport (cycling, walking) and new ways of organizing their lives (people working from home, home deliveries becoming more common, etc.).

Mobility services are developing and the relationships that people have with their own cars are changing, so that they choose a vehicle that is better suited to the type of trip that they are making (small electric vehicle in town, etc.). The number of cars (private vehicles, including fleets of service cars, light utility vehicles) falls by approximately 40% compared with 2010. As far as goods transport is concerned, significant efforts are made to rationalize traffic, and local production is favoured. The result is that the number of tonne-kilometres remains stable compared with 2007 (before the world economic crisis) — some 360 billion tkm.

The relative shares of the various modes of transport remain the same as in 2010 for the whole period in the DIV and ELE scenarios. But they change dramatically in the SOB scenario: the share represented by the car in people's mobility is reduced, falling from more than 80% in 2010 to 50% in 2050. Instead of the car, people travel by rail, public road transport and mopeds/motorcycles; as far as goods transport is concerned, significant efforts are made to increase the use of piggyback combined transport. This increases by a factor of three compared with its current level, i.e. an increase of 50% compared with the highest level which was observed in 2000.

# The energy scenarios put forward by the Ancre

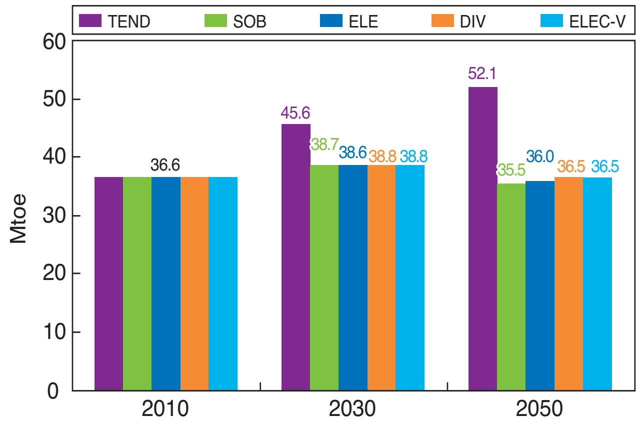
Regarding technology, the speed at which it is developed and distributed increases in all of the scenarios. This results in high penetration rates in the numbers of vehicles powered by alternative engine systems and a much faster improvement in overall energy efficiency than seen over the last few years. In all scenarios, the share of electrified vehicles (electric vehicles and rechargeable hybrid vehicles) is at least 25% in 2050. This figure even reaches 45% in the ELE scenario which places the emphasis on this type of solution. Innovation will reduce the unit consumption of cars which continue to use hydrocarbon fuels by 50% (ELE and SOB) to 55% (DIV) compared with 2010.

For the three pathways studied, there is a considerable technological challenge involved. The rate at which new technologies are developed has to be increased, as well as the rate at which they are incorporated into vehicles. And these technologies mainly meet two aims: reducing their unit consumption and developing alternative engine systems.

## Change in energy consumption in industry

The scenarios have been developed using a factor analysis method that cross-references the three following determinants: an indicator of activity for the branch, an energy intensity level and an energy consumption vector. The branch activity indicators are the same in all three scenarios and the way in which they have been constructed is in line with the Enerdata AMS-O scenario for the French General Directorate for Energy and Climate. This scenario supposes a 1.7% industrial growth rate until 2030. Initially, this trend has been continued until 2040, and the rate increased to 1.8% between 2040 and 2050.

Fig. 4 – Energy consumption in industry 2010-2050




*Source: The Ancre's calculations*

Altogether, given the growth that the industrial sector will experience, its energy consumption will remain stable over the projected period owing to a reduction in energy intensity of around 30%. The remaining savings can be attributed to changes in the energy mix, with an increase in the share of electricity (particularly in the ELE scenario) and green energies (mainly biomass in the DIV scenario). Other very important factors include the use made of nuclear cogeneration (40 TWh of thermal energy in the DIV scenario) and $CO_2$ capture and storage (Fig. 4).

## Investment pathway

Investment requirements in the residential and tertiary sectors are approximately €900 billion over the whole period (2010-2050) for the SOB scenario (not the same as for the benchmark scenario) for which the volume of renovation work and performance levels required are the highest. The average annual investment requirements would therefore be around €4 billion in the TEND scenario, €12 billion in the ELE and DIV scenarios and €24 billion in the SOB scenario.

Table 2

Total investments by sector between 2012 and 2050
and annual average for all sectors (in € billion, 2012 base)

| | Tertiary and residential sectors | Transport | Electricity generation | Average annual investment (all sectors) |
|---|---|---|---|---|
| TEND | 159 | 3,917 | 589 | 123 |
| SOB | 889 | 2,116 | 468 | 92 |
| ELE | 459 | 5,068 | 606 | 161 |
| DIV | 462 | 4,293 | 491 | 138 |

*Source: The Ancre's calculations*

Investment requirements in the transport sector are approximately €2,100 billion over the whole period (2012-2050) for the SOB scenario, as opposed to €4,000 billion for the TEND and DIV scenarios and €5,000 billion for the ELE scenario. For the SOB and ELE scenarios, the spending which will most likely be more encouraged by local authorities, i.e., spending on road and rail infrastructure, rail equipment — transport of goods and people — and on buses, is higher than in the TEND scenario (or benchmark scenario). The greatest increases are seen in the SOB scenario, with significant investments associated with developing public rail and road transport and rail freight. The ELE scenario follows, with significant investments needed for equipment and charging terminals (rapid terminals in particular) for developing electric vehicles and hydrogen vehicles.

The DIV scenario is marked by the requirement for major investments in the building of biofuel production units (both liquid and gas) — more than €4 billion/year on average over the period 2012-2050.

For the period 2012-2050, spending on road vehicles (private vehicles, light utility vehicles and lorries, excluding buses) which is mainly considered as being borne by households and companies, is higher in the ELE scenario than in the TEND scenario (+30%), whereas it is similar for the DIV scenario (+5%) and falls significantly in the SOB scenario compared with the TEND scenario (–50%). For this last pathway, it is important to bear in mind that the assumptions made in terms of reductions in individual mobility and the widespread increase in car sharing type solutions result in total vehicle numbers in 2050 being halved compared with the current situation.

In the ELE scenario, this significant increase can mainly be attributed to the proactive distribution of electric and hydrogen-powered vehicles which have a net additional cost, at least in the first few years of their being marketed. Another explanation is the fact that the vehicles have a shorter lifetime, which is linked in particular with the need to speed up penetration of new higher energy performance vehicle technologies, or technologies that generate lower $CO_2$ emissions.

In the electricity generation sector, investment requirements for the period 2012-2050 are between €468 billion for the SOB scenario and €606 billion for the ELE scenario. Investment in the electricity sector will be higher for the ELE scenario than for the others. But it may initially be partly offset by an extension in the operational life of nuclear reactors (or by a higher load factor). The rapid development of variable renewable energies — despite the fact that we have still not learnt all there is to know about them — could be a factor resulting in higher investment costs in the mid-term, although this phenomenon could cease to be a factor in the longer term. Integrating a larger share of variable renewable energies could also mean significant costs for developing and reinforcing the electricity system (intelligent grids, interconnections, storage) and new tools for managing electricity demand (building technical management systems, smart grids, etc.).

The Ancre intends to assess the impacts of disruptive investments for each of the scenarios in its future projects: storing massive quantities of electricity (ELE), carbon capture and storage (SOB) and nuclear cogeneration low-temperature heating networks (DIV and ELEC-V).

## Employment

The impact that the Ancre's various scenarios will have on employment has been assessed for the different sectors. But the results should be regarded with circumspection, given the uncertainties associated with macroeconomic scenarios. All of scenarios would result in an increase in energy prices and the impact that this would have on the competitivity of other sectors (and so on employment) has not been measured.

In the residential sector, the TEND scenario would result in 72,000 jobs being created, as opposed to more than 400,000 with the SOB scenario. In the transport sector, nearly 400,000 jobs would be created with the TEND, DIV, ELE and ELEC-V scenarios, while 168,000 jobs would be lost with the SOB scenario.

## Impact for households

Changes in energy prices for consumers are driven by a cascading set of assumptions in relation to the international prices of imported energies, the costs of energy production-conversion-provision equipment for consumers and taxation — a major factor in managing the energy transition. In particular, the Ancre is assuming that international oil prices will continue to increase. In real terms, prices will reach $130/bbl in 2020 and $215/bbl in 2050 — the equivalent of €100/bbl in 2020 and €165/bbl in 2050 (assuming that the euro/dollar exchange rate remains constant for the whole period).

Table 3

Total household energy spending (in constant euros)

| €/year | 2010 | 2030 | 2050 |
|---|---|---|---|
| TEND | 2,790 | 3,204 | 3,400 |
| SOB | 2,831 | 2,819 | 2,408 |
| ELE | 2,824 | 3,336 | 2,627 |
| DIV | 2,836 | 3,047 | 2,473 |
| ELEC-V | 2,824 | 2,979 | 2,540 |

*Source: The Ancre's calculations*

The important role given to the thermal renovation of buildings in all of the scenarios is also a reason to consider the financing of these investments as being part of the energy bill with, where appropriate, the corresponding annual payments being refunded.

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In all of the scenarios, energy prices are going to increase significantly.

## Energy independence and foreign trade

The various scenarios all result in a major reduction in France's energy dependency, with falls from 51% today to 27% (ELE), 28% (DIV) or 36% (SOB), all because of a decline in hydrocarbon consumption by 2050. Significant savings are afforded by all scenarios in terms of oil product imports.

Altogether, imports would be almost halved in the ELE and DIV scenarios, resulting in a significant drop in the country's oil and gas bill (by around €50 billion/year at the end of the period). This positive and major macroeconomic effect should, however, be considered in light of the significant investments that will be required for the transition.

## Environmental impacts

The environmental impacts are relatively similar in all scenarios. The DIV scenario, which supposes increased use of biomass, is based on the assumption of there being a neutral energy biomass trade balance and no major changes to cultural practices. Approximately 50,000 km² would be required in order to grow biomass (so as to reach 20% in gross tonnes of the 30 Mtoe of bioenergies), which is around 10% of total surface area. The ways in which our countryside landscapes are changing would be accelerated. The footprint required for solar and wind power infrastructure would be considerable in the scenarios that place the emphasis on increased electricity usage (the ELE scenario in particular, but all are concerned). Nearly 700 km² could be required for 60 GW of solar power and 500 km² for 50 GW of offshore wind power. But these results should be looked at with caution: more effective usage of built up areas could go a long way towards meeting requirements. The development of offshore wind power would also shift the impacts towards uninhabited regions.

The Ancre is also trying to analyse other types of impact, such as accident risks (of natural or industrial origin, or associated with terrorist attacks), social perceptions of technological changes and economic and regulatory constraints, the "political feasibility" of the pathways, etc. A sophisticated analysis of the scenarios can only be carried out once relatively wide-ranging interdisciplinary discussions have taken place.

## Conclusions

The Ancre's work shows that although successfully implementing the factor 4 project (for energy $CO_2$) is possible, doing so will require considerable efforts, irrespective of the scenario, in at least four areas: getting people to modify their behaviour (with suitable regulatory and energy price policies), factoring in the cost-performance ratio for the technologies used, developing infrastructure and facilities and making major technological breakthroughs. Creating all the necessary conditions will require major investments.

The Ancre points out that all analyses indicate that reaching factor 4 will not be possible without a European energy policy that sets out to properly structure the whole energy landscape's complementary aspects and ensure consistency across it; this does not only apply to network industry, electricity and gas policies... it also applies to R&D programmes.

To a very great extent, the macroeconomic consequences will depend on how much capacity is installed (at both national and European level), coordinated policies in terms of research and development, taxation (environmental in particular) and support for deploying competitive industrial sectors. A number of technological barriers will also need to be lifted, and obstacles removed so that a new energy system can be accessed, one that is less centralized and which provides regions and stakeholders with more flexibility (and responsibility).

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