France Chapter

# pathways to deep decarbonization

2014 report

IDDRI
SciencesPo.

SUSTAINABLE DEVELOPMENT SOLUTIONS NETWORK
A GLOBAL INITIATIVE FOR THE UNITED NATIONS

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# Preface

The Deep Decarbonization Pathways Project (DDPP) is a collaborative initiative, convened under the auspices of the Sustainable Development Solutions Network (SDSN) and the Institute for Sustainable Development and International Relations (IDDRI), to understand and show how individual countries can transition to a low-carbon economy and how the world can meet the internationally agreed target of limiting the increase in global mean surface temperature to less than 2 degrees Celsius (°C). Achieving the 2°C limit will require that global net emissions of greenhouse gases (GHG) approach zero by the second half of the century. This will require a profound transformation of energy systems by mid-century through steep declines in carbon intensity in all sectors of the economy, a transition we call "deep decarbonization."

Currently, the DDPP comprises 15 Country Research Partners composed of leading researchers and research institutions from countries representing 70% of global GHG emissions and different stages of development. Each Country Research Partner has developed pathway analysis for deep decarbonization, taking into account national socio-economic conditions, development aspirations, infrastructure stocks, resource endowments, and other relevant factors. The pathways developed by Country Research Partners formed the basis of the DDPP 2014 report: Pathways to Deep Decarbonization, which was developed for the UN Secretary-General Ban Ki-moon in support of the Climate Leaders' Summit at the United Nations on September 23, 2014. The report can be viewed at deepdecarbonization.org along with all of the country-specific chapters.

This chapter provides a detailed look at a single Country Research Partner's pathway analysis. The focus of this analysis has been to identify technically feasible pathways that are consistent with the objective of limiting the rise in global temperatures below 2°C. In a second—later—stage the Country Research Partner will refine the analysis of the technical potential, and also take a broader perspective by quantifying costs and benefits, estimating national and international finance requirements, mapping out domestic and global policy frameworks, and considering in more detail how the twin objectives of development and deep decarbonization can be met. This comprehensive analysis will form the basis of a report that will be completed in the first half of 2015 and submitted to the French Government, host of the 21st Conference of the Parties (COP-21) of the United Nations Framework Convention on Climate Change (UNFCCC).

We hope that the analysis outlined in this report chapter, and the ongoing analytical work conducted by the Country Research Team, will support national discussions on how to achieve deep decarbonization. Above all, we hope that the findings will be helpful to the Parties of the UNFCCC as they craft a strong agreement on climate change mitigation at the COP-21 in Paris in December 2015.

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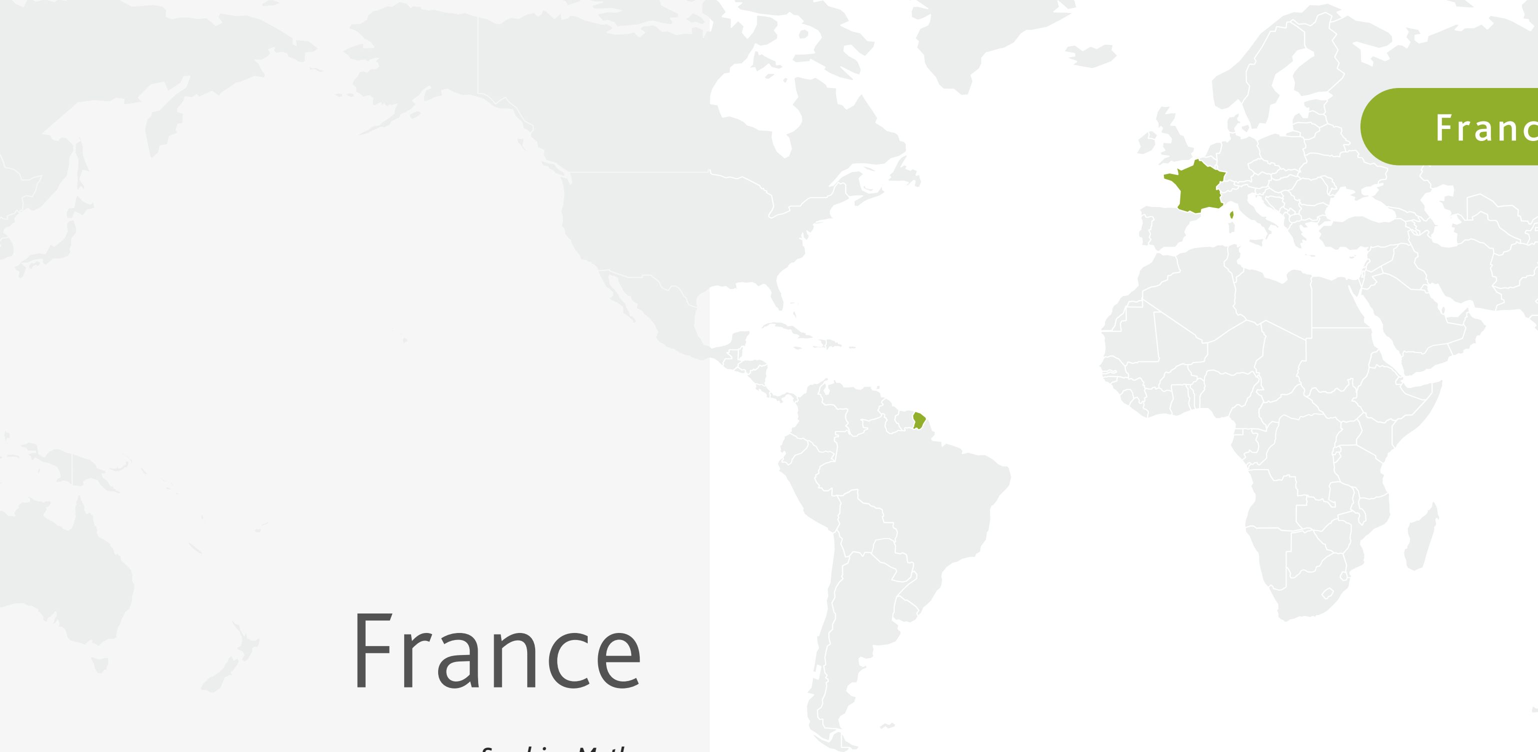

# France

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## 1 Country profile

### *1.1 The national context for deep decarbonization and sustainable development*

France has a low endowment of domestic fossil resources (domestic production represents less than 2% of primary consumption) and energy imports, mostly oil and gas, are a substantial source of total external trade deficit (these imports represent around 110 billion US$ (2012), a deficit close to the total external trade deficit in 2012). Faced with this situation, France has developed a specific energy security strategy resorting notably to the launching of an important nuclear energy program in the 1970s. Today, France is in particular equipped with 63 GWe of installed nuclear capacity, which supplies 77% of the electricity produced and 24% of total final energy. As a result, France is today already a relatively low energy consumption country (2.6 toe/cap) and has GHG emission intensities at the lowest end of OECD countries (5.7 $tCO_2$/cap).

In the French policy debate, decarbonization was first introduced in 2005 with the adoption of a Factor 4 emission reduction target for 2050, compared with 1990. More recently the discussion on carbon taxation has given rise to several commissions and reports (Quinet 2009, Quinet 2013; Rocard 2009). The experts who drafted the Quinet report in 2009 recommended a carbon tax set at a rate of €32 per ton of $CO_2$ in 2010, rising to €200 (150-350) in 2050 as the implicit value of the constraints for reducing $CO_2$ emissions entailed by the targets for 2020 and 2050. In 2009, France was therefore on the verge of adopting a carbon tax for diffuse emissions

France

(transport and building) that, combined with the ETS for large industries and electricity, would have provided a comprehensive system of economic incentives through carbon prices in all sectors. However, the constitutional council dismissed the law on the eve of its enforcement, while it had already been voted upon by the parliament. More recently, decarbonization has been an important component of the Energy Transition, which has been set as a priority by President François Hollande. To investigate this issue, the National Debate on Energy Transition took place in 2013 as a deliberative process between different groups of stakeholders (NGOs, Trade Unions, Business, MPs, Mayors) aiming at identifying and assessing the consequences of different scenarios.

Three policy commitments structure the decarbonization scenarios (or "energy transition trajectories") for France:

- European targets to be translated into domestic objectives: EU 3x20 for 2020 targets (20% reduction in EU GHG from 1990 levels; raising the share of EU energy consumption produced from renewable resources to 20%; 20% improvement in the EU's energy efficiency)
- Factor 4 reduction of emissions in 2050 compared to 1990 (-75%)
- The reduction of the share of nuclear in power generation, down to 50% by 2025, target set in 2012 by President François Hollande

Key challenges for the French economy and society that are directly or indirectly related to the purpose of decarbonization include:

1. the rebuild of industrial competitiveness to counterbalance the de-industrialization observed over the last 40 years (industry's share in the economy has been steadily falling during the last 30 years from 25% in the 1980s to 19% in the 2010s), and the 2.6 million fall of employment in industry.
2. the reduction of energy poverty, which has become a crucial issue as, in 2010, more than 6% of the French population is below the threshold defining fuel poverty (expenditures on fuel and heating represent more than 10% of income); in particular, low-income households living mostly in rural areas or in small towns spend on average 15% of their income on energy, for housing and transport.
3. a long term effort in directing land and urban planning towards more sustainable patterns through ambitious infrastructure deployment. This is in particular crucial to control mobility needs in a relatively low-density country.
4. the highly controversial issue of nuclear energy beyond 2025. France's nuclear power plants are, on average, nearly 30-year old and an intense debate concerns the choice between upgrading them with new nuclear plants, extending their service life in some cases, or replacing them altogether with other technologies.

## 1.2 GHG emissions: current levels, drivers, and past trends

GHG emissions in France amounted to 549 $MtCO_2eq$ and 392 $MtCO_2$ in 1990 (excluding LULUCF). In 2010 they were down to 501 $MtCO_2eq$ and 366 $MtCO_2$, respectively a 9% and 7% decrease. LULUCF induce negative emissions (-24 $MtCO_2eq$ in 1990 and -37 $MtCO_2eq$ in 2010). Between 70% and 75% of the GHG emissions are $CO_2$ emissions (Figure 1 and Figure 2).

*Transport*

The main sector for GHG emissions is the transport sector with 138MtCOe representing 27% of GHG emissions and 38% of $CO_2$ emissions (excluding LULUCF). The 17% increase since 1990 has been mostly triggered by road transport, which represents almost all the emissions from this sector.

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In the passenger transport sector, the rise of mobility, notably driven by a rise of the distance per capita, has been the main source of sectoral emissions increases, notably because modal breakdown has remained stable at an 80% share for individual cars. Energy efficiency improvements have also been significant, particularly in the last decade, but not sufficient to compensate for the rise of activity levels. In the freight transport sector, the rise of emissions has been driven by a continuous rise of activity levels; indeed, demand for freight transport has increased very fast over the 1990-2008 period (+57%), at an even faster rate than GDP, and the partial decoupling observed since the 2008 economic crisis has only moderated this rise without reversing it. The evolution of the modal breakdown has also played an important role in the increase of carbon emissions, with a continuous decline of rail share (from 27% in 1984 to 8% in 2010) and the domination of road (84% of freight transport in 2010) that were only partially compensated by energy efficiency. According to the government's targets, rail and water transport modal share has to reach 25% in 2022 compared to 14% in 2007 .

Figure 1. Decomposition of GHG and Energy $CO_2$ Emissions in 2010

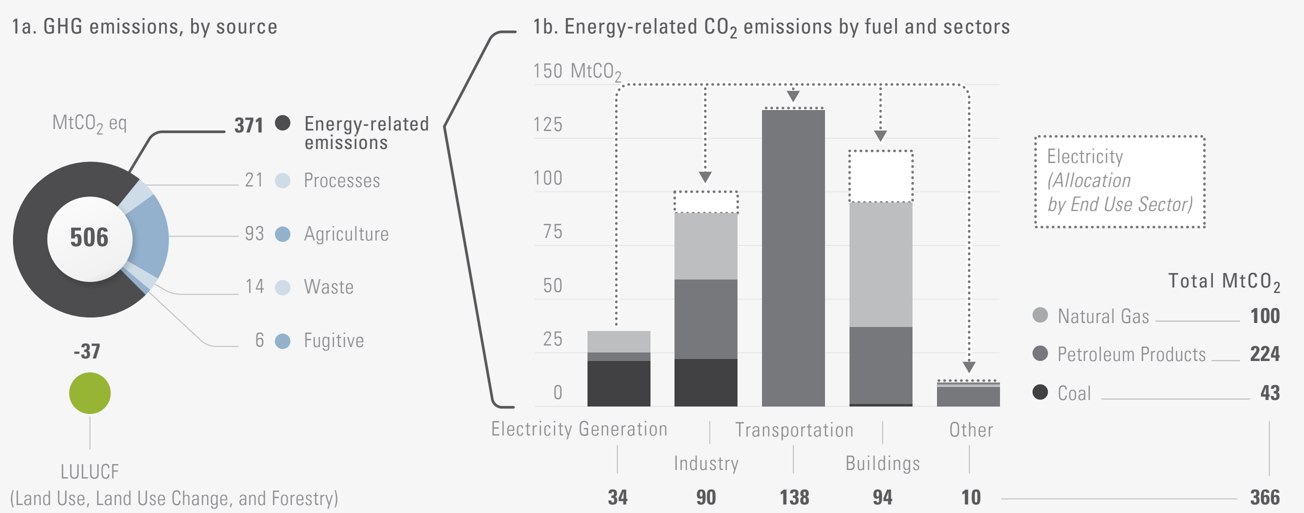
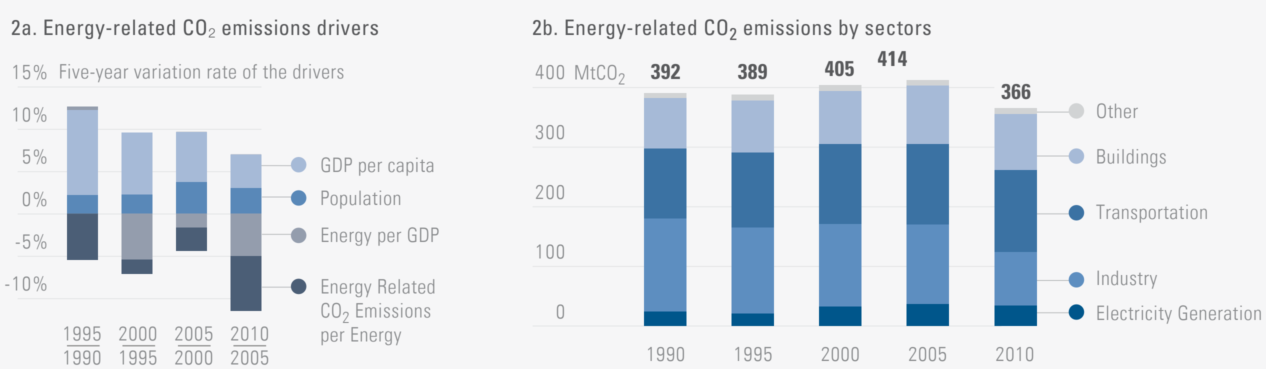



Figure 2. Decomposition of historical energy-related $CO_2$ Emissions, 1990 to 2010



*Buildings*

The residential and tertiary sector represents 19% of GHG emissions, and its increase has been driven by demographic trends and a steady increase in the per capita surface. Important decarbonization of the energy consumption happened in the 1980s because of the electrification associated with the nuclear program, and nowadays electricity is one of the main carriers used for heating, which is a French peculiarity. Energy efficiency improvements developed during the 1980s and have been reinforced between 2000 and 2010 notably thanks to the implementation of successive thermal regulations for new buildings and to the introduction of fiscal incentives for thermal retrofitting.

*Industry*

Industry represented 18% of GHG emissions in 2010, a 42% fall since 1990, half of it being due to the drop of industrial production over the last three years. The main drivers for the significant decrease in emissions between 1990 and 2010 are the overall decarbonization of the energy used in industry and further improvements in energy efficiency, notably triggered by the European Emission Trading Scheme. In particular, structural evolutions have gone towards a decrease of energy-intensive industries (e.g. -17% and -27% for steel and cement production respectively), and technical progress has permitted significant reductions of the $CO_2$ content of production (e.g. the diffusion of electric arc furnace for steel production driving the emission rate from 1.78t$CO_2$/t steel in 1990 to 1.32t$CO_2$/t steel in 2010).

*Agriculture*

Agriculture represents 18% of total GHG emissions, N2O, and methane being major contributors (51% and 41% respectively) while $CO_2$ from energy consumption represents only 8%. Major sources of emissions include land fertilization (46%) and enteric fermentation (27%). Between 1990 and 2010 GHG emissions have decreased by 8%, particularly because of the decrease in mineral fertilizing uses, in milk production intensification and in the size of cow livestock.

*Power*

France is characterized by low emissions in the power sector because of the contribution of nuclear (77%) and hydro (11%) energies. On average, current emissions in the power sector amount to 62 g$CO_2$/kWh; this is to be compared with the European average 347 g$CO_2$/kWh. However, due to the weight of nuclear, renewable electricity (excluding hydro) currently represents only 2% of electricity production.

# 2 National deep decarbonization pathways

## 2.1 Illustrative deep decarbonization pathway

### 2.1.1 High-level characterization

The assessment of the Illustrative Deep Decarbonization Pathway for France is based on the results obtained with the IMACLIM-France model, developed at CIRED.[1] This Illustrative Deep Decarbonization Pathway combines an overall ambitious energy efficiency improvement program and a diversification of low-carbon energy carriers mobilizing electricity penetration, bioenergy and renewables, or waste heat.

Between 2010 and 2050, economic projections for France anticipate an average annual growth

1 For more information on the IMACLIM modelling platform, see http://www.imaclim.centre-cired.fr/?lang=en

of 1.8%, population is expected to increase by 11%, and the structure of the economy is supposed to be stabilized during the next decades. The deep efficiency measures would reduce final energy consumption by nearly 50 percent in 2050 compared to 2010, and electricity, although decreasing by 20% in absolute terms, sees its share increasing from 24% to 39% in 2050.

The decrease of the carbon intensity of fuels in end-use sectors is allowed by a division by three of coal consumption and, even more crucial for the transport sector, by a massive

Table1. The development indicators and energy service demand drivers in France

| | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| Population [Millions] | 65 | 66 | 69 | 71 | 72 |
| GDP per capita [$/capita] | 33400 | 39400 | 45400 | 52500 | 61500 |

Figure 3. Energy Pathways, by source

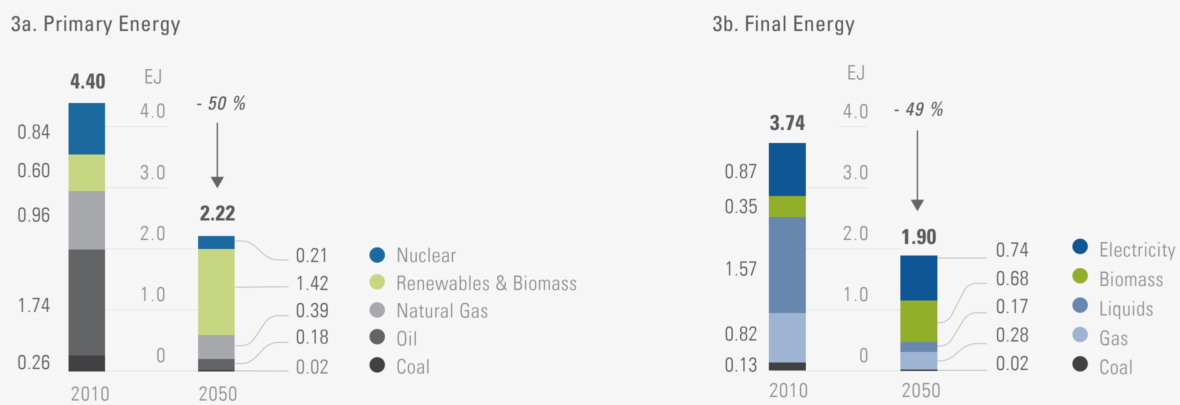



Figure 4. Energy-related $CO_2$ Emissions Drivers, 2010 to 2050

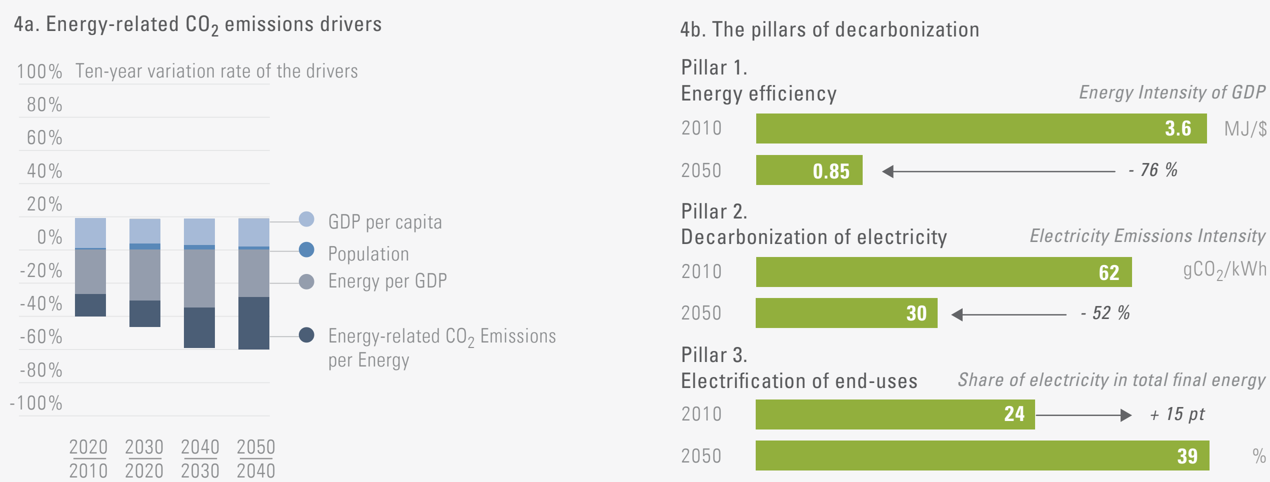
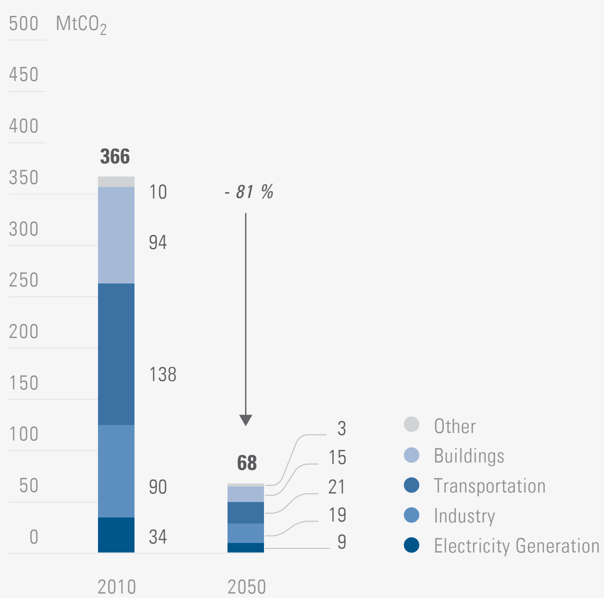


Figure 5. Energy-related $CO_2$ Emissions Pathway, by Sector, 2010 to 2050




substitution of oil by gaseous fuels and biomass. On the supply side, the decrease of the share of nuclear (from 77% in 2010 to 50% in 2025 and 25% in 2050) does not create a rise of carbon emissions because it is accompanied by deep diffusion of renewable electricity—mostly hydro, wind and PV—which increases from 17% in 2010 to 71% in 2050.

Under this pathway, buildings and electricity emissions are deeply decarbonized and the core of emissions remaining in 2050 comes from the transport and industry sectors. As for transport, very important reductions are obtained over the 2010-2050 period, but given the high initial emission level transport still represents 30% of 2050 $CO_2$ emissions. Industry becomes the second major emission contributor in 2050 (26%); this is notably because of the assumption of constant structure of the economy which assumes in particular a constant share of energy-intensive industries.

### 2.1.2 Sectoral characterization

*Energy supply*

Despite the deep electrification of energy consumption, electricity demand slightly decreases over 2010-2050 as a result of strong efficiency gains in the energy system and a convergence of net exports (30 TWh in 2010) to zero by 2050. Power-generation technologies are deeply modified over the period towards a diversification of energy carriers with, in particular, a significant long-term decrease in nuclear share in the mix, a significant increase of renewable energy: in 2050, nuclear represents 25% of production, while wind, photovoltaic, and other non-hydro renewables produce 140TWh, 70TWh and 14TWh respectively. Due to environmental constraints, and in spite of an important technical potential, hydro production is considered to remain stable around 60TWh. Combined-cycle gas turbines are needed to ensure both the transition between the decrease of nuclear and the full deployment of renewables and the balancing of the network with high intermittent sources in the long term.

Other energy carriers are also deeply decarbonized thanks to the diffusion of bioenergy: in 2050, second generation biofuels and biogas represent, respectively, 22% of liquid fuels and 53% of gas.

*Transportation*

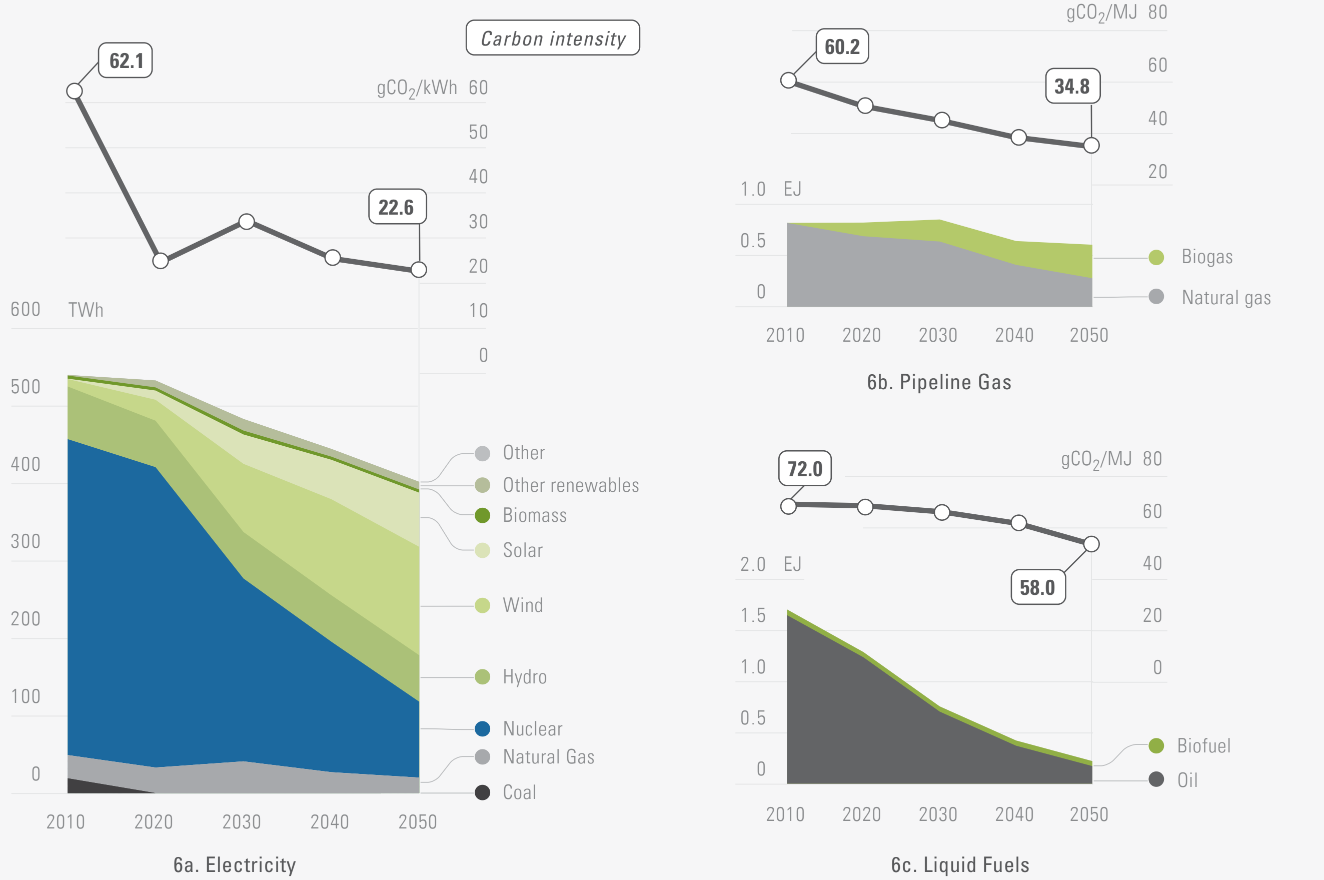
In the transport sector, total passenger mobility is stabilized over the period notably thanks to a limitation of urban sprawling, combined with the development of new services for the reduction of mobility (remote working) and the deployment of a functionality economy (car sharing systems), which decrease the global demand for mobility particularly at local level. In parallel, a 30% increase of the modal share of collective transport and soft modes alternatives (bicycles) is permitted by i) organizational measures and infrastructure deployment for urban and local mobility and ii) new investments in rail infrastructures and the retrofitting of existing rail infrastructures. On the technology side, motorization types are diversified to adjust to specific mobility segments (hybrid electric and full electric vehicles) and offer more flexibility in uses (range extender and plug-in hybrid electric vehicles). Significant energy efficiency improvements are assumed: +50% for cars (2,5l/100km on average), +20% for buses, +40% for planes.

A decoupling of freight volumes and economic activity driving a stabilization of freight demand in the medium and long term is obtained through better logistics and the development of eco-conception or new technologies such as 3D printing. Rail transport reaches 25% of freight transportation in 2050 and water transport is developed. Concerning trucks, major evolutions are energy efficiency improvements (reaching 30% in 2050) and the switch to natural gas.

*Buildings*

More than two thirds of the dwellings that will exist in 2050 are already built so that efficiency improvement through the thermal retrofitting of existing buildings is a crucial component of the decarbonization strategy. A proactive strategy is necessary to address nearly all existing building (600,000 retrofitting per year after 2020 in the residential sector and 21 Mm² in the commercial

Figure 6. Energy Supply Pathways, by Resource



sector) and ambitious improvements per unit are considered (-55% in the commercial sector and -65% in the residential). Additionally and consistently with the measures from the "*Grenelle de l'Environnement,*" standards impose new buildings to consume less than 50 kWh/m² in 2020 and to reach zero energy consumption after 2020. In parallel, the share of multi-dwelling buildings should increase, inducing only a small increase in the per capita surface. Electricity and off-grid renewables become dominant heating fuels and specific electricity consumption is controlled by a 30% performance improvement for all appliances, corresponding to a pervasive penetration of the most energy efficient appliances currently available.

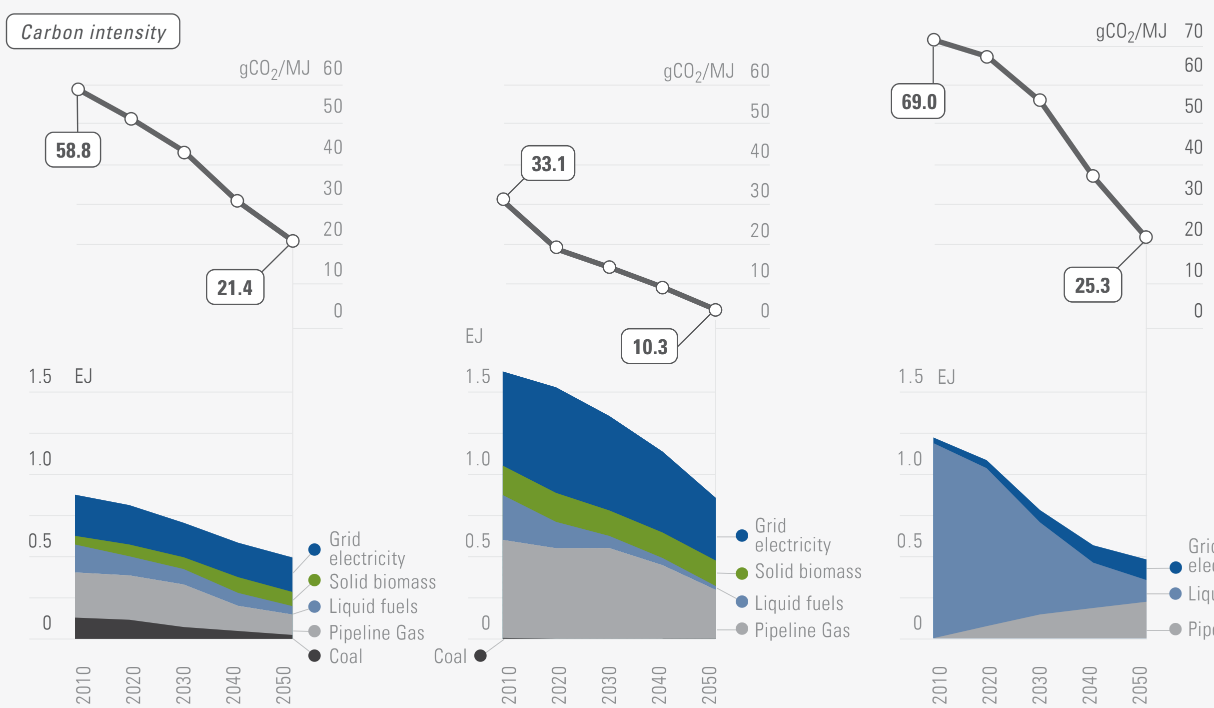
*Industry*

The Illustrative Decarbonization Pathway considers no major change on the structure of production, industry remaining at a constant 20% share in GDP, neither on final industrial energy mix, the decrease of the carbon intensity being essentially due to the development of biogas and of renewable energy. The major breakthrough specific to the industrial sector is a significant reduction of energy consumption, which is obtained by the diffusion of optimized industrial processes (circular economy and industrial ecology principles), combined with 30% energy efficiency gains.

## 2.2 Assumptions

While low or zero energy solutions may be relatively easily implemented in new buildings, the retrofitting of existing buildings will have to be implemented at a very large scale, in the range of 600,000 units per year. This will require a com-

Figure 7. Energy Use Pathways for Each Sector, by Fuel, 2010 – 2050




7a. Industry

7b. Buildings

7c. Transportation

bination of technical advancements (incremental innovations in the building practices and radical innovations in materials and control instruments), capacity building in the industry, and specific policy measures to overcome legal and regulatory barriers.

The transport pathway is supported by a combination of land and urban planning, organizational innovations, and behavioral changes. Technological innovation is also decisive to promote smart logistics and support the diffusion of alternative motorization types (hybrid electric, plug-in hybrid electric, full electric, and natural gas vehicles). In particular, the development of natural gas vehicles in France could be facilitated by its development in neighboring countries, which are already adopting this technology, and by the progressive deployment of biogas combined with the decrease in gas consumption for heating.

In industry, technological breakthroughs are not central to the Illustrative Decarbonization Pathway; the optimization of industrial practices (circular economy and industrial ecology principles) is the key option to decouple energy use and carbon emissions from production.

Finally, energy production is highly decarbonized essentially thanks to power-generation renewables, biogas and biofuels, the development of all these sources being in line with available assessments of their potentials for 2030 (Tanguy & Vidalenc, 2012).

## 2.3 *Alternative pathways and pathway robustness*

After consideration of 16 pre-existing energy scenarios (from NGOs, or academic research, or public agencies), the National Debate on Energy Transition in 2013 identified four families of possible pathways: SOB for sobriety, EFF for efficiency, DIV for diversity, and DEC for decarbonization (Ardity et al., 2012). Each describes contrasted but consistent alternatives for the deep decarbonization of the French energy system along two dividing lines: the level of demand and the energy mix (between a priority to nuclear, to renewables, or to a diversified set of energy carriers).

All these trajectories describe a plausible deep decarbonization pathway, since they all reach the Factor 4 emission reduction target (SOB and EFF even reach more ambitious reductions of carbon to leave more flexibility on other GHG gases) and the Illustrative Deep Decarbonization Pathway belongs to the EFF family.

The common features among these four pathways are numerous, although each supposes different ambition levels for sector by sector developments, and define a set of minimum requirements to reach the Factor 4 overall target. This concerns in particular:

- In the building sector: a deep retrofit of buildings with important efficiency improvements (at least 300,000 units in the residential and 15Mm$^2$ of commercial surface with an average energy efficiency gains of 45%), a phase out of oil product uses for heating and systematic improvements of appliances' energy efficiency
- In the transport sector, a switch from individual cars and trucks to rail and collective transport and important efficiency gains in vehicles (at least 50%)
- In industry, energy efficiency improvements (at least 20%) and optimization of industrial processes

These common features provide a robust identification of the key dimensions of the decarbonization strategies for France. However, the intensity of some actions driving the pace and ultimate potentials of energy demand reduction and of energy decarbonization in the Illustrative Pathway may be questioned. This concerns particularly the retrofit of the whole building stock by 2050 implying 600,000 annual retrofits, the role of biogas as an important combustion fuel, the mix of new technologies, including biofuels, replacing the conventional car (electric vehicles, hybrid vehicles, and NGV) and the rapid scaling-up as well as high final level for renewable electricity. Should these targets prove to be too difficult to attain, then the decarbonization strategy should integrate the constraints and be adjusted in due time. To compensate for weaker reduction in final energy consumption, a higher level of decarbonization could be sought with more nuclear and more of other decarbonized sources, particularly biomass and waste heat, and finally the introduction of carbon capture and storage, particularly in industry. A DIV – i.e. diversified mix – trajectory would provide such an alternative pathway resorting to less ambitious assumptions on efficiency but still reaching deep emission reductions thanks to more low-carbon supply in due time. It is worth noting that a DIV-type trajectory can be considered as a "second-best" pathway, in the sense that it is not the most robust given its dependence upon the availability of a vast set of not currently commercially available technological options (notably CCS); such pathway then offers a solution if it appears that the implementation of an EFF-type trajectory does not allow to reach the deep decarbonization trajectory because of unexpected barriers and difficulties in mobilizing energy efficiency potentials.

The Illustrative Deep Decarbonization Pathway relies on the assumption of an economic competitive nuclear in the future. If this assumption proves to be optimistic for future nuclear development, more renewable energies can be mobilized for electricity production reorienting the scenario in a SOB-type trajectory.

## 2.4 Additional measures and deeper pathways

Some technical options are not considered in the Illustrative Pathway, but play a central role in alternative scenarios presented above, notably:

- Methanation: synthetic methane from a recombination of carbon dioxide (from fuel combustion), hydrogen (from renewable electricity), heat and a catalyzer can be used as storage capacity in gas network and as a non-carbon energy for transportation.
- Carbon capture and storage: significant storage capacity in the North of France could store 40 $MtCO_2$/year from 2040 mainly for industry.
- Nuclear cogeneration, although a sensitive issue, can be used to supply heat for buildings and industry.

## 2.5 Challenges, opportunities, and enabling conditions

*Bio-energy supply*

A crucial challenge for the Illustrative Pathway is associated with the capacity of the agricultural sector to develop an important bio-energy supply with second generation biofuels and biogas for energy substitution.

*Implementation of a carbon tax*

One of the most important instruments to trigger the necessary changes in technologies and behaviors for the energy transition is the implementation of a price signal through carbon taxation, which could be used to lower taxation on labor, to finance energy efficiency and renewable energy development, or be transferred as a lump sum to households, particularly the more vulnerable ones.

*Financing the energy transition*

Whatever the energy pathway, the energy transition would require very large investments amounting to around 2,000 bn€ over the period (the building retrofitting program only would require between 20 bn€ and 30 bn€ each year). Even if the energy transition will more than compensate the extra investment by decreases in the energy bills of households and industries, one of the main barriers to finance the energy transition is the lack of short-term profitability of energy transition investments for private agents: the difference between private discount rates (typically 10-15% p.a. or more) and social discount rates (2-6% p.a.) has since a long time been identified everywhere as the major cause of the "efficiency gap." Several proposals for triggering the financing capabilities exist: orienting household savings, such as saving accounts (1,300 bn€), in low-carbon investments, creating a public bank such as the KfW in Germany for the thermal retrofitting of buildings, creating an entity for the financing of the energy transition (focusing on the retrofitting program, and on the development of renewable energies) with a guarantee from the State..

*Professional transitions and formation*

Employment has become a very central issue of the energy transition debate. Quantitative studies of the energy transition in France conclude to a positive assessment with massive job creation potentials in renewable energy, construction, infrastructures, and collective transports. New skills will have to be developed (for thermal retrofitting for instance) at a very large scale and as rapidly as possible. On the other hand, occupational retraining programs will be needed for jobs in activities such as road freight transport, car industry, or in nuclear energy. With around 10% of active population currently unemployed, the acceptability of energy transition is conditioned upon credible answers for professional transitions in these sectors.

*Local authorities, governance, and social feasibility*

Concrete examples of energy transition actions such as building retrofitting, optimizing local renewable resources in function of specific uses, developing networks for heat or for gas, show that concrete actions already happen at local level. Energy issues are indeed directly linked to many other local policies: urban planning, local transports, wastes, housing , and also social policies at the urban or municipality levels. Regional authorities are already in charge of transportation, land planning, economic development and training. Participatory processes are also an element of acceptability of energy transition. Further, by empowering local governance systems, national policies could leverage existing local experiments, accelerate policy responses, foster resource mobilization, and engage local stakeholders.

*Stability in climate policy orientations*

The long term Factor 4 objective that became a legal target in 2005 is an important catalyst for climate policies by stabilizing expectations of consumers and economic agents in their low-carbon investment decisions; a medium to long-term stability of climate policies is needed. Although this target has been unopposed by any stakeholder group since its very first introduction by the Mission Interministérielle pour l'Effet de Serre in 2003, some governmental decisions apparently contradictory to official objectives have been observed notably for wind and photovoltaic policies: administrative decisions impose new constraints on wind development and, since 2011, the feed-in tariffs for photovoltaic are revised every 3 months. As a result, wind and PV development have significantly slowed down and the 20% target for renewable energy development in 2020 may become unattainable. The implementation a pre-established increasing carbon price would be central for a full environmental and economic efficiency of public policies.

*Ambitious EU and international climate energy objectives*

Ambitious EU and international climate energy objectives are also of paramount importance for numerous reasons: leverage effect of EU objectives and induced directives on national policies, credibility and acceptability of national policies, industrial strategies for low carbon technologies and economic competitiveness issues.

### 2.6 Near-term priorities

Near-term sectoral priorities should focus on renewable energy development and the implementation of the building retrofitting plan. These two actions are crucial for any deep decarbonization pathway in France, but face strong inertias (both because they are associated to long-lived infrastructure and require the development of specific skills that are not currently available), which make early development crucial. In addition, these actions have strong potential positive effects on employment that can increase the social and political desirability of these measures.

In addition, specific financing mechanisms must be conceived to support in particular the massive retrofitting program and a carbon price has to be rapidly implemented, even at a low level during the first years, but with a pre-established increasing rate (in the range of 4-5% p.a., the level of the social discount rate), in order to reach a level near to the 100 €/t$CO_2$ in 2030 that has been already identified as consistent with the policy targets.

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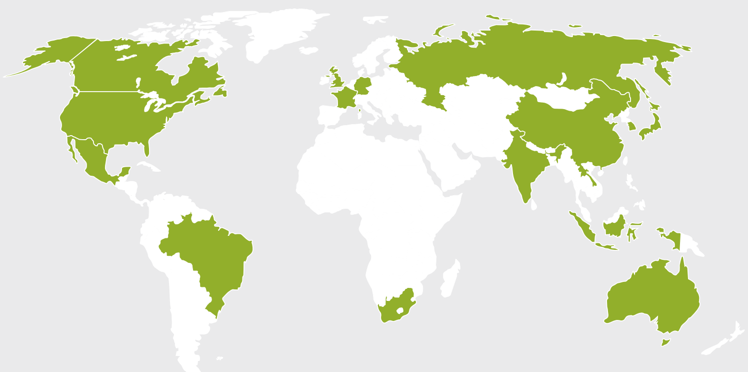

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