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ZEN

net-zero

2050

Imagining and building a carbon-neutral France

entreprises pour l'environnement

CHAIRMEN'S MESSAGE

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"France wants to achieve carbon neutrality by 2050", announced the Prime Minister back in July 2017, causing us to ask in puzzlement: what does this goal actually mean? Is it within reach? Is it not already too late? What would be the use of a national target if it was not also adopted by our closest economic partners?

Twenty-seven EpE member companies (the list is set out on the back cover) asked themselves those questions and decided, in light of the complexity of the subject, to address them together. To this end, they tasked a group of experts to condense the mass of relevant information and explore the lifestyles compatible with that goal. They then shared those insights with each other as well as with various stakeholders, and discussed many critically important points with a view to ensuring consistency of actions in the different sectors (food, industry, energy, transport, housing, etc.).

The main conclusion of this study is positive: yes, it is still possible to achieve carbon neutrality, without stifling the economic growth critical for employment and living standards, and without giving up on good life.

The second conclusion too is positive: achieving greenhouse gas emissions neutrality is also desirable because the changes required will lead to healthier, indeed more enjoyable, lifestyles than those we have today.

The third conclusion expresses a condition. Achieving neutrality involves unprecedented change. A transformation on such a scale could only be achieved if the three following groups of stakeholders realise that they are interdependent, do the heavy lifting, and act together:
- Corporate actors must transform their offering through innovation and massive investment, against a background of changing solutions and renewed, strong competition;
- Public authorities (local, regional, national and European) must deploy new instruments geared to accelerate overall investment without unnecessary risk;
- The French people themselves (consumers, citizens, actors of change) must make up their mind what they want to build collectively and along which pathways. We need basic low-carbon products and services to be accessible, and policies regulating community life to ensure that everyone bears their fair share of the collective effort.

Coming together and acting in concert with our international partners is the sine qua non of such net-zero society.

As well as showing that such a transformation is possible, this publication aims to arouse a collective willingness to move forward, lay out pathways and, above all, open up dialogue with other actors to upscale action.

The French people will benefit because the issue of climate is critical and many actively support action on it.

Business will benefit because making this transition will create economic growth. France is not alone in this effort. Businesses, cities and citizens all over the world intend to move forward in the same direction and have been engaged for many years in the pursuit of low-carbon technology, often very successfully. In this connection, we have to be mindful of emerging global markets and of the need to gain a foothold in them sooner rather than later.

Public authorities will also benefit because they have the task of securing the best possible outcomes nationally and locally, and of proposing a future that people understand and desire.

At the end of this study, we encourage stakeholders to move along pathways that have been decided upon together. The necessary changes identified in our study are ambitious and will transform our way of life. The fact that they must start now leads us to make recommendations for action in the short term.

EpE member companies have already made commitments and initiated many changes. They hope this study will be a new significant step towards addressing one of the greatest challenges of our time.

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EXECUTIVE SUMMARY

Commissioned by a group of companies from all sectors, the ZEN 2050 study explores the feasibility of carbon neutrality in France by 2050, in terms of the balance between emissions in metropolitan France and absorption through carbon sinks. It identifies a number of conditions for a successful transition, and concludes with proposals for short-term actions that ensure the transformation remains economically and socially viable.

It is an ambitious - and original - study in that it incorporates the physical, technical, economic and sociological aspects into a coherent and plausible whole. Thus it is neither a forecast, nor a corporate commitment, nor a prescriptive requirement. It concludes with a **proposal** from these companies to the other components of society (general public, government authorities and economic stakeholders), **inviting** them to define together the detailed actions required to undertake the transformation.

Meticulous study of cross-cutting issues

Throughout, the study follows a set of principles that determine many of its conclusions, which the reader should be aware of:

- The aim of the study is not to come up with a single scenario, but to highlight potential options and inherent difficulties and opportunities;
- It primarily targets emissions in metropolitan France under the Paris Agreement, and secondarily a reduction of the country's carbon footprint;
- It assumes that decarbonisation occurs in a context of GDP growth without the outsourcing of economic activities, even if such delocalisation has so far largely contributed to a reduction in French emissions. On the contrary, it suggests developing new industrial activities;
- Priority is given to the deployment of existing energy-efficient and fossil fuel substitution technologies, rather than to breakthrough technologies;
- The study aims to assess the conditions of carbon neutrality in France and assumes that greenhouse gas absorption in other countries will not be used as offsets, nor will there be massive biomass imports;
- It has not factored in the country's adaptation to climate change at regional level, nor the variations in carbon sinks or in the energy needs driven by this change.

The methodology of the study, after reviewing existing studies, consisted in the convergence of two parallel projects:

- A definition of **carbon neutrality by 2050**: what role would carbon sinks play? How would emission reductions required for neutrality be shared between economic sectors?
- **A sociological review of lifestyle changes** conceivable by 2050, consistent with and respectful of France's diversity.

Upon completion of these two projects, the study focused on transformation pathways towards this goal, and on the consequences for employment and investment in the sectors most directly affected.

The next stage consisted in identifying and describing in detail some of the **conditions necessary for the success** of these pathways.

The last stage of the study consisted in drawing up **recommendations** for all actors on the short-term actions to be taken to ensure that 2050 neutrality-compliant pathways remain within reach.

Economic and societal revolution

The primary conclusion is that carbon neutrality is within reach. The underlying assumption is that France would double its carbon sinks up to approximately 100 $MtCO_2eq$, which would equal the country's emissions, themselves down by some 80% compared to 2015. This transition is a **revolution** in that it reduces emissions by over 4% a year over the next thirty years, in sharp contrast to the paltry 0.5% annual drop in emissions over the last twenty-five years, mainly due to reductions in industry. **This change is unprecedented**.

The lifestyles described in 2050 are diverse, credible and realistic. While some trends, notably in food consumption, will continue, others will have to change, including the distance from home to workplace, the rebound effects of energy efficiency, mobility modes, and home insulation. This will involve deploying on a widespread basis the current lifestyles of the most engaged key consumers, while respecting the diversity of motivations and consumption patterns. Such a transition would deliver a **host of benefits**, including improved air and food quality, health, noise levels and living conditions.

This neutrality is compatible with economic growth. The transition is expected to be employment-friendly, but modestly would require sweeping changes within and between sectors. Some regions will also have serious transformation needs and should be assisted with their reconversion. The transformation would require substantial investment from both the public and private sectors. However, the study does not deal with the policies and conditions needed to ensure that growth assumptions are fulfilled.

The major systems that organise our lives would be transformed: more urban housing, largely electric, service-based mobility, locally sourced food with less meat, a circular economy driven by virtually fossil fuel-free modes of consumption and production, final energy consumption halved, and a tax and financial system geared to the transformation.

The development of new uses for agricultural and forestry products (energy, materials, chemicals) will certainly place a strain on biomass availability, which will become a key issue. The transformation therefore calls for increased production and new forms of governance.

The second message, too, is positive: achieving greenhouse gas emissions neutrality is also desirable because the changes required will lead to healthier - indeed more comfortable - lifestyles than those we know today.

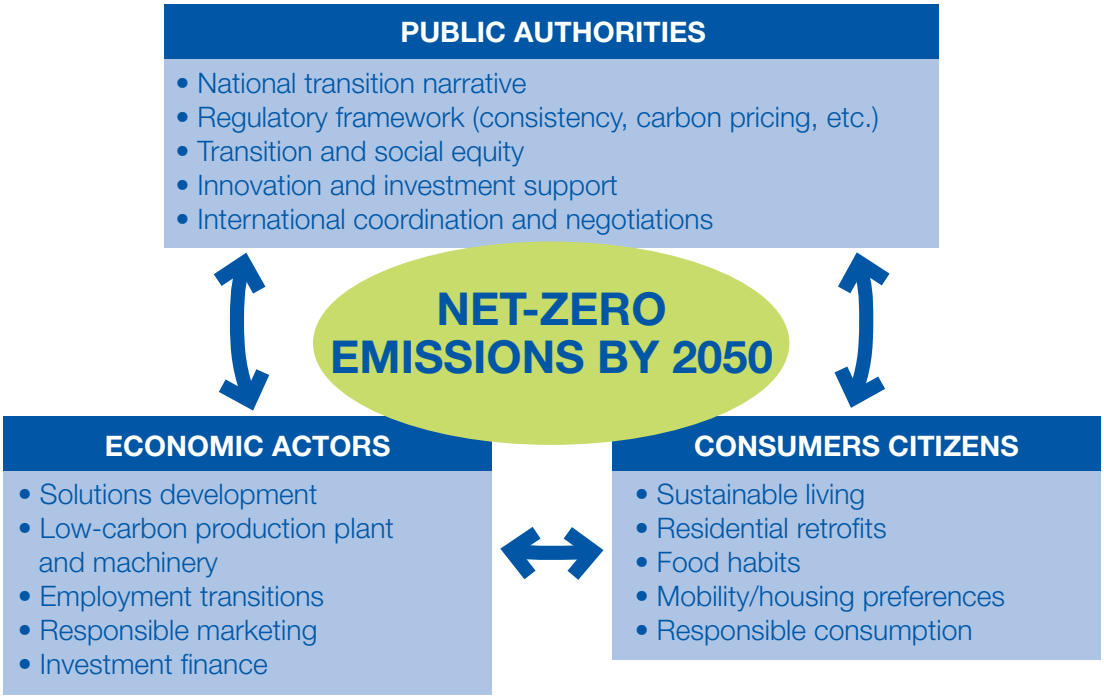
The third key message is conditional: everyone needs to do their share and all solutions should be leveraged. Stakeholders, all levels of government, consumer citizens, and economic actors are interdependent and need each other for this transformation, with each group playing multiple roles.

The economic viability of the transformation is conditioned by the level of international cooperation, which must extend to incorporating climate into international trade rules and European non-climate policies (external trade, transport, common agricultural policy, industrial, economic and R&D policies, etc.).

Apart from very rare exceptions, **the massive deployment of existing technologies** would achieve the required reduction levels without requiring breakthrough technologies. **Research and innovation initiatives** in companies, coupled with public research, could contain costs and alleviate the burden.

Because France is falling behind on its emission reduction commitments and the transformations required are significant, any additional delay would jeopardise the attainment of the goal announced in 2017. **Transition at the required pace creates an urgent** need for **binding, incentivising and socially fair policies** that take the long view in a credible way for both business and consumers.

The study concludes with recommendations for actions to be undertaken as soon as possible to ensure that the transformation towards the goal of carbon neutrality by 2050 remains within reach.



Recommendations on ways to bring about this transformation

1 / Mobilising French people by sharing awareness of the climate emergency and the 'carbon-neutral France by 2050' project.

One condition for the acceptance of this undertaking is joint mobilisation of national and local authorities, businesses and consumer citizens and their adherence to a shared narrative.
However, the communication on climate change has so far largely ignored action by the general public. Assuming collective ownership of the issues, pathways and means related to the transformation therefore implies a major education and mobilisation drive.

2 / Acting internationally to use access to the European market as a lever for global decarbonisation, and the European carbon as a lever for competitive industrial transformation.

There are three reasons for accelerating international action:

- France's carbon footprint remains very large; giving preference to imports from countries with an ambitious climate policy would reduce it;
- Industrial investment will occur in the context of a foreseeable increase in the European carbon price and fair competition;
- Acceleration in French exports with a significantly lower carbon footprint than those of most other countries would lead to a reduction in global emissions.

3 / Giving a positive image of carbon taxation by explaining its purpose, pathway, revenue utilisation and accompanying social measures, so that it is perceived as fair and equitable.

Higher taxes on emissions and a rise in energy prices are a precondition for the transition. Their impact on household spending and decisions are noticeable daily. We recommend transparency in the use of tax revenues and allocating those revenues to financing the transition to net-zero emissions. Measures to ensure socially fair taxation should support the efforts of social services to improve household resilience and address energy poverty.

4 / Ensuring that transition-related investments mobilise both the private and public sectors and include employment and territorial transitions.

We recommend increasing annual investment in net-zero 2050 pathways from €40 billion today to upwards of €75 billion a year by 2030 (we were not able to include the investment requirements of all sectors in our study). A national private and public investment plan would be easier to finance if funds were diverted from emissions-intensive activities by carbon price increase expectations.

5 / Developing town and country planning projects in line with climate goals.

The current urban growth model, largely conditioned by taxation, history, town planning policies and social representations, should be altered for the purpose of climate transition in favour of denser, more resilient cities and villages. This involves strengthening the attractiveness of urban space through the provision of neighbourhood services and better living conditions, as well as cutting by half the speed of land take.

6 / Developing, managing and valuing various biomass services.

With biomass extracted from waste, agriculture and the forest playing a key role in the substitution of fossil fuels, its limited supply (excluding imports) would be an economic constraint.
Forestry and farming policies must double the capacity of sinks and maximize resource availability based on differentiated territorial dynamics. We recommend introducing governance to manage competition and synergies between uses.

7 / Introducing building retrofit schemes based on binding obligation and financial support mechanisms.

Retrofitting is one of the most critical and difficult transition issues, particularly in view of the multiplicity of decisionmakers involved. We therefore recommend introducing mandatory low-carbon retrofits based on appropriate solutions for people and buildings (individual and collective housing, public buildings) that combine public and private funding, depending on circumstances. We suggest making retrofits mandatory when transferring ownership or drawing up long-term leases for individual dwellings, and in complement to the obligation on condominiums to clean up building façades.

8 / Switching to non-emitting mobility and phasing out fossil fuel engines.

The transformation of mobility must combine the phasing out of GHG and local air pollutant emissions-intensive options with the rapid introduction of low-carbon modes of transport: soft modes, public transport, electric mobility, biogas and carbon-free hydrogen fuels. In order to reach net-zero emissions by 2050, the marketing of all-combustion-powered vehicles must stop much earlier. The market share of plug-in hybrids will be restricted by the limited availability of biofuels.

9 / Modernising industry by promoting low-carbon investment.

Because rising carbon prices are a necessary but not sufficient factor in influencing corporate decisions in the right direction, we recommend encouraging low-carbon investments (energy efficiency, circular economy, process electrification, etc.) through appropriate mechanisms such as grants for industrial and social conversion, innovation, carbon leakage prevention, risk reduction, and more.

10 / Assisting the transition of agriculture to a quality-based model.

It is urgent to rethink the European economic model of agriculture, currently based on integration into an undifferentiated global market. The building of quality clusters that also address climate, environmental, productivity, nutritional and health issues could be driven both by European and French agricultural policies and by the development of new products and services provided by agriculture.

11 / Eating better by promoting healthy eating habits for humans and the climate.

A profound change in patterns of food consumption is already under way, promoting emissions reductions and health. This trend should be accelerated and perpetuated by food and health policies, public as well as private mass catering practices, and a reduction in food waste which, along with meat consumption, should be cut by half.

12 / Educating all young people about our environment and climate.

Today's younger generations will devote the bulk of their working life to climate transition, and must be prepared for it. Dedicated programmes must be developed and incorporated into middle school and higher education and teachers must be trained in all fields from life sciences to technology and humanities.

13 / Shifting advertising towards sustainable consumer habits and lifestyles.

Through advertising companies do play a key role in shaping representation of lifestyles by consumers. Advertising should be consistent with the lifestyles of a carbon-neutral France.

14 / Anticipating impacts of climate change and adaptation needs of regions.

The effects of climate change are already noticeable and will be even more so in 2050, even if the world follows a trajectory compatible with the Paris Agreement. Although the study has only partially touched upon this point, we recommend anticipating such impacts now and strengthening territorial resilience.

The solutions exist and companies are already committed to developing them. The ZEN 2050 study sets forth an ambitious and demanding vision of a common destiny that businesses, citizens and public authorities must build together.
Businesses are ready to throw in their lot with this movement if the nation collectively takes the decision to drive it.

CONTENTS

WHY CARBON NEUTRALITY?

In April 2014, based on the reports published by the IPCC, the Secretary General of UNFCCC called on countries to raise their collective ambition, pointing out that global carbon neutrality in the second half of the century is a necessary condition for the protection of humanity from the adverse effects of climate change.

A year and a half later, the Paris Agreement endorsed in article 4-1 the aim of the parties "*to achieve a balance between anthropogenic emissions by sources and absorption by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty*", and called on all countries to develop long-term strategies by 2020.

The Climate Action Plan submitted in July 2017 by the Minister for Ecological Transition and Solidarity Nicolas Hulot confirmed France's commitment to carbon neutrality by 2050. This goal is reiterated in 2018 in the second National Low-Carbon Strategy plan. The plan highlights France's dual responsibility as the torch-bearer of the Paris Agreement, and as a rich country with the resources to be ahead of others. The assets possessed by France, its low-carbon electricity and the economic opportunities presented by this transition are also highlighted. France is not alone: at the end of 2017, 19 countries and 32 cities, as part of the Carbon Neutral Coalition, voluntarily committed themselves to carbon neutrality.

There are four main levers for acting on carbon neutrality (carbon refers to all greenhouse gas emissions whose impact on climate is measured in "tonnes of carbon dioxide equivalent"):

1 Reduction of the share of fossil fuels in energy production. In 2012, the International Energy Agency (IEA) estimated that consumption of more than one-third of proven fossil fuel reserves is incompatible with the 2°C goal[1], unless there is widespread deployment of Carbon Capture and Storage (CCS) technologies.
In 2015, new estimates(2) show the 2°C goal requires that one-third of today's recoverable oil reserves, half of the gas reserves and 80% of coal reserves should remain underground.

2 Reduction of energy consumption. Thinking about going carbon neutral requires action not only on energy production, but also on energy consumption across all sectors of the economy, because all the alternatives to fossil fuels have significant drawbacks or limited availability.

3 Reduction of non-energy emissions from agriculture and some industrial processes.

4 Increase in carbon sink capacity: the use of negative emissions is considered in an IPCC special report on the impacts of 1.5°C global warming as critical and complementary to emissions reduction.

Carbon neutrality is thus a necessary, ambitious but also unifying goal, since it implies the involvement of society as a whole. Each one of us can in one way or another activate any one of the above four levers.

1 *World energy outlook 2012*, AIE.
2 *The geographical distribution of fossil fuels unused when limiting global warming to 2°C*, Christophe McGlade & Paul Ekins, Nature volume 517, pages 187–190, 8 January 2015

ABOUT THE STUDY

Approach

Throughout the 18-month study, EpE sought to identify and understand the greatest possible diversity of facts, arguments and opinions. Accordingly, the approach and methodology relied on:

- A steering committee, composed of representatives from the 27 companies supporting the project and a representative from the 2050 Pathways Platform that met monthly to guide, enrich and validate the study. The diversity of sectors represented in this group is one of the distinguishing features of the study and strengthens its credibility;
- A consortium of recognized experts that carried out the modelling, the sociological study and the sectoral analyses;
- A wide review of existing work, in particular sectoral, national and supranational road maps;
- Consultation on three occasions of a panel of stakeholders (scientists, NGOs, economic actors, etc.) known as the "Circle of Inspiration";
- Consultations, especially regarding recommendations, with many professional organizations;
- A citizen consultation, based on the widely accepted Ipsos method.

All these elements are described in the Annexes.

Organising principles - credibility and consistency

The preparation of prospective studies is a complex exercise based on assumptions, and therefore bound to have limitations of which one must be aware at the time of reading.

The structuring principles are outlined in the executive summary for "Meticulous study of cross-cutting issues".

Moreover, the study assumes the existence of a global environment in which all countries are mobilised to achieve the goals of the Paris Agreement, with France setting the pace.

Plan and contents

The description of the lives of nine households that opens the study showcases the point of arrival, underlined by a diversity of lifestyles and attitudes which many may share. These portraits are compatible with France becoming carbon neutral by the target date.

The study goes on to describe what these different lifestyles reflect, namely the changes that must be made in society's key organizational systems (food and agriculture, cities, territorial mobility, energy, industry) and macroeconomic balances.

The study continues with an analysis of economic sectors, focusing on the levers that can be mobilised to bring about change.

These elements form the basis of a credible, consistent and ambitious approach, whose feasibility is subject to a number of success factors dealt with in the fourth chapter.

The last chapter lays out recommendations on what should be done in the short term, over the next few years, to ensure that the goal remains realistic. The transformation of France proposed over thirty years already constitutes an unprecedented change, the delaying of which would jeopardise it irreversibly.

1

LIVING
IN A NET-ZERO FRANCE

Portraits of nine
French families

The description of a net-zero emissions society by 2050 rests on a forward-looking examination of the changes in the lifestyle and behaviour of households[3], that will enable the transition. The ZEN 2050 study relies on a forward analysis, innovative in sociology, of daily life in a carbon-neutral France.

To avoid the pitfalls of presenting "statistically mean" portraits that do not refer to any real household, our analysis draws on **a set of factors representing the diversity of households and their lifestyles**, and portrays diverse families, socio-professional categories and places to live.
It also shows **the varied attitudes and reactions of citizens**, ranging from passionate climate action commitment to various forms of reluctance, underpinned by motivations that at times have no direct bearing on climate.
For example, while flexitarianism[4] has been on the increase over the last five years, it is mainly for reasons of health and animal ethics. Conversely, those who remain attached to cars are not necessarily climate sceptics as such.

The nine portraits are based on empirical data, as contained in sociological studies carried out over the last ten years[5].
These studies reveal the **different motivations of households** and divides them into two groups: **the level of needs and thus of emissions initially, and the level of motivation or ability to change their practices.**

The level of needs reflects the quantity of services required to meet the needs for energy, products and services (including food) that emit greenhouse gases. These needs are shaped by the convergence of three key factors: **place to live** (urban, peri-urban, rural), **family situation** (without children, with children, retired), and **income** (three levels). For the sake of simplification, households are divided into three need levels: low, medium, high.

Households are divided into three groups based on the incentive **to change practices:**

- **"Drivers"** (20% of households), who want to change and value restraint for its own sake;

- **"Waverers"** (60% of households), who employ differentiated strategies of resistance or participation, depending on which stage of life they are in, their felt needs at that point in time and the type of need;

- **"Foot-draggers"** (20% of households), who reject the demand for change.

If these determinants and motivation levels were to be combined, 81 portraits are theoretically possible.
For the sake of simplicity, only 9 are presented here. They may not be representative of the share of these determinants in the French population, but they do illustrate the latter's diversity.

3 For the definition of the term "household" see https://www.insee.fr/fr/metadonnees/definition/c1879
4 The fact of eating meat less often and in smaller quantities, without being vegetarian
5 See ZEN 2050 methodological note. Inter alia: ADEME, Énergie Climat 2030/2050. Quels modes de vie pour demain ? La Documentation française, 2014. D.Bourg. Les Scénarios de l'écologie, Éditions Hachette, collection "Questions de société", 1996. Elioth, Egis Conseil Bâtiments, Quattrolibri et Mana. Paris change d'ère. Vers la neutralité carbone en 2050. 2017

By convention, the respective shares of the three motivation groups (drivers/ waverers/foot-draggers) are stable over time, with the lifestyle of the people within each group evolving at varying speeds.

Emissions decrease among all groups depending on the availability of infrastructure and low-carbon services and goods. How often, and the extent to which, the solutions on offer are used varies from one profile to another.
An over-50 male "foot-dragger" will not have the same emissions reduction as an over-50 "driver", even if they live in the same building.

In sum, we assume that change will be cross-cutting. Flexitarianism may be a minority position in 2020, but it will become the norm among "waverer" households by 2050, which will still account for 60% of the population. Among "drivers", flexitarians will have become vegetarians, and "foot-draggers" will continue to eat meat like the "waverers" of today. This is the rationale behind both the preparation of the nine portraits and the analysis of needs for goods and services in different sectors.

In preparing the portraits,
we have striven to ensure that they:

- **are communicable**, i.e. easy to read, based on a limited number of families;
- **focus on essentials** rather than on being exhaustive, and target the main sources of emissions (food, housing, travel), followed by secondary sources (consumption, services, health, leisure, social relations);
- **factor in some of the known impediments** to change, such as income constraints, inadequate infrastructure or public services, values, previous choices;
- **take into account the reactions** to public policies, including the fact that the pathway between 2020 and 2050 will involve more than just awareness-building policies and appeals to voluntary action.

1.1 Summary of portraits

The nine portraits chosen here to illustrate the lives of French people represent some of the households that will be living in France in 2050. Each household has varying motivations and levels of interests as part of a society where the search for a drastic reduction in emissions affects them in different ways and with varying degrees of involvement on their part. The characteristics highlighted are purely for illustration purposes. They are the elements taken into account to draw nine household portraits out of a possible 81. One can imagine so many more!

emissions / motivation	LOCATION / FAMILY SITUATION / FOOD / HOUSING / MOBILITY / INCOME		
	LOW	**MEDIUM**	**HIGH**
Foot-draggers 20%	**Frustrated foot-draggers** • Urban, multimodal with car, new/retrofitted flat, meat-eating flexitarians, low-income, holidays by car, soft mobility out of obligation. • Emit little and cannot afford to emit either less (EV, retrofits, etc.) or more. Feel obliged to be careful and do not like it. If they could afford it, they would not want to emit more, but would consume more without caring too much about their emissions. • Frustrated because if they could, they would consume and emit more, even though this is not a goal in itself.	**Comfortable foot-draggers** • Urban belt, electric car, unretrofitted semi-detached house, children, meat flexitarians, higher-than-average income, holidays by car. • Emit moderately and have the means but no desire to be exemplary, taking only those measures which don't impact their comfort and pleasure. • Hooked on comfort, they are little concerned and not greatly affected by the climate. While they pay attention to their emissions, it is never based on restraint, but on the use of available technology.	**Unabashed foot-draggers** • Rural, hybrid car, house refurbished in the past, children, flexitarians, high-income, holidays abroad by plane. • Can afford to emit a lot or lead a really low-carbon life, but are unreservedly wedded to their comfort in all areas. • The obligation to be careful annoys them. Want to eat lots of meat, be on the move and travel as they wish.
Waverers 60%	**Moderate waverers** • Urban, multimodal, car at weekends retrofitted flat, children, low-income, little-meat flexitarians. • Emit little and have few means either to emit less or much more; the quality of their home increases flexibility in other areas. • Tend towards restraint, but don't shy away from comfort/pleasure in some emitting areas, deemed important for their quality of life, while being careful.	**Comfortable waverers** • Semi-urban, multimodal, car, house, retired, medium-meat flexitarians, middle income, holidays by plane or car. • Emit moderately and feel comfortable about their position. Make strategic choices about their mobility and consumption. Don't seek to consume more, but look for the right balance between comfort, pleasure and emission. • Sometimes feel their efforts are not much use and the financial, physical and cognitive demands are quite excessive. How they view those efforts also depends on where they live and their desires and living conditions.	**Emitting waverers** • Couple in their fifties, refurbished flat in town, medium flexitarians, high-income. • Hooked on quality of life with an "old world" touch; feel they do enough not to emit too much, but their effort impinges on their comfort and pleasure. • Bigger-than-average consumers (goods, space and mobility) and emitters.
Drivers 20%	**Happy moderates** • Urban, multimodal, new flat with children, vegetarian, low income; have the means to be moderate, practise restraint with pleasure and conviction in all areas. • The happiness of restraint: restraint becomes a way of life, a pleasure and an exercise. They are the ideal type of net-zero citizen: happy regardless of their means, because their personal satisfaction criteria are more intangible and immaterial than material.	**Frustrated moderates** • Semi-urban, multimodal with car, refurbished flat, 3 children, little-meat flexitarians, middle income. • Emit little but would like to emit less (EV, retrofit, etc.), while maintaining a degree of comfort/pleasure in some areas; their life circumstances don't afford the flexibility they would like.	**Dissenting moderates** • Middle income, one child, medium-sized town, tenants. • Emit little but feel it's too much and cannot afford to emit less. • Like and seek restraint, but their life circumstances make this difficult, so feel guilty.

The table summarises various living conditions, key emission factors and overall feeling.
The portraits also point to salient changes in the key systems that structure our lives and society:

- **Food :** overall decline in meat eating, especially due to an increase in the number of flexitarians consuming less meat, as well as an increase in organic and locally-sourced meat consumption. Being vegetarian will be less marginal in 2050 than today, but will still represent a minority. Health and animal ethics will remain the driver of change for all profiles.

- **Housing :** shift towards increasingly efficient buildings, both new and retrofits. However, all building stock will not be entirely retrofitted. Consumption will be focused on better energy management due to the adoption by all the profiles of home automation systems and more technically efficient household appliances, but also due to restraint, practised in varying degrees primarily by "driver" households as well as some "waverers". The relationship between housing and its direct environment will be strengthened across the board: for leisure, at work, in relation to nature and in everyday life.

- **Mobility :** the modal shift will continue towards low-carbon soft and mass transport modes, made possible by a cap on urban sprawl. The quality of supply will encourage and facilitate these uses for all profiles. For car transport, more carpooling and shared vehicles (driverless or not) will reduce fuel consumption per passenger-kilometre.
The deployment of electric vehicles will respond to the needs of "foot-draggers". Overall, mobility will continue to increase.

1.2 Foot-draggers

If the foot-draggers of 2050 emit less than those of 2020, it will largely be due to technological improvements, higher-quality buildings, changes in the energy mix, and a wide range of new mobility developments. In fact, only a very small part of their progress would be due to a shift in their practices or values. They are not necessarily climate sceptics, but they either reject any injunction to tighten their belt, or feel that their efforts are disproportionate and therefore useless given the size and global scale of the problem. Their daily comfort is their way of defining their well-being or the "good life". They often perceive policies, even service offerings, as obligations or restrictions in disguise. They follow and use those they agree with, and ignore or circumvent the others. Exercising restraint is perceived as diminishing their quality of life and well-being and imposing excessively restrictive rules. Indeed, only technical and structural management and efficiency will allow them to reduce their emissions.

Frustrated foot-draggers are forced to exercise restraint, because they cannot afford to do otherwise. They are not bent on emitting more GHGs, or consuming more energy, but would like to have more money, consume more products and services, and have fewer limitations on leisure activities, getting around, travel and everyday purchases. If their income increases, they will consume more. However, retrofitting is not a priority, whether or not they are owner occupiers. This profile is more prone to economic insecurity than others.

Comfortable foot-draggers are more comfortable precisely because their lifestyles match their values. They are quite comfortable with their non-involvement, without being radical about it. They can cut back a little on their comfort, but not much! Their level of income allows them to satisfy most of their reasonable desires, to travel a bit, and from time to time to afford more expensive and thus higher-emitting goods.

Unabashed foot-draggers defend their position. They consider their comfort and pleasures a non-negotiable right to their well-being, even though, like their fellow foot-draggers, they do feel social pressure. Any form of restraint is regarded as an assault on their rights and quality of life. They advertise their position, which is the basis of their day-to-day decisions. Their consumption and emission patterns are governed by their purchasing power, which is higher than that of dissenting moderates. As far as they are concerned, they are not responsible for the climate problem and thus don't have to pay for it or restrain themselves.

FRUSTRATED FOOT-DRAGGERS

Emma and Aude,

thirtyish without children

Emma and Aude, approaching thirty and without children, have been sharing a flat in collective housing for the last three years. Emma has just landed her first work contract - a temporary contract that may be converted into a permanent one - in the field of human resources, with a local, medium-sized construction company. Aude, after doing a Master's degree, has been on a string of temporary work contracts in digital resources.
For Aude, Emma is the "house green", as it is mainly she who is careful and she who says that everyone should do their share. Aude sees no reason why she should "*make an effort when climate is already a mess*". Anyway, given what they emit, she fails to see how she could make a difference.

In an effort to build their careers, they don't like the restrictions being placed on cars, which forces them to waste time on public transport or bicycles. The partial refund of the annual pass only solves Emma's problem up to a point, whereas Aude is not eligible for any refund.

Therefore, they share a hybrid car that they had bought second hand. It seems to them that building a career must have been easier before, when there were fewer restrictions and limits on transport.

Their 68 m² flat is in a fairly new building that is energy neutral (a standard requirement) and equipped with home automation systems. They are moreover unable to control the temperature ("*it's supposed to be regulated for optimum performance, we were told by the lessor*"), or the operation of the high-performance water heater. As they are a bit sensitive to the cold, they bought a supplementary electric heater for each bedroom. Their flat may be new and efficient, but at 19°C it's just too cold! In summer, it's the opposite. Their flat is south facing and is too hot, especially Aude's room.

They bought a small air-conditioner for the drawing room-cum-kitchen but, in what was a long drawn-out process, had to submit their inside temperature readings to the management company to obtain special permission. Otherwise, the flat is comfortable and does not cost much in energy.

The washing machine is shared; there are two on the ground floor in a common area. At first, "*washing one's dirty linen collectively was embarrassing*" and negotiations to allocate time slots created tensions. Since the *energy caretaker* installed an app on the home automation box, things are better and more flexible. On the other hand, not having a clothes dryer is a real problem, but it seems it consumes a lot of energy and disrupts the energy and humidity balance of the building.

They don't have many common activities, except for occasional evenings between friends. Aude has a boyfriend and spends her weekends at his place. They often go out of the city by car. Emma prefers to stay in the city and go to the parks and cycle greenways for pleasure, not for getting around. This enables her to recover from her crossfit sessions three evenings a week. On those days she uses the car to get around. The club is between her workplace and home, but she has to make a detour. However, to visit her parents (once or twice a month), she takes the train. During the one-and-a-half-hour journey, she either works or watches a TV series. Connectivity and opportunities for mobile work on trains have improved a great deal over the last ten years and make the journey much more pleasant and work-friendly. She often does video-meetings on the train which usually pass off without interruption.

Both women are careful about what they eat. They want to stay in shape and in good health, but both love meat. They don't eat it every day. Over the last few years, prices have increased far too much and meat has become too expensive on their salaries. "*But it's better for our health; we wouldn't eat it every day even if we had the money*".▲

COMFORTABLE FOOT-DRAGGERS

Paolo, Marie-Ange

and their three children

The work of 46-year-old Paolo explains his attitudes and practices, as well some of those of his family. He has a high position with matching pay. He's always in meetings, seeing people endlessly and working plenty of overtime. When he returns home, on the outskirts of Lyon, his wife and three under-12-year-olds are waiting for him. His hybrid car belongs to the company for which he works. It doesn't matter to him whether his car is petrol, electric or hybrid. What's important is to have a car. He "*does not like all the anti-car strategies being implemented by the local authorities!*" His car is his own personal bubble, "a personal mobile lounge, the only time I'm alone, and it's great!" He's therefore an addicted motorist. Public transport is not for him and he refuses to take it: "*the Bus or tram is livestock transport*". The bicycle is for leisure and children, "*not for proper travel*".

The family is, in their own words, "*unconventional in their conventionalism*": his wife does not work but has an active social life, in part because of - or thanks to - her networks associated with the extra-curricular activities of the three children, and her friends from the neighbourhood with whom she looks after a communal garden. She is the one responsible for the shopping, which she usually does in the neighbourhood, where "one finds everything". She sometimes buys organic products, but that depends on the products: "*organic bananas and oranges are no good as the skin is thick*". She does not look at the emissions label on the products. They are medium flexitarians, and eat meat several times a week but not every day: "*organic or not, it's too expensive, especially for five! But in summer, we just love our barbecues*", so they buy vegesteaks for their vegetarian friends..

They live in a semi-detached house built in 2014 which they retrofitted in 2035 as a result of a legal obligation indexed to income levels. Accordingly, they were eligible for a zero-rated loan and some tax deductions that were too little. The retrofit extended by eight years the repayment period of the property loan. They waited as long as possible to undertake the retrofit, thinking they might be able to avoid it but that proved impossible. In the end, waiting was not a good idea. They did the minimum required by law for a building of its age. As the children pointed out, it has reduced noise from the busy street as well as the energy bill. It has also enhanced their comfort in summer. Two years after the retrofit, they reduced the heating from 22° to 21° in winter, mainly for financial reasons, but also because the new thermal comfort standards made it possible. Another - unexpected - benefit is more comfort in summer and a lower air-conditioning bill.

In renegotiating their utilities contracts with their supplier, they were able to obtain the latest version of their energy home automation system. Marie-Ange and Paolo have an app on their telephones that allows them to control the heating, air conditioning and water heater during their absence with pretty aggressive yet financially attractive pricing. "*Make sure you don't overshoot during peak hours as it's extremely expensive!*" In the end, their bill is down by 8%. They pay attention to the lights and the children take one bath a week, otherwise they shower. They have bought the very latest clothes dryer, but "*with three children, laundry is nothing short of slavery - we don't need to overdo the ecological bit either!*" The dryer is very efficient, but the cycle is long. Thanks to the programmer, they only run it in the middle of the night. It means starting the washing machine quite late in the evening and moving the laundry to the dryer before going to bed, which they often forget to do.

For leisure, they stay primarily in their neighbourhood, except for the second child's fencing class, which is slightly out of the way. He would soon be able to go there by tram on his own, but for the moment his mother takes him by car and his father picks him up on his way back from work. They alternate holidays *in France (or neighbouring countries)* by car and holidays much further away by plane, every other year: "when we go by plane, once we are there, we don't move much, enjoying the local way of life and getting around by train or bus". Otherwise, they like the green services offered by their community, "*which are pretty good, with activities for children, places for barbecues, courses on biodiversity along the waterway. Really nice! We love our green belt, it brings real freshness*".▲

UNABASHED FOOT-DRAGGERS

Olivier and Audrey,

stepfamily couple with children living in a village

Olivier works in construction, Audrey is the manager of a large, well-known fashion store. Their hours sometimes see them working late into the evening and Olivier is often on the move. They are uncompromising when it comes to their comfort and they acknowledge it: they like meat and weekend barbecues among friends and adore baths. They even have a heated jacuzzi on the terrace, which stays on nine months a year.

They have two children, one each from their previous relationships. Audrey's daughter is in her teens. She is fairly self-reliant and lives with her mother and Olivier every other week. Olivier's eight-year-old daughter, on the other hand, comes every second weekend. Weekend hours are therefore very difficult to manage, more than during weekdays. They need two cars; they don't have a choice if they want to maintain their comfort and not burn themselves out. They refuse to budge. Moreover, because of his work Olivier cannot buy an electric vehicle as he is travelling around and carrying building materials. Audrey is more flexible in her mobility modes: on some days she takes public transport or the bicycle (but only in fine weather), and on others the electric car, when she has appointments or has to make deliveries.

They live in a small house in a rural municipality 25 km away from town. They have benefited from retrofit grants allocated to rural areas. They believe their relationship will endure and they will age together. It therefore made sense to retrofit their 60-year-or-so-old house. It had been refurbished in 2008, but technology has advanced a lot since then. After discussing the issue, they decided that air-conditioning was not really worth it. The village, which is protected from the summer heat by a hill, is well-vegetated and has won the "urban green spaces" award several times. Children's spaces are well designed, and the playground amenities are incorporated into the trees and the small stream. It adds a lot to their quality of life and is one of the factors that encouraged them to move into the village.

They share the shopping according to whoever has the time. There is a supermarket not far from the house where they shop when they need little things. There is also a local market twice a week with many local organic products, but they can go there only on Saturdays. They do the bulk of their shopping at a large supermarket in a business estate between their home and the town but, as it's not on the route to work, they have to make a special trip.

Pooling equipment is not for them. Having to share a washing machine or dryer is too personal. And frankly, the timings are too restrictive. They have therefore kept their washing machine and dishwasher, but not their clothes dryer as it seemed to them too costly relative to the time savings it generated, all the more so because the children take care of spreading the laundry.

For leisure, Olivier teaches sports once a week, even though sometimes the hours are difficult. But this sports lesson also gives him friends and help networks when he needs a hand or some advice. Audrey has no regular recreational activity, but she often goes out with her girlfriends either during the week to have a drink, or during the weekend for walks. In this case, they car share as it's more fun.▲

1.3 Waverers

Waverers are complex people and more diversified in their representations and practices than foot-draggers and drivers. Like the other profiles, they vary between three levels of motivation depending on their stage of life. They also differ from one consumption sector to another. They adopt different attitudes to these sectors according to their stage of life, and find a balance which remains stable in some cases or sectors, but evolves in others according to their preferences and desires. From the standpoint of the transition narrative, the range of possible interactions between practices, motivations and sectors is therefore greater. Waverers make up the largest and most diverse category of the population, which is why only three portraits hardly do justice to them.

Waverers do trade-offs, often in reaction to changes, opportunities (change of work, pay rise, arrival of a second child, moving house, etc.), or new difficulties. These trade-offs are between: (i) their pleasures; (ii) their "needs"; (iii) their levels of effort - and their perception of the effects of their efforts; and iv) their values (in terms of the environment and their definition of their quality of life and comfort). Therefore, while some prefer to travel and are concerned about the amount of meat they eat, for others the opposite is the case. Preferences can also be turned around depending on the stage of life, for example the birth of a second child. Some would rather give priority to soft modes, while others might feel they need a private vehicle. The transition to retirement has a real impact, resulting in a change of priorities or an increase in travel, but also greater involvement in the life of the community and local associations.

In other words, waverers are people with an adaptable profile, who calibrate and calculate in a flexible manner, and for whom an activity easily practised with restraint can become a constraint and vice versa. The relative emission levels (low, medium, high) with which they are comfortable therefore depend on complex trade-offs that fluctuate within certain limits. Their restraint pleases them at times, depending on the sector and their stage of life, but at other times it is felt to be too restrictive. Energy management and efficiency then become a part of this variable restraint.

Environmentally-friendly values are not a priority, but are not altogether ignored. Environment and climate change are more important to moderate waverers than to the other two categories. Although their pleasure and comfort are not always consistent with net-zero emissions reduction goals, they may take them on board as a partially acceptable restriction. With so much fluidity and change, the distinguishing criterion becomes the relative emissions level associated with their practices. Indeed, in general, waverers pay more attention to the technical efficiency and management of their appliances (within their means) than to restraint. The felt need for restraint varies from one stage of their life to another or from one sector to another depending on the stage of life, but it is never as pressing as it is for drivers.

Moderate waverers are close to "happy moderate" drivers in terms of emissions and attitude, but don't go quite as far, nor take as much pleasure in restraint or in their efforts at reduction. They nevertheless think they ought to be practising restraint on ethical grounds, without either going overboard or doing too little.

Comfortable waverers (together with "happy moderates") are very likely the profiles of persons most comfortable with their position in a net-zero society, whereby one believes one's efforts match one's goals and appreciates what those efforts yield. Their attitude is: it's worth it, even if it does not solve the problem as such. They have the satisfaction of knowing that they are not part of the problem, while enjoying a quality of life consistent with their values.

Emitting waverers are close to "comfortable foot-draggers". They think they must make an effort for others, but as this comes at a price, they only do what will not impinge on their comfort. If they are careful, it's often for reasons other than climate. For example, they pay attention to the amount of meat they eat for reasons of health rather than greenhouse gas emissions.

MODERATE WAVERERS

Marie,

single mother of a twelve-year-old boy, and "environmentalist"

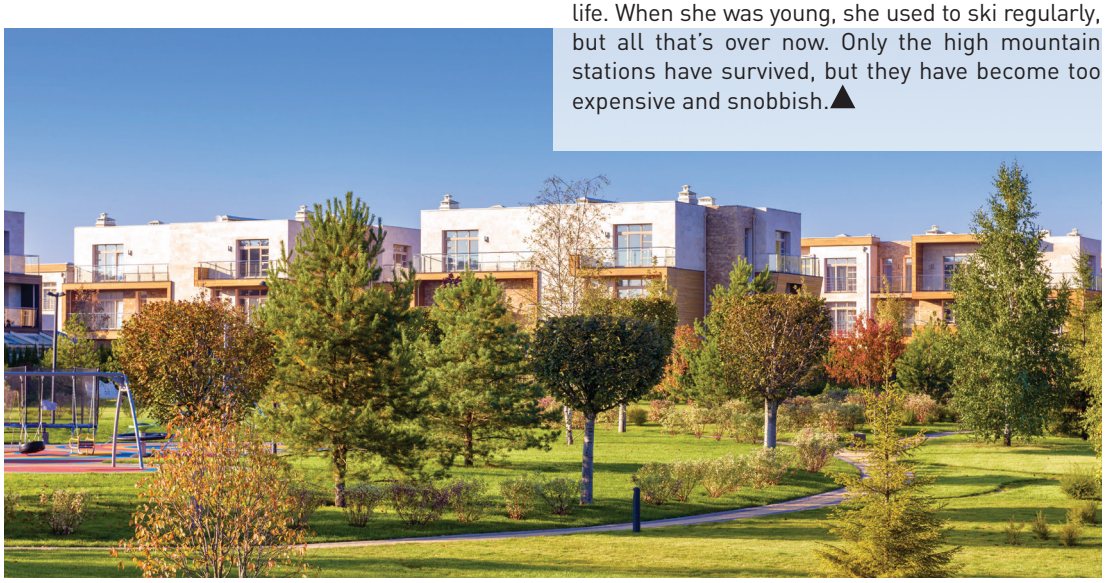
Marie is a single mother of a 12-year-old boy. She has "only a school leaving certificate", but has a broad general knowledge and feels personally concerned by climate change. She does not make it "*an ideology; it's just a matter of common sense and intelligence*". For her, the efforts of the last twenty-five years are in the right direction, but she would like to see more done for households in the same position as her.

She does a number of part-time jobs, including one involving half-time work for a government agency. She is also employed by the town (25%) to look after a communal garden. She has a good network of friends and mutual help, and uses the local currency a lot ("*one of the first to register!*" she says proudly). Her income is low, but she lives in a new apartment, managed by a social landlord. Her costs are low; the heating doesn't cost much and there is a double-flow, dual photovoltaic-hot water system on the roof. She finds it rewarding to live in such a building. Moreover, a lot of the equipment is pooled (washing machine, car service on loan, bicycles, barbecue). The social landlord has banned air-conditioners and clothes dryers, but then again she doesn't really suffer from the heat. She thinks it's a good thing, but her neighbours, with three children, don't think so and have bought a small air conditioner. She does not even have a "real" oven, just a little one on the worktop to make mini-gratins. She prefers making simmered or stir-fried dishes on her electric cooker.

Most of the exterior walls are vegetated and her flat is in an apartment block with gardens, fruit trees and small water bodies. Outside her flat on the fourth floor grows a vine, whose grapes are edible and adored by her son. While it may attract insects, the vine keeps her cooler in summer as her flat is south facing. It also has a small balcony garden with tomatoes, peppers, aromatic herbs, flowers, and a mini-composter to feed them. It teaches her son "*the real taste of food and offers him direct contact with nature; the plants are his responsibility and stop him being glued to the screen!*"

She doesn't consider herself a vegetarian since she eats fish and dairy products: "*we are veggie-leaning flexitarians!*". Meat is consumed about once a week; it is (almost) always organic, but it weighs heavily on her very limited budget. However, she feels her son needs it for his growth. Thank goodness for the organic baskets provided by the farmers' cooperative (AMAP).

Her biggest source of emissions (she makes a calculation regularly) is her petrol car (one of the last to be allowed on the road before the total ban). However, she was entitled to an exemption on account of her income, because even with the bonus-malus system factored in, she cannot afford a recent one. She uses it as sparingly as possible - mostly to get out of the city at weekends, "*recharge her batteries in nature, swim in lakes, and see our AMAP friends*". It allows both of them to have real fun, as well as improve their quality of life. When she was young, she used to ski regularly, but all that's over now. Only the high mountain stations have survived, but they have become too expensive and snobbish.▲



COMFORTABLE WAVERERS

Thomas and Céline,

retired 10 years ago

Thomas and Céline have been retired for ten years. When they were young, before meeting each other, they both took full advantage of various opportunities offered by the European Union and the Region during their studies to travel and live abroad. While they no longer travel rough with a backpack, they still travel, albeit in comfort, and still refuse package tours: "*That's for when we are really old!*", says Céline jokingly. They calculate their emissions once a year: it's their biggest source of emissions. They take the plane twice a year, but once there, they still travel around "*like young people by bus, train, or bike*". If necessary, they rent an electric car to get around.

In their daily lives, they feel they are environmentalists, but "*we're not climate ayatollahs*"; they value their comfort and heat themselves at 21°C ("*the old feel the cold!*"), but closely monitor energy usage in their home and the sources of consumption, with the help of home automation systems. Thomas is an engineer. They have installed air conditioning which they only use during heatwaves. Outside these periods, they make sure the house is closed during the day and properly ventilated at night. They haven't had a dryer for at least twenty years and with their neighbours purchased a washing machine, installed in an adjoining garage which they share amicably. The two households also use the garage to store objects and park their bikes (the neighbours have two children). They use their bikes for daily mobility and the electric car for out-of-town trips: "*it doesn't pollute, so we have no reservations about using it*".

They bought a house in a semi-urban environment twenty years ago, not far from the centre, with a garden, a cherry tree, and strawberry and raspberry bushes. They put in a beehive ten years ago. The garden provides cool comfort in summer, which means they don't take advantage of the town's green spaces since they have them at home! They did some retrofit work to further improve energy quality, installing dual purpose photovoltaic-hot water panels on the roof. They were not required to do so due to the building's high quality, but the idea of self-consumption - and not paying for their energy - pleased them immensely. They pay attention to their health and, in addition to sport and cycling, eat as much organic and locally sourced produce as possible, mostly purchased from farmers' cooperatives where they personally know some of the producers. They eat between two and three meals of - always organic - fish or meat a week. Except on their travels, where they don't stick to this diet because tasting local food is one of their greatest pleasures.

Overall, the transition is going well for them, with the speed and scope of the changes very much in line with their lifestyle and values. They would like some aspects to be less punitive - such as the price of organic meat - but fully understand the situation and what it involves, and so accept the drawbacks or pay for their extras. However, they believe it must be very difficult for poorer people struggling to make ends meet.▲

EMITTING WAVERERS

Lucien and Sofia,

near the end of their working life and wedded to their comfort zone

Lucien and Sofia, who are nearing the end of their working lives, acknowledge that some effort has to be made for the climate, but they gave enough when they were young and now wish to make the most of it, i.e. prepare for their retirement which is less than a year away, take advantage of their free time, enjoy the company of their grandchildren, travel, and meet for family meals at weekends. They live in an old refurbished apartment in a nice part of town with green spaces and a small stream which the town has brought back into the open air. "*It stays cool in summer, but also draws mosquitoes!*" They are on the ground floor with a small lawn and flowerbeds. They have a dryer and a washing machine, which they have had for years and Lucien has himself repaired many times (being a bit of a handyman). "*The appliances consume quite a lot of energy, but if one takes their environmental footprint into account it is best to keep them and make them last as long as possible!*"

Their income makes them middle class, but "*the section that usually falls outside the eligibility criteria for most retrofit grants*", they say with frustration. They fully understand the purpose, but feel the resources earmarked are inadequate. They have refurbished only the north windows of their flat and added a pergola in the south to protect themselves from the heat. They could have done more; they had made an estimate and could have afforded it (by squeezing a little too much), but since they were under no obligation and given their age and the time they spend at home, it just wasn't worth it. They are rather happy with these small changes; it's a little more comfortable in winter and also in summer what with the heatwaves, and much less noisy (the activities of young people in the park carry on until late at night and are quite noisy!).

The heating of their house does not cost too much, as it is district heating from a nearby wood-fired plant with the bill prorated to consumption. The photovoltaic system installed on the 6th floor roof supplies the common areas, cellars and car parks, as well as the three washing machines and two dryers which they share. The surplus is sold to the energy provider and provisions the condominium's account for work and maintenance. "*This reduces the building's charges for families, which is good.*" The issue of building charges has in fact led the property management company to have just two dryers that can be used only during off-peak hours. "*But frankly it's stupid: who will dry laundry at 2 in the morning?!?*" Less energy expenditure, they feel, just means more money for the management company.

For their retirement, they offered each other a gift - a fantasy they had been dreaming about for fifteen years: a comfortable, almost luxurious, camping car. They know it runs against current trends. Anyway, they are footing the bill.
It's something they discovered during one of their trips to the United States after seeing retired couples travelling in Winnebago with a home cinema, shower (even a jacuzzi) and satellite internet. Back in France, they first thought of having an electric vehicle but found it too small for comfort. Besides, where do you put the refrigerator? They therefore opted for the bigger, hybrid Voyageur. They are often on the road in France, but also in Germany, Switzerland, Austria and all of southern Europe during winter. The bulk of their savings go into these trips. Sometimes they are joined by friends or family. With all the restrictions placed on this type of internal combustion engine over the years, "*our way of life is almost an act of resistance!*" Be that as it may, they cannot contemplate retiring any other way.

When they are in town, their activities are fairly simple and ultimately not very urban. They don't go much to the 4D cinema or the theatre. Instead, they prepare for their travels: Lucien takes courses in photography. He has even begun to display his works. Sofia takes language courses in sync with the country they will be visiting the following summer. They often get around by bike (which they take with them on their travels), but not if it's cold or raining or very hot. In those circumstances, they use their electric car.

They are fairly careful about their diet for health reasons: "*if one can no longer enjoy oneself, what's the point!*". They eat meat several times a week; sometimes it's organic, though not always.
At times they feel the pressure to do more ("*to tighten the belt, as it were*"). But they are already doing enough. Occasionally, they have heated discussions with a couple of neighbours: "*friendly lot, but environmentalists through and through*", who heat at 18°C and believe in the happiness of restraint. "*It's not as if they were poor!*" Moreover, they are vegetarian and even take part in an individual CO_2 emission allowances program, imagine! There is no conflict between them, but they interact very little - our values are too different.▲

1.4 Drivers or moderates

Drivers are opinion leaders and trendsetters in both senses of the term ZEN: not only are they very careful about their emissions, they are also extremely at ease in their role as drivers. They derive pleasure from the application of an ethical principle. For them, the exercise in self-restraint is a game they enjoy playing. Behaving with restraint contributes to their quality of life and well-being. All moderates however are not in the same boat: some have a harder time practising restraint across the board, despite their convictions. Inequality and financial insecurity have specific consequence for drivers: when there is just not enough money, it's difficult to install solar panels on the roof, retrofit your place or eat organic and locally sourced food at each meal. For them, it's not the "climate imperatives" that are restrictive, but their inadequate purchasing power that hampers greater restraint, as opposed to the foot-draggers. Their desires and pleasures are in harmony with a net-zero society. As a result, their discomfort stems not from the fact that society prevents them from consuming what they wish, but from the fact that certain circumstances prevent them from doing as much as they would like. There are therefore two salient criteria for distinguishing drivers: depth of environmental conviction and Income/ purchasing power. It is not surprising then that none of them have air conditioning or a dryer.

The values of restraint are broadly in line with their practices. Moreover, they enjoy observing themselves, assessing their own efforts and raising their game.

Happy moderates like to practice a high degree of restraint and voluntary simplicity. Their environmental values play an important role in their daily life. They are vegetarian for reasons of climate and animal ethics and make it a point to avoid what they believe are the pitfalls of a "fossil fuel society" doomed to extinction.

Frustrated moderates share with happy moderates the same values and the same enjoyment of practising restraint, but their life circumstances make this more difficult. It's a source of frustration, but they don't have much choice. Ever more insecure, they struggle to pay for the services, products and fittings that would enable them to reduce consumption. Or else their circumstances do not allow them to do so, i.e. they might be tenants or living in a rural area. This they find unfair, although they are comforted by the fact that over the last few years there is an observable shift in their direction.
They therefore suffer a sense of discomfort and dissatisfaction which they resolve as best they can, sometimes by making an even greater effort than the middle-class happy moderates. They also take comfort from the fact that they are not far from reaching the objectives they have set themselves and their values call for.

Dissenting moderates are one of the unhappiest of our profiles, along with frustrated foot-draggers, but for opposite reasons. They have deeply held environmental values, and their goals both for themselves and society are ambitious. They feel the same sense of frustration and dissatisfaction as frustrated moderates, but much more strongly. When they do their carbon stocktake, they find themselves at the same level as foot-draggers and don't like it one bit. The strong cleavages between their lifestyle, their emissions and their deep-seated values create a cognitive dissonance that, in their case, translates into guilt. They therefore have a poorer sense of enjoyment than their moderate counterparts. Often middle class, they don't always qualify for financial grants aimed at promoting climate and energy transition.
In fact, they make a much bigger effort than the other profiles to reduce this gap.

HAPPY MODERATES

Kylian,

single father, "environmentalist", moderate

Kylian is a single father in his early forties. Deeply moved by the climate crisis, he enjoys trying out "new things" with his thirteen-year-old daughter to reduce their emissions. They have completely embraced all the advances of the last twenty years because they do not see them as restrictions.

The two of them have only ever used bikes and public transport, even when it rains. He acknowledges that it is easy to do so in town and is not sure he would manage it in the countryside. He and his daughter are happy moderates. For them, it's "*like a treasure hunt or playing hide-and-seek with one's own footprint*". When they arrived at their new flat five years ago, they spent several weeks trying to find how they could further improve their comfort, bill and footprint. It was also a way of learning how to get to know their new home better. Both have only ever been vegetarian for reasons of climate as well as animal rights. They also belong to an association that advocates for the improvement in the living conditions of animals on slaughter and in zoos.

Kylian's daughter takes lessons in martial arts and travels by tram, while he takes yoga lessons twice a week. Their lessons take place the same evening, which simplifies transport scheduling. It's more easy-going at weekends, which they usually spend strolling in town, watching a film or attending a free concert. The cycle path network is well developed and reaches far into the countryside, which they love exploring in all directions.

Kylian looks after the vegetable garden on the roof of the building. As a matter of fact, he occupies a position that was created a few years ago: energy caretaker-expert. He gives advice on energy restraint and efficiency to the inhabitants of the block of four buildings where he lives. He has a mid-level salary but a low rent, which brings him enormous satisfaction. What's more, he learns a lot from having to fix small technical problems related to the new technologies used in BEPOS connected, water-efficient and energy-plus buildings. Sometimes it's the shared washing machine on the ground floor of each building in the block that is not working properly. Naturally, there is no dryer in these new housing developments - they are prohibited in the flats, along with air conditioners.

Most of the inhabitants are now aware and the block's performance depends on final household consumption of water and energy. And, as he has learned on the job, "*it's not because you make people aware that they take action!*" Part of his work therefore also involves education and awareness-building, along with support for subsequent action.

For their holidays, they travel by train. Every other year they remain in France. In the alternate year, they travel around Europe by train or take the boat to Tunisia.

Naturally, they keep household appliances down to a minimum. The block has special areas for shared equipment: electric cars and bicycles, a washing machine, board games, gardening equipment, etc. For other consumer products, highly conscious of the impact of transport among others, they use e-commerce only sparingly and look for the best locally sourced products. This, too, they regard as a game to which they happily devote a great deal of their time.▲

FRUSTRATED MODERATES

Nicolas and Bouchra,

couple, three children, moderate, but wish to do much better

This moderate couple is dissatisfied not because they would like to consume more, but because they would like to do more. Their objective life circumstances make things difficult. With three children, they use their (hybrid) car more than they would like, since both of them work. They do part of their shopping locally, but can't find everything in the neighbourhood as they live in an old-fashioned district next to a medium-sized town. Their flat is in a three-storey building with eight housing units. The building dates back to the 1990s, but has been retrofitted and is heated with biogas. Before the energy mix and the law changed things about a dozen years ago, it was heated with natural gas. Even though it's an improvement, they would prefer "*really green*" electric heating.

Having travelled a lot in their youth, Nicolas and Bouchra are especially fond of cooking Asian "fusion" food. The neighbourhood shops don't have all the ingredients - the children adore Japanese - and there is no large supermarket in the vicinity. That's a shame, but they have to put up with it, even if this clearly increases their carbon footprint!

With two teenagers who eat like a horse, they shop by car once a week at a large supermarket and go into town on the same occasion for "non-standard" groceries. They are of course aware that if they ate more traditional food, they would have to do fewer miles for their shopping. However, they will not give up this pleasure. Another factor in their shopping mileage is that they are vegetarians (but not vegans). While these products are much more widely available now than in the past, the local shop is simply not adequate.

Their small neighbourhood is very good in all other respects: the schools are not too far (the elder children go by bus or by bike), and their daughter, who is the youngest, is in the last year of primary school and uses a walking bus. There is a park and a leisure centre where she does judo. One of the boys plays online games, while the other does indoor climbing. It's a little far, so once a week he goes there by bus, but his father has to pick him up by car, otherwise he would only be back home around 8.30 pm. The parents' recreational and leisure activities largely depend on the children's activities. "*The little free time we get is spent doing nothing if possible!*"

They regret that there is no communal equipment. This is not for lack of trying. Bouchra tried creating a project with the neighbours and parents from the school but gave up after a few months. Nobody wanted to share their washing machine or dryer - due to lack of time apparently - and as for bicycles, most of them already had one. In the end, there weren't enough volunteers and the local culture was too self-centred. Fortunately, equipment sharing for the surrounding garden worked with close neighbours.

They have been looking for land for three years because they dream of building a truly environmentally-friendly house, but the new planning and land use rules limit opportunities for detached houses, or else one has to go very far away from urban centres. They are still looking to buy one, but their ecological and energy criteria are very strict. They reject materials that are artificial and not natural on health and environmental grounds: "*a sick planet is a sick body*". But property is expensive and there are few opportunities, since they need a place which should not involve using the car even more than they do.▲

DISSENTING MODERATES

Sacha and Mathieu,

one child, moderate, but wish to do a bit more

A working couple in their thirties, Sacha and Mathieu consider themselves committed environmentalists: they are vegetarian for environmental reasons ("*not health even if that matters*"), and buy the best possible organic products, usually in an AMAP (farmers' cooperative), whose producers are known to them.
Moreover, their environmental approach is solidarity-based and social and they buy, as far as possible, fair trade products for reasons of equity ("*if we can afford to eat healthily, we can also afford to be fair with producers from poor countries*").

They are anti-car and, until the birth of their child, did not even have a driving license. Six months later, both had passed their driving test and, a few weeks later, bought an electric car which they use as sparingly as possible not without a sense of guilt. For them, electric vehicles in town are no way of solving the private car problem. The fewer there are, the "*greater the availability of clean energy for the right uses*", he says. But, according to her, "*frankly, we were burning out, what with our work schedules and our child who had started Judo; too hard*". All the same, they use public transport as often as possible: "*It's great, it's a bubble, and there's no need to drive!*"

They exercise restraint in a house that is not quite as energy efficient as they would like. They rent a 1960s flat in a slightly far removed but thriving neighbourhood; "*it's semi-rural in fact, with local farms selling their produce in the local market*".

The landlord has put in double glazing at their request, but not insulation: too expensive they were told, and yet they occupy the top floor ("*it's very annoying he refused, saying it was too expensive. We don't know how he gets away with it because there's a legal obligation, isn't there?*"). They heat their home at 19° with electricity and have to wear a sweater inside during winter. Four years ago, they participated in the Energy-Plus Family Challenge, then the year after in its "Use-Less-Water" forum, then the following year in the Food-Plus Family Challenge. This year they enrolled in the mobility initiative ("*in fact, we didn't learn much there, except for weekend trips on which they gave good tips and info*"). Much to their surprise, they have succeeded in cutting their energy consumption by 15% - but since their consumption was already low, it hasn't reduced the bill by much. "*We do it essentially because we don't want to be part of the problem, but rather part of the solution, even if it's only tinkering at the edges*". The biggest improvement has been in their food habits: they have learned to cook differently, more efficiently and tastily. They ultimately dispensed with an oven.

Their recreational activities are in the neighbourhood and they go there by bike. They take weekend trips in their region, very often by bus or train or, when it's really necessary, by car. Their neighbourhood is somewhat "mixed-bohemian". When they arrived, there were already several equipment sharing centres with freezers, a washing machine, a dryer (which they don't use) and gardening tools for the community vegetable gardens. Pooling is here to stay, even if there are problems with late returns or poorly maintained appliances at times. What's more it enriches community life and social interaction.

They love to travel by train, visiting a different region of France every year and, every two or three years, taking the train to neighbouring countries, where they rent an electric car locally to get around freely.▲

1.5 Co-benefits for households of the transition to net-zero emissions by 2050

Beyond its direct and indirect effects on the climate, the transition to net-zero emissions described above will yield multiple benefits for people, even if it is difficult today to quantify or list them. One of the most striking will undoubtedly be **the significant improvement in health outcomes due to a radical reduction in atmospheric pollution** (SOx, NOx, ozone, fine particles) caused by the combustion of fossil fuels, particularly by motorised urban transport and inefficient wood-fired heaters which will have been replaced.

The quality of urban life will be improved by decongested towns, roads recovered for soft modes, enhanced pedestrian safety and air quality, green space utilisation to reduce heat islands, and better access for the entire population to various services through the provision of higher-quality public transportation and neighbourhood services. The revitalization of city centres and small towns, better sharing of public space between different uses resulting from a reduced car usage, and a reduction in noise caused by internal combustion engines will also contribute to urban attractiveness.

The expected change in food habits is likely to result in major public health and nutritional benefits for all consumers.

In rural areas, the introduction of land take management and integrated land-use strategies should be accompanied by the remuneration of environmental services. This could foster agricultural development that pays more attention to product quality. For farmers and their neighbours, the health **benefits of farming practices involving fewer chemical inputs** will also be significant.

Health and Climate Change

The beneficial effects on health of the transition to a climate-friendly economy must not prevent us from analysing and factoring in the health consequences of climate warming, such as the northward spread of tropical diseases (dengue fever, malaria), allergies caused by pollens or micro-organisms different from those to which we have adapted, and diseases due to heatwaves or the health impacts of extreme weather events.

Treatments already exist for the more southern regions, but patients and medical systems will have to apply new learning to diagnose these new problems and deal with them appropriately.

2

KEY SYSTEMS
OF A NET-ZERO 2050 FRANCE

As is evident from the above description of lifestyles, the transition to net-zero emissions presupposes profound transformations in the main socio-technical systems that constitute society and the production apparatus. This chapter describes **the state of each of the key systems in 2050.**

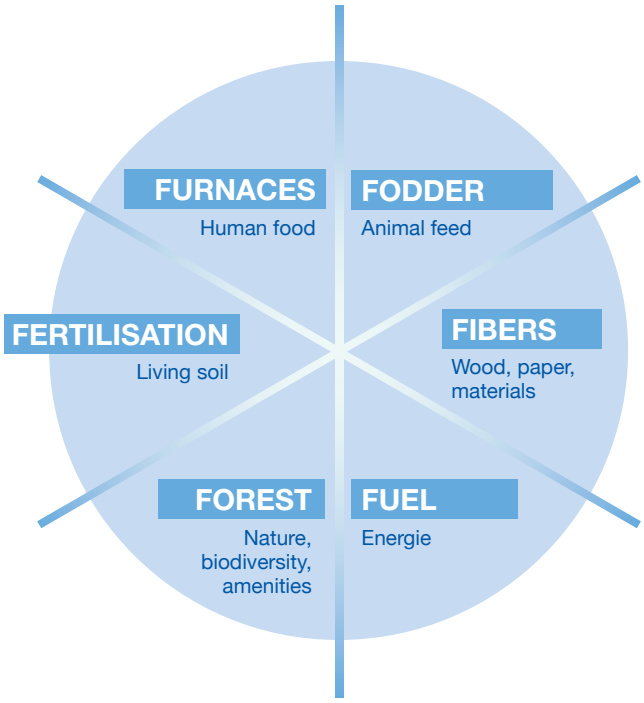
2.1 Food, agriculture, forestry and land use

Carbon neutrality involves taking into account all the emissions - positive and negative - coming from the food-agriculture-forestry-land use system.

Changes in this system are, under this approach, instrumental for reducing residual emissions from other sectors.

Figure 1

The "6Fs" of biomass use, Afterres2050



The food-agriculture-forestry-land use system can be described thus: farmland and forested land provide consumable organic resources for the needs of society (food and feed, materials, energy); their usage mobilises energy or non-energy inputs; the system contributes to emissions of GHGs and other pollutants, and affects the ability of these areas to store carbon, preserve biodiversity and offer environmental, cultural and economic services. The search for better management of this system, with a view to carbon neutrality, is indeed extremely complex.

Competition and synergy between land use and biomass use (see Figure 1) therefore lie at the heart of the issue. Accordingly, waste from pruning logs used for lumber or industry can be converted into energy, but a farm plot cannot be used both to graze animals and to produce grain.

In the first instance, given the major differences in impacts between a diet rich in animal proteins and a diet based mainly on foodstuffs of plant origin, changes in food consumption models towards lower consumption of animal protein seem essential. This seems all the more obvious because it is already under way. These developments are primarily motivated by considerations of health and animal ethics (source: CREDOC) and reflect significant changes in motivations and behaviours.

As a result, we can expect not only fewer direct methane emissions from livestock and greater availability of land for forest and pristine spaces (and therefore energy and biodiversity), but also significant changes in landscape (pasture-forest mix) and local economies.

Against this background, it is necessary **to rethink the agricultural and rural economy** for the transition to carbon neutrality. There is every reason to think that this new economy should be designed as a collection of more versatile, multifunctional territories providing a comprehensive response to every aspect of climate change.

Sharing land use between production of renewable resources, agricultural production and grassland for stock breeding, while making the necessary trade-offs between food, feed, materials, energy, carbon sequestration and soil and water conservation, will undoubtedly demand revised governance procedures for dealing with the current situation.

The prospect of developing amenities and services rendered by the land and various other services will also involve a profound transformation of agriculture and forestry business models, together with agricultural and forestry raw materials processing lines.

France's carbon neutrality ambition makes biomass a critical resource. Its competing uses will have to be managed in such a way that prioritises food and increased biomass production (see 3.7), without undermining carbon dioxide absorption and other ecosystem services.

Biodiversity and climate

The links between biodiversity and climate are clearly multiple and complex, but also better and better known, as attested to by the many calls to address the two issues simultaneously within the framework of international conferences. More and more studies examine them together. The climate is one of the main causes of biodiversity loss[6]. Ecosystems work in reverse to protect populations from the effects of global warming. For example, mangroves offer protection from storms, and revegetation of city centres cools the atmosphere. The alteration of ecosystems, such as melting permafrost or less absorption of CO2 by forests, could also exacerbate climate change.
In France, the Biodiversity Plan of July 2018 provides for limiting urban sprawl and setting a date for a net-zero land take goal. It also aims to strengthen nature-friendly solutions for adapting and developing territorial resilience to climate change

6 Wildlife in a warming world : the effects of climate change on biodiversity, mars 2018 https://www.worldwildlife.org/publications/wildlife-in-a-warming-world-the-effects-of-climate-change-on-biodiversity.

2.2 Town and country planning, urbanisation, transport

Town and country planning policy is a focal point for several issues: meeting housing and business needs, ensuring access to health, educational, cultural, shopping, and recreational services, improving access to jobs, and accordingly addressing mobility needs.

From several points of view, urban sprawl is increasingly seen as inimical to climate because it swallows natural and agricultural spaces, causes emissions and other risks related to land take, induces restricted mobility and impacts biodiversity. However, many households still see peri-urban housing as a way of enjoying larger living spaces close to nature.

Dense cities and small towns and villages, if well-equipped to provide multiple proximity services, could emerge as the dominant model by promoting better energy management for home heating and for meeting professional and recreational mobility needs. This model is feasible as it reconciles urban density and quality of life. It assumes the formulation of deliberate and proactive policies on housing (adequate supply of suitable dwellings), the revegetation of buildings, and the development of unbuilt spaces promoting close contact with nature, and noise abatement.

Here too, concerns surrounding the transition to net-zero emissions will result in critical trade-offs. Local authorities will have a key role to play in ensuring **the development of denser and more attractive city and small town centres where the bulk of the population resides**, and in managing well-connected peri-urban and rural areas through better access to urban services. In urban centres, the triptych - soft and public transport modes, very low energy housing and low-carbon energy networks - should meet household needs. In peri-urban and rural areas, the emphasis could be placed on good management of shared individual transport and the attainment of a degree of energy independence through locally produced energies at the individual and regional levels.

More generally, this would include linking the city and its countryside (food, land use, mobility, energy production, etc.) more closely than is the case today, when long-haul transport is still cost-effective. This would promote the development of the circular economy.

2.3 Towards industrial renewal

The third main system to be transformed is that of industrial manufacturing. **In terms of the transition to net-zero emissions**, the study assumes stable production volumes and **no carbon leakage** (whereby a business, to escape the costs related to climate policies, moves its production to another country applying less stringent emissions limitation rules). However, the transition also broadly concerns the ability of industry to undertake the energy transformation of existing sectors and to develop a range of new resource management businesses.

Energy transformation and industrial opportunity

If the transition unfolds and its outcomes are in line with the scenario contemplated, the transformation of industry will be driven by the transformation of the energy system which, by 2050, will exhibit radically new features, particularly as regards the production and decarbonisation of its different components. A profound reorganization of industrial branches and players is already under way (see section 2.4 among others for funding considerations). The emergence of the electric car, mobilising car manufacturers, fuel cell producers, transport players, energy providers and digital players, is the clearest example yet of this trend. Other examples of new industrial activities driven by the emissions reduction momentum and innovation include:

- Activities involving a **reduction in energy consumption**: energy efficiency systems, insulation production and energy retrofits;
- Activities conducive **to smart, energy-efficient management**: energy management and control systems, home automation, smart mobility services, electricity storage;

- **Biomass value chains** dependent not only on strong **biogas** growth, whether biosourced or synthetic (methanisation, pyrogasification and methanation), but also on the optimisation, conversion and use of biomass sources (wood and fiber processing);

- **High value-added industries**: green chemistry, chemical recycling, electrolyte supply for batteries, high-performance materials;

- **Industries linked to breakthrough technology development**: CO_2 sequestration and storage, hydrogen production[7] by electrolysis or even a combination of the two, and power-to-liquids technologies are now under development. Reducing their cost and setting an adequate carbon price will scale up the industrial opportunities they provide.

While the opportunities are manifold, some industrial sectors dependent on fossil energies, including oil and gas, refining, petrochemicals and internal combustion vehicle manufacturing are facing a more difficult transition. These sectors will see their activities shrink or transform into biomass plants and refineries producing perhaps more limited volumes, or become less labour intensive (electric vehicle manufacture), or dependent on technological breakthroughs (power-to-liquids).

It should be noted that the ZEN study is based on the same annual GDP growth assumptions for the French economy as the scenarios prepared by the Ministry for Ecological Transition and Solidarity, with rates of 1.3% and 1.4% until 2030, and then 1.7% a year till 2050. Reaching carbon neutrality in the ZEN study therefore factors in this economic growth assumption and is compatible with it. However, the study does not cover the conditions required to fulfil these assumptions (resources, costs, funding, timetable, risks).

New resource management business models

The transition to net-zero emissions cannot be considered in isolation: it is intimately bound up with two major mutually reinforcing developments already under way - the circular economy and the digital revolution.

The circular economy is crucial for the transition to net-zero emissions of which it is a component. While transition would reduce the country's economic and geo-strategic dependency on fossil resources, it would increase reliance on a number of critical minerals (lithium, cobalt, rare earths, manganese, nickel, copper) found in remote locations[8], thus making their recycling one of the sources of local supply.

Rising demand for such minerals is likely to improve the profitability of some deposits and technological investments geared to lowering raw material and energy content and to developing recycling technologies (urban mining, separation and purification). The issue of domestic (or European) mineral resource development could be examined from this perspective following the acquisition of stakes in resource development outside France.

In the case of **structural materials using high-emitting production processes** (cement, steel, glass, etc.), the circular economy is one way to reduce process emissions. A **more incentivising carbon price** than that prevailing today, should make recycling operations - for which there is currently no business case - profitable, along with CO_2 capture and storage.

Moreover, the principles of **the circular economy include reducing material and energy flows, promoting the use of renewable or recycled materials and ensuring decoupling between value creation and resource consumption**. This is a valuable new industrial transformation pathway to carbon neutrality.

Very specifically, by intervening upstream of the cycle with ecodesign policies, service functionality economics (selling a service rather than the product required to perform this service), and measures to promote reuse, repair and equipment sharing by multiple users (of which we have seen many examples in chapter one), we can reduce the amount of equipment entering the market. And then downstream of the cycle, by developing industrial estates, wherever possible, in line with the principles of industrial ecology, we can make big strides in recovering materials and energy from waste.

7 In the context of net-zero 2050, the sector's development will match that of green hydrogen in that it will be partially produced from carbon-free energy
8 The Democratic Republic of Congo has the world's largest recoverable reserves of cobalt, Chile, those of lithium and China those of rare earths

The **building and automotive sectors** are of course essential to the deployment of the circular economy as they use up a large volume of materials.
In the case of construction, meeting the challenge of large-scale retrofits (even if it sometimes involves pulling down and rebuilding) will dampen the demand for materials.
The key challenge facing the automotive sector is the rapid penetration of zero-emission vehicles on the back of highly innovative solutions.

The digitalization of technical systems already has a strong impact on some levers of the net-zero emissions pathway via connected objects, simulation and design technologies (see BIM - Building Information Modelling), and 3D printing.
Two major pathways are worth mentioning:

1. Growing role of digital technology in energy management systems through supply-demand adjustment; smart communication networks to facilitate distribution; energy management systems designed to reduce energy consumption and accelerate the switch to carbon-free energy, demand flexibility, short-, medium- and long-term electricity storage (battery, hydraulic, pumped energy transfer) and conversion to storable energy carriers (methane, hydrogen).
2. Optimisation of transport systems (traffic management, modal transfers and occupancy rates), and energy efficiency improvements in industrial production systems.

These synergies, however, will not be possible without an awareness of the issues at stake in the digital sector's energy consumption (see box), and of the factors behind the rebound effect, i.e. whether sharing platforms really generate greater efficiency or in fact create additional consumption.

Energy prices will provide the answer to this question by ensuring that efficiency gains are not offset by higher consumption.

Environmental impact of digitalisation

Little visible to users, the environmental impact of digitalisation is indeed considerable. In fact, according to some studies the sector's electricity consumption was estimated in 2016[9] at around 2 000 TWh/year, i.e. more than the electricity consumption of India (1,050 TWh), but less than that of China (5,900 TWh) or the United States (3,800 TWh). What's more, it is expected to grow by 9% a year[10]. In one hour, 8 -10 billion emails are exchanged around the world, according to ADEME, which also holds that an estimated 10 g of CO_2 emissions are released every time we send an email. This amounts to 100,000 tCO_2eq per hour worldwide, or close to one billion tCO_2eq every year, i.e. over 2% of global emissions. Then there is the issue of resources used for data storage, equipment production and end-of-life sorting of poorly collected and recycled equipment.

In France, the sector consumed 56 TWh of electricity in 2015, about 12% of total electricity consumption and 3% of the country's final energy consumption[11]. Nearly half comes from equipment used by individuals and businesses (smartphones, connected objects, etc.), a quarter from data centres, and the remainder from communication infrastructure and networks[12].

Pathways are available to limit the sector's impact: digital restraint and behavioural changes (deleting and reducing email weight, limiting streaming and cloud use, lengthening the service life of equipment)[13], functional, graphic and technical ecodesign of computer software to limit data exchange and related consumption, and lastly reduction of the sector 's carbon intensity through improvements in infrastructure and equipment energy efficiency and measures to decarbonise electricity supply.

9 The World Fact Book, Central Intelligence Agency
10 Lean ICT- towards digital restraint, The Shift Project, June 2018
11 La transition numérique fera-t-elle exploser notre consommation d'énergie?(Will digital transition cause our energy consumption to soar?), Green IT, February 2018
12 La face cachée du numérique (The hidden face of digitalisation), ADEME, November 2018
13 The Shift project, ADEME

2.4 New macroeconomic balances

As well as combining sociological (Chapter 1), sectoral, energy and climate (Chapter 3) approaches, the study brings to light a macroeconomic dimension, particularly as regards investment and employment.

From an overall macroeconomic perspective, the transition to carbon neutrality will lead to the substitution of recurring purchases of imported energy - mainly oil and gas totalling €39 billion in 2017 - with investment (or refunds of investment) in more energy efficient buildings and equipment, and in carbon-free energy production, transportation and distribution infrastructures. This radical transformation of the energy component of the economic system will lead to a **massive reduction in the energy deficit**. France's external energy bill could indeed be virtually negligible in 2050, depending on the level of development of its electrical equipment industry, in particular electricity storage systems.

This external trade scenario is nevertheless contingent on potential future imports and industrial choices (see chapter 2.3): **renewable energy capture equipment** (permanent magnets for wind turbines, solar panels), **components for electric** (or hydrogen) **vehicles** or the vehicles themselves.

If equipment or vehicles are made in France, the import of **critical materials** required for their construction might contribute to the continuing external trade deficit.

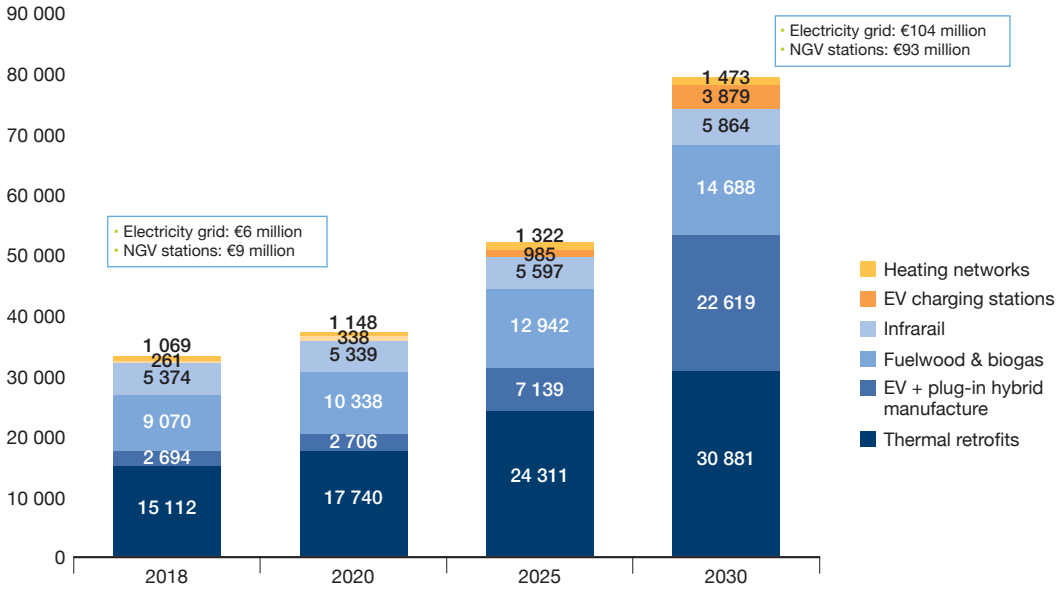
The first knock-on effect of a reduction in fossil energy imports will be greater **short-term pressure on household consumption** from transition-related investment needs. Next will be the issue of the inherent efficiency of transition investments, including very different lead times between the long-term perspective of public economics and the somewhat shorter-term decisions of businesses and households.

The ZEN 2050 study carefully examines the potential consequences of the transition for **spending and employment** in three key sectors strongly affected by the transition: **Buildings, transport and energy**. In 2016, these three sectors already allocated about €30 billion to investment and maintenance from public and private sources. In the net-zero pathway, spending must be ramped up and multiplied by a factor of 2 to 2.5 between 2018 and 2030 (see Figure 2).[14]

Figure 2

Major sectors of spending (investment and operation) (€ million, 2018-2030)

ZEN 2050 Study, EpE



14 It should be noted that the scope of the study is slightly different from that carried out by I4CE (Panorama des financements climat en France, 2018 edition, I4CE - Panorama of climate finance in France, 2018 edition, I4CE), which came up with a figure of €38 billion for 2016 and a spending requirement of €55-80 billion in 2030, based on SNBC (National Low-Carbon Strategy) 2015 data - an estimate that should accordingly be revised upwards under the second SNBC review scheduled for 2019

Direct and indirect employment quantification by the input-output model (measured in FTE - Full Time Equivalent) is based on the method developed by CIRED which links total spending in each branch (investment and operations) to its employment component. Only sectors most directly related to the transition (buildings, transport, energy) were assessed quantitatively. It can be argued, however, that many other sectors (distribution, retail, services, etc.) will also need to change, albeit more indirectly. The model sets out the following broad outcomes (see Figure 3: Jobs in key energy transition sectors):

• **Buildings:** slight increase from current levels to over one million jobs in 2030, followed by the loss of over 200,000 jobs until 2050, 90% as a result of productivity gains. The downward employment trend for new constructions, underpinned by demographic trends (the demographic scenario used being the median scenario outlined by INSEE under which France's estimated population will be 70 million in 2050), will be more than offset until 2030 by **job increases in the retrofit industry**.

• **Goods and passenger transport:** jobs will increase to 1.8 million in 2050 from 1.7 million today. Declining employment in the automotive sector - due to lower vehicle maintenance requirements and lower employment intensity in electric vehicle and battery manufacture compared to ICE vehicles – will be more than offset by the construction of charging infrastructure and the growth of public transport and railway freight. This will however require reconversion and redeployment of a proportion of automotive sector jobs from regions where they are heavily concentrated.

• **Energy:** from just over 100,000 today, jobs will peak at 120,000 **in 2035 on the back of new renewable** capacity, before falling back to 90,000 in 2050 (permanent operation and maintenance jobs in renewable energies will not offset job losses due to declining oil activities and productivity gains).

These employment forecasts for the buildings, transport and energy sectors in a net-zero 2050 scenario show total employment numbers stabilising at 3.1 million FTEs until 2035, before declining slightly to 2.9 million in 2050. However, this drop does not stem from the transition to net-zero emissions: under the sole impact of trend productivity gains (0.5%/year) without any transition, employment would fall further to 2.6 million FTEs in 2050.

The net-zero emissions 2050 pathway thus results in a small number of net job creations in 2050 compared to baseline projections (estimated at 280,000 within the scope of this study, which is limited to certain transition sectors, i.e. about 10-15% of total jobs in France).

Agricultural and industrial employment has been assessed in qualitative terms. In agriculture and forestry, many factors will contribute to higher employment: the transition to net-zero emissions will lead to the development of employment-friendly market garden production, organic agriculture and quality supply chains, the tricky bit being the reduction in livestock farming. However, here too, the effects of mechanization may be more significant than the effects of a transition to net-zero emissions.

In industry, the impact on employment will depend on technical and policy choices and so has to be studied on a case-by-case basis.

In all sectors, the transition will lead to changes in the requisite skills and career pathways, thereby creating new training requirements.

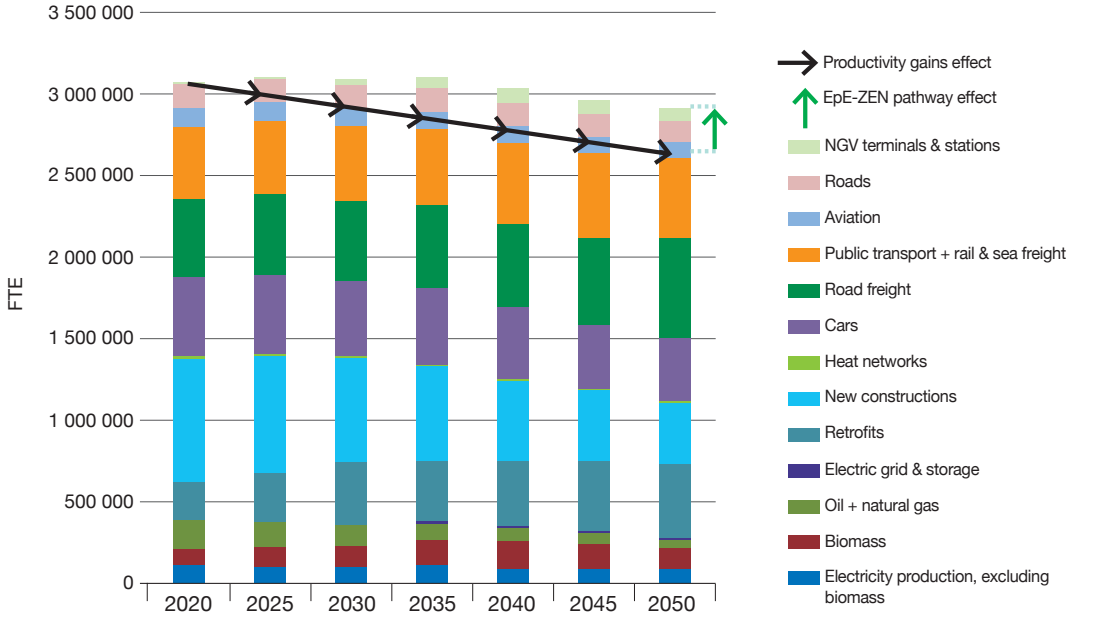
Net changes in employment caused by the transition to net-zero emissions therefore appear to be fairly moderate, compared to previous transformations: farming jobs have fallen tenfold since 1949, and industrial jobs have halved since 1974. On the other hand, services' share of employment has doubled since 1949[15]. These changes might be negligible compared to the changes produced by economic growth or the digital transition: 15% of professional activities could be replaced as a result of automation gains[16].

The underlying investment costs arising in connection with changes across all sectors would however be significant (see 4.4).

15 INSEE national accounts (T_6209)
16 Jobs lost, jobs gained: workforce transitions in a time of automation, the McKinsey Global Institute, December 2017

Figure 3

Jobs in key energy transition sectors



2.5 Changes in consumption patterns

As household consumption and living patterns will probably be very different in 2050, with or without the transition to net-zero emissions, the methodology of the study cross-fertilises different approaches based on carbon footprinting, household energy consumption, sociology, values and practices.

Since the late '90s, **household energy expenditure has remained remarkably stable, accounting on average for 5% of housing spending and 4% of travel spending** (€1,600 and €1,200 respectively in 2015)[17]. These amounts should increase in the short term as a result of measures to raise the carbon tax and the increase in transition-related investment costs. Over the medium term, investment in retrofits, electric vehicles and house moving will help stabilize expenditure and bring total household energy and travel costs down to more or less current levels, but with enhanced comfort.

To calculate the **carbon footprint of French consumption,** the model used includes trade in goods and services with the rest of the world. With the decarbonisation pathway of other countries in the world assumed to be slower than that of France, the carbon footprint of the French decreases less than France's emissions due to imports of consumer goods.

Over the last few years, **the carbon footprint of French household consumption has been slightly over 10 tCO_2eq per capita per year. It would be slashed threefold under the ZEN 2050 study** (see Figure 4). The most significant reductions would be achieved in mobility and housing (-80%). They would be smaller in food and utilities (-66%), and even more so in private goods and services with a high import component (-33%).

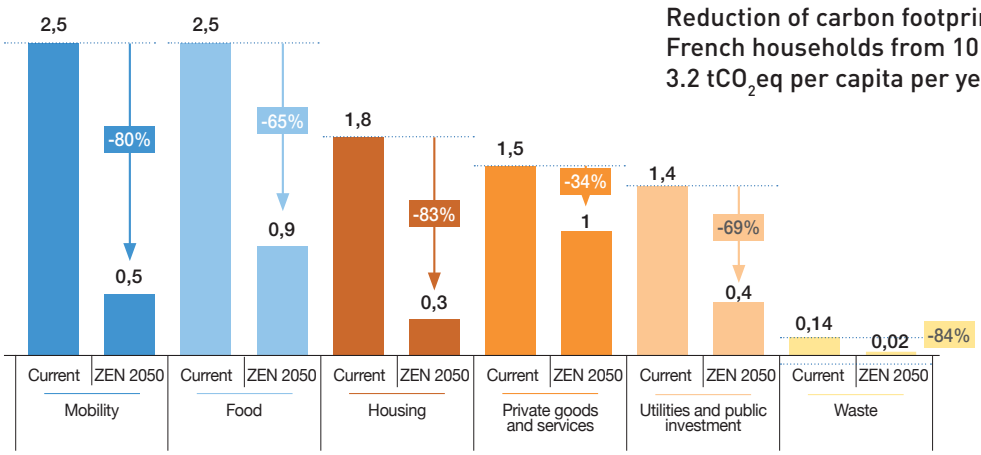
17 Ménages et environnement, Chiffres clés 2017, CGDD (Key data on Households & environment, French Ministry for the Ecological and Inclusive Transition)

Assuming that French industrial production remains constant in volume terms, the study holds that rising production will lead to a reduction in global emissions and in France's carbon footprint, while making it more difficult to meet France's territorial emissions target (see Figure 5).

Figure 4

Carbon footprint of French households by use (2015-2050, tCO_2eq per capita per year)

ZEN 2050 Study, EPE, Carbone 4 analyses



A reduction in the carbon footprint involves changes in household practices along with improvements in industrial processes. The role companies play on both fronts is crucial. Marketing highly energy efficient products, introducing smart meters that automatically give clear **energy-climate readings**, and communicating to consumers a message promoting other **desirable lifestyles** would go a long way towards changing household behaviour. Businesses could also make a big difference by passing on ongoing efficiency improvements in production processes and supply chains to suppliers and customers. At the interface of household and business lie the two strategic options of developing the circular economy and backshoring some production.

To support the changes in consumption patterns, a change in lifestyles and social perceptions seems unavoidable. This would entail, among other things, reducing dependence on higher-carbon equipment, products and services

Territorial emissions and footprinting - two complementary approaches

National inventories and international conventions use the territorial emissions approach, which measure the emissions produced within a country's borders (including products intended for export). This defines the scope of direct government action.

Carbon footprinting, on the other hand, takes into account total emissions over the life-cycle of products consumed, from manufacture and transport to use. Strictly speaking, this method is best suited to ensure a real reduction in emissions because it bypasses borders. But it is also more complex and more vulnerable to uncertainties if only because foreign data, especially about future outcomes, is often hard to come by.

France's carbon footprint differs from its emissions after taking into account the country's "carbon balance" (equivalent to the balance of trade in greenhouse gas emissions from goods and services). It includes emissions from French household consumption, including utilities and public investment, and has little changed since 1995.
In 2015, it stood at 731 $MtCO_2eq$, or 170% of territorial emissions. Its stability, at a time when the national inventory fell by 30% (see Figure 5), highlights the growing impact of imports in France's carbon footprint.

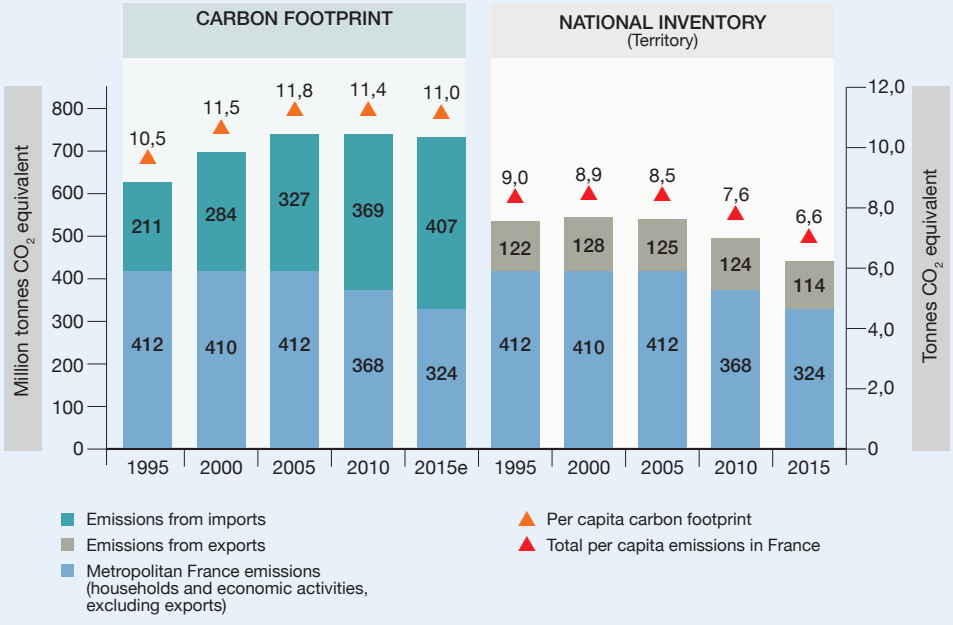
Increasing the consumption of foreign-manufactured products may indeed reduce French territorial emissions without reducing the carbon footprint. This effect can be avoided:
- either by promoting a shift towards domestic production, particularly of locally sourced and seasonal food, but also of industrial products that are especially energy-intensive.
- or by contributing to a reduction in the carbon content of imported products through stronger overall ambitions and the promotion of low-carbon technologies and practices. This is a field where the link between climate policy and external trade policy could be strengthened at EU level, as both fall under European jurisdiction.

Figure 5

Comparison of carbon footprint and emissions in France

(Field: Metropolitan France)

Source: IEA, Citepa, Customs, Eurostat, INSEE. Processing: S0eS. 2017



Note: footprint and inventory of the three main greenhouse gases (CO_2, CH_4, N_20) e = estimate

2.6 Co-benefits for economy of transition to net-zero emissions by 2050

A successful transition to net-zero emissions in France, along with similar moves in other pioneering countries, will serve as a powerful example to other countries and help drive them towards carbon neutrality, with obvious benefits in terms of climate change limitation.

Moreover, controlling urban sprawl, lowering atmospheric pollution and developing well-managed forestry will have a positive impact on **nature conservation and biodiversity**.

The spillover effects worldwide would have multiple positive consequences for the outcome of the transition in France.

At the macroeconomic level, as tensions on international energy markets ease, prices could come under pressure, thus **driving down the energy bill**. Less energy dependence would also have the effect of reducing geopolitical risks.

At the microeconomic level, the learning effects in low-carbon technologies would help bring down costs faster.

For businesses, it would be very worthwhile to **innovate in widely available low-carbon technologies**. The spinoffs in terms of enhanced international competitiveness from what the World Economic Forum has called the "fourth industrial revolution" must not be under-estimated. While past experience shows that "first mover advantage" is not always easy to obtain, it is equally true that deployment of low-carbon technologies and systems in France and in Europe is a precondition for ensuring that both are strategically placed in these areas. Banking and financial services too would need to develop 'low-carbon" service offerings in insurance and finance.

Lastly, the overall effort to fight climate change would mitigate its negative impacts, as highlighted by the IPCC special report on the effects of warming at 1.5°C (climate refugees, biodiversity erosion, frequency and magnitude of heat waves, spread of diseases, etc.). For France, the cost of natural disasters alone for the 2015-2040 period is an estimated €92 billion, up 90% on the previous period[18]. The efforts recommended by the ZEN study for this period are unlikely to reduce this cost, so strong is the climate inertia in the world. Nevertheless, they must be made to reduce the cost of climate damage after the 2040-50 period.

18 https://www.ffa-assurance.fr/la-federation/publications/enjeux-climatiques/etude-changement-climatique-et-assurance-horizon-2040

3

KEY SECTORS
IN THE TRANSITION TO NET-ZERO 2050

While the approach by key systems shows how economy and society interact and function, the sectoral approach is complementary, proposing organizational, technological and energy-related changes in key economic sectors.

First, we assess the potential of carbon sinks, which are key components of the total carbon budget available. Second, we describe the levers of action by sector. The transition to net-zero emissions by 2050, like the far-reaching decarbonisation and carbon neutrality scenarios, relies on three levers to reduce energy emissions: efficiency, consumption management, and energy carrier decarbonisation. The reduction of non-energy emissions is a fourth lever on hand.

3.1 Overview

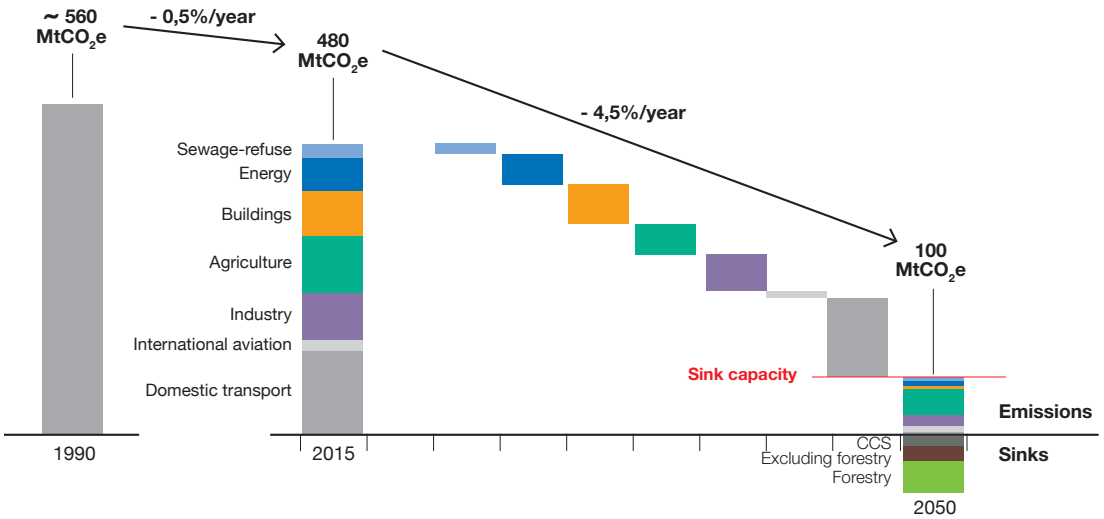
The ZEN 2050 study shows that it is possible to reduce overall emissions from 2015 levels by almost 80%. The study, which proposes one of many pathways to achieve the goal of neutrality, would make it possible to cap emissions at 100 $MtCO_2eq$, equivalent to estimated sink capacity, and in doing so achieve carbon neutrality. This amounts to a 4.5% reduction in annual emissions for the entire period, which is extremely fast as it matches France's coal output in the '70s and '80s. Moreover, the potential for change is greater.

The ZEN 2050 study therefore recommends a fivefold cut in emissions between 2015 and 2050. It should be noted that "factor 4", i.e. France's commitment to reduce its annual emissions fourfold to 140 $MtCO_2eq$ by 2050, uses the 1990 baseline emissions level of 562 $MtCO_2eq$. By adopting 1990 as the baseline year, net-zero 2050 would see emissions reduced almost sixfold.

Figure 6

GHG emissions in France (2015-2050, $MtCO_2eq$)

ZEN 2050 Study, EpE



The pace of reduction required between 2015 and 2050 (approximately 4.5%) is much faster than that actually achieved between 1990 and 2015 (about 0.5% a year, especially in industry).

Moreover, the rise in French emissions in 2016 and 2017 and the overshooting of national reduction targets set in 2014 (+ 6.7% versus the 2017 target)[19] illustrate the scale of this ambition. This pace of emissions reduction - which affects many sectors - is similar to the pace of the sweeping changes made by France to its energy system in the 1960-1970 period, among other things by limiting coal production.

Achieving neutrality would be the result of significant reductions in all economic sectors, ranging from a 50% cut in emissions to complete decarbonisation. These variances are explained by the ease with which potential levers may be activated in the different sectors, as Figure 7 shows. Some emissions are difficult to reduce, in particular agricultural emissions from natural processes such as enteric fermentation (ruminant digestion), or from the breakdown of nitrogen fertilizers into nitrous oxide, a powerful greenhouse gas. Similarly, some chemical processes release CO_2 (production of clinker, a raw material for making cement, production of basic constituents of nitrogen fertilizers, urea, ammonia), as do coolant gas leaks. Figure 7 presents an overview of the main levers and residual emissions by sector.

Figure 7

Emissions, levers and residual emissions by sector

ZEN 2050 Study, EpE

	Sector	Main deployable levers	Residual emissions
Moderate (~50%)	Agriculture Food	Agricultural practices, meal recomposition (livestock), non-food use (bioeconomy)	Enteric fermentation, nitrous oxide (fertilizers)
	International aviation	Bio-jet fuel, energy efficiency, new technologies	Fossil fuel combustion
High (70-90%)	Industry	Circular economy, energy efficiency, energy carrier substitution and decarbonisation, process optimization (cement, refrigeration, etc.)	Some industrial processes (clinker, chemicals, steel, glass, etc.)
	Sewage and refuse	Waste reduction, material and energy recovery, methane leakage reduction	Medical and hazardous waste reduction, methane leaks, treatment plant emissions
	Energy production	Carrier decarbonisation (electricity, heat), biomass mobilisation (fuelwood, gas), flexibility and storage	Non-decarbonised and leaky gas network
Near-total (>90%)	Buildings	Retrofitting, BBC low energy consumption certification, energy carrier switch (gas, heat pump), "A" construction, energy management systems, home automation and behaviours, air conditioning leak reduction, densification, city-centre and small town beautification	Non-decarbonised gas and residual fuel oil
	Domestic transport	Decarbonisation, occupancy optimisation, modal shift, engine efficiency, urban design	Aviation, hybrid vehicles, non-decarbonised NGV
+ 50 - 100%	Carbon sinks	Forestry intensity, agricultural practices, CCS, land take reduction	-

19 https://www.observatoire-climat-energie.fr/

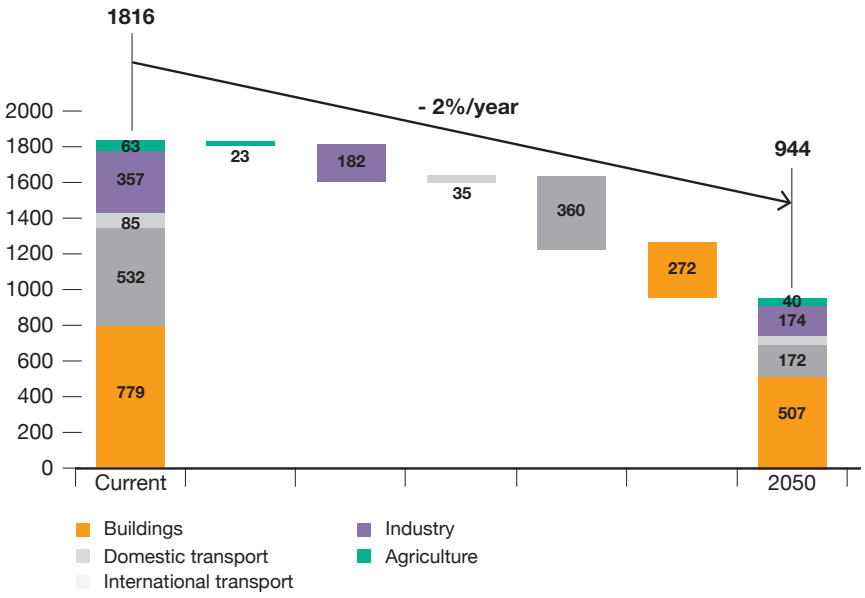
The potential for low- or zero-carbon energies is also limited, with no source free of disadvantages or opposition. As a result, the ZEN 2050 study favours energy restraint and efficiency and shows that a **50% reduction in final energy consumption** is possible if significant cuts are made in buildings and transport (see Figure 8).

This restriction could be relaxed if decarbonised energies were more abundant, but some limitations (conflict between land users, acceptability, physical restrictions) would probably prevent its widespread implementation.

Figure 8

Final energy consumption in France (2015-2050, TWh)

ZEN 2050 Study, EpE



3.2 Carbon Sinks

Carbon sink capacity is crucial for neutrality pathways. France will attain carbon neutrality when the amount of greenhouse gas emitted annually is equivalent to the amount of CO_2 absorbed by the country's carbon sinks, which in turn are dependent on town and country planning policies.

Forest sinks, for example, are different from non-forest sinks, which incorporate changes in land use. In addition to natural sinks, industrial capture technologies for CO_2 storage and utilisation (CSU) could provide complementary mitigation solutions (see dedicated box).

2050: vast increase in carbon sinks

In 2015, annual sink capacity was estimated at 50 - 60 $MtCO_2$ (according to the scope and method of calculation associated with a high degree of uncertainty). The ZEN 2050 study shows a sharp increase in net carbon sink capacity to an estimated 100 $MtCO_2$.

Forest sinks result from the yearly natural increase in forest biomass. The scale of this increase reflects the forestry management approach implemented. For example, heavy logging reduces the sink, but produces more wood material and energy, so avoiding CO_2 emissions through substitution of fossil energies or materials, reducing the risk of accidental drawdowns (through fire, disease, or storm damage), and increasing forest resilience. Beyond the trade-off between sink and biomaterial production, the aim is to maintain multifunctional forests by preserving biodiversity and their recreational purpose and ensuring their adaptation to climate change. The sinks covered by the ZEN 2050 study are adapted from the "territorial dynamics" scenario described in the INRA-IGN study[20] - a median scenario between extensification and intensification. The study forecasts forest sink capacity at around 70 $MtCO_2$.

This sink is characterised by a moderate pace of forest extension (40,000 ha/year) and more intensive management in some regions based on reforestation and forestry management strategies to make forest ecosystems more resilient to the effects of climate disruption. This level of forest development will generate a greater volume of wood than is currently the case (some 60 mm^3 in 2050 against 42 mm^3 in 2015).
Non-forest sinks will be obtained by drastically reducing land take, and especially by adopting carbon storage practices in agriculture (agroforestry, minimum or reduced tillage, intermediate crops as advocated by the "four per thousand" initiative) and elsewhere (urban revegetation, hedges, wetlands, etc.). All this could increase sink capacity to about 20 $MtCO_2$ in 2050, whereas the current balance is 7 $MtCO_2$ of net emissions. CCS (carbon capture and sequestration) amounts to 10 $MtCO_2$/year, including at least 5 $MtCO_2$ from industrial emissions capture.

Carbon capture, use and storage (CCUS)

CO_2 capture can be done by absorbing carbon through a natural sink (forest, soil, etc.), or through industrial CCUS processes.
This is a significant option to achieve carbon neutrality. Moreover, it is covered by an EU directive of 2009 which has been transposed into French national legislation[21]. CO_2 can be captured in industrial facilities or power plants through biomass combustion using CCS (BECCS), and subsequent storage by injection in depleted hydrocarbon reservoirs or saline aquifers. Between 4 and 5 $MtCO_2$ a year are today stored in an aquifer at six facilities in Norway, North America and Japan. The operation is financed by the oil and gas production it facilitates.
In France, carbon dioxide gas once separated could be stored in the Paris and Aquitaine basins, although the potential for injection remains to be determined. The gas could also be exported and stored in aquifers abroad, such as those in Norway. Although sequestration technology is known, questions about its acceptance by the population and its economic model hamper its development today.
Lastly, carbon capture and utilisation (CCU) involves incorporating the captured carbon into manufactured or building products, or using it in new energy carriers through methanation. CCU is not facing the acceptability issues of CCS, but its climate balance depends on storage duration (low for carbonated drinks, higher for carbonation), the energy consumed to produce it, and its use as a substitute for another industrial process.

20 Quel rôle pour les forêts et la filière forêt-bois françaises dans l'atténuation du changement climatique ? (What is the role of forests and the French forest-timber sector in climate change mitigation?), INRA, IGN, November 2017.
21 https://www.actu-environnement.com/ae/news/stockage-CO_2-decret-transposition-directive-14085.php4

LEVERS

The levers identified to increase carbon sink capacity to the required levels include:

- Restrictions on clear felling in forests;
- Increased production of softwood lumber, particularly for use in construction and industry;
- Larger-scale development of co-products and waste wood for building heating, heat networks and renewable gas production;
- Restriction of fuelwood forestry to low commercial value forests;
- Increasing forest biodiversity;
- Halving the rate of land take, and conservation of natural grasslands and farmlands with a view to initiating a profound change in agricultural practices.

These changes raise issues about the regulation, compensation and remuneration of carbon storage associated with the new agricultural, forestry and land use practices.

3.3 Agriculture and food

2050: key role of food models

The transformations in agriculture are closely related to those in food habits. As regards the latter, we assume that the trends already noted will continue, based on growing awareness among consumer citizens of their health, animal welfare, the environment and a fair price for farmers[22]. The crucial trend is **inversion of the ratio between animal and vegetable proteins**, involving consumption of less but better quality meat, and more abundant, healthy and diversified consumption of vegetables.

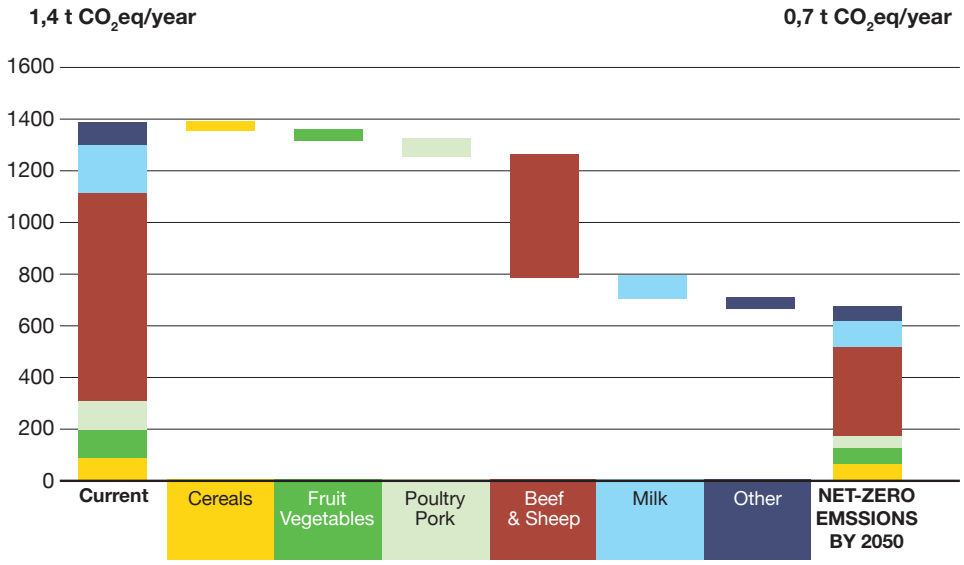
This means building a new socio-technical agricultural system based on the best practices in agriculture, soil conservation and agro-ecology, supported by the sensible use of technology, new forms of mixed farming and less international specialization of production.
In the ZEN 2050 study, direct emissions from the agricultural sector will be cut by more than half to 42 $MtCO_2eq$ in 2050 from 92 $MtCO_2eq$ today

22 Ipsos study for the Daniel and Nina Carasso Foundation, 2016

Figure 9

Patterns of food consumption and emissions coming from "waverer" households 2015-2050, kgCO_2eq per adult per year

ZEN 2050 Study, EpE



2015	
Cereals	220 g/day
Fruit and vegetables	940 g/day
Meat	80 g/day
Dairy products	230 g/day

2050	
Cereals	280 g/day
Fruit and vegetables	830 g/day
Meat	50 g/day
Dairy products	180 g/day

FLEXITARIAN **SOCIOLOGY**

2015

- 30-35% of the population.
- Matches the profile of waverers who are meat flexitarians.
- Flexitarian numbers have been increasing during the last few years, but they are not yet in the majority.
- Rising consumption of industrial products among the least well-off.

2050

- 60-70% of the population.
- The meat flexitarians of 2015 have become occasional meat flexitarians in 2050.
- Average meat flexitarians have become the average population, eating 3 to 5 meals with meat/fish per week, and often organic and local produce.
- Climate ethics plays a role, but less than health and animal ethics.
- Decline in consumption of dairy products compared to 2015.

***Note**: emissions In Climagri format (agricultural production); consumption in Inca 2 format (ingested food).*

Direct emission reductions will be obtained by:

- **halving losses, overconsumption and wastage** of food products;
- recomposing meals[23], with **half the amount of meat**, fewer dairy products and more fruit, vegetables and pulses (see Figure 9);
- **reducing the cattle population** (-40% in 2050 in line with current trends) to one grazed on natural grass pastures or fed more locally. Grasslands contribute to carbon sinks and litter to soil enrichment;
- reducing the use of nitrogen fertilizers (-80% N_2O emissions);
- enhancing energy efficiency in farm equipment and cultivation techniques;
- using green waste and intercropping **for low-carbon energies** (biogas for grids or vehicles, biofuels made in France, electricity);
- **developing livestock manure methanisation** (70% capture rates), and using digestates for fertilization.

These changes will be reflected in the development of quality production and supply chains with a bearing on nutrition and health issues, positive net outcomes in terms of employment (mainly dependent on improvements in labour productivity, the sector's key determinant) and lower household bills thanks to the decrease in overconsumption and wastage. Such changes will require **a 50% reduction in land take** and agricultural land conservation. The new economic model involves a radical change in direction, with society agreeing to finance agriculture in return for improved product quality and services aimed at fighting climate change and preserving ecosystems, and not just at producing the cheapest possible food.

LEVERS

Food:

- The development of less energy intensive and less meat-based foods requires awareness-building and support initiatives that promote the introduction of suitable mass catering menus and better public information on the relation between food, health and climate.
- These transformations are based on voluntary approaches by the agri-food industries (proper labelling and packaging) and the incorporation of environmental health practices into government-run schemes (National Food Plan, National Health and Nutrition Programme, National Low-Carbon Strategy).
- The system for setting purchase prices and farmers' incomes should also serve as an important guide when managing these developments, by attaching a value to services such as wastage reduction.
- The consequences for household food budgets would be moderate because the reduction in meat would be offset by an increase in the price of other foods, reflecting lower productivity per hectare. In principle, transport and (greenhouse) energy costs should also fall.

Agricultural production: most of the changes in can be facilitated by incorporating agri-environmental and climate measures (MAEC) into the Common Agricultural Policy and French agricultural policy, including:

- replacement of nitrogen fertilising with nitrogen-fixing pulse crops and increased use of livestock manure;

23 Adapted from the Q5 Bionutrinet plate

- widespread installation of intermediate cover, reduced tillage and agroforestry;
- large-scale methanisation of intermediate crops, agricultural by-products (livestock droppings, crop residues) and agri-food by-products;
- diversified production to reduce dependence on meat and milk production;
- higher proportion of grass in animal feed through conservation, indeed redevelopment, of natural pastures.

Physical impacts of climate change and adaptation

It is estimated that France's climate has warmed by one degree during the twentieth century and that even in a scenario where the +1.5°C objective is reached, negative impacts will be felt in the form of floods, coastal flooding and ever-hotter heatwaves, affecting ecosystems, agricultural yields and cities. The goal of France's second National Plan for Adaptation to Climate Change (NAPCC) is "to limit the impacts of climate change and related damage on socio-economic activities and nature".
Due to a number of complexities and uncertainties, these aspects have not been taken into account in the ZEN 2050 study. What is certain is that there will be impacts, particularly on agriculture, forests and cooling needs, and that stakeholders must prepare for them.

3.4 Residential and office buildings

In light of the legislation applicable to new constructions, emissions reduction in this sector will primarily be driven by the pace and scale of retrofits carried out by 2050. Today's pace and scale are inadequate due to a number of factors, including low profitability, the timelag between improvements and an actual return on investment, and the complexity of decision processes for owners, particularly those owning condominiums. Some progress has been made, as in the training of professionals and the accuracy of energy assessments, which makes the prospect of a sharp increase in retrofits more likely.

The decarbonisation of energy carriers supplying heating, which includes replacing fossil fuels while developing geothermal energy, and providing carbon-free electricity, heat pumps, biogas and biomass from different sources, could be speeded up if economic conditions are favourable. Urban densification, cited above, will in fact also allow increased use of efficient heat networks.

The sector's electricity consumption will grow mainly on the back of household equipment, but its ability to be carbon-free will be directly dependent on the decarbonisation of the energy mix.

For the residential and office building sector, the ZEN 2050 study expects a tenfold reduction in emissions by 2050 from 74 to 7 $MtCO_2eq$. This reduction will result from a fivefold cut in consumption and a twofold reduction in the carbon content of energy.

2050: almost totally retrofitted housing stock

In 2050, highly energy efficient retrofitted housing will account for 80% of housing stock (with A-ertified new dwellings making up 30% of total stock). Fuel oil will have disappeared to be replaced by heat pumps, heat networks, renewable gas or wood. Office building stock will have been fully retrofitted.

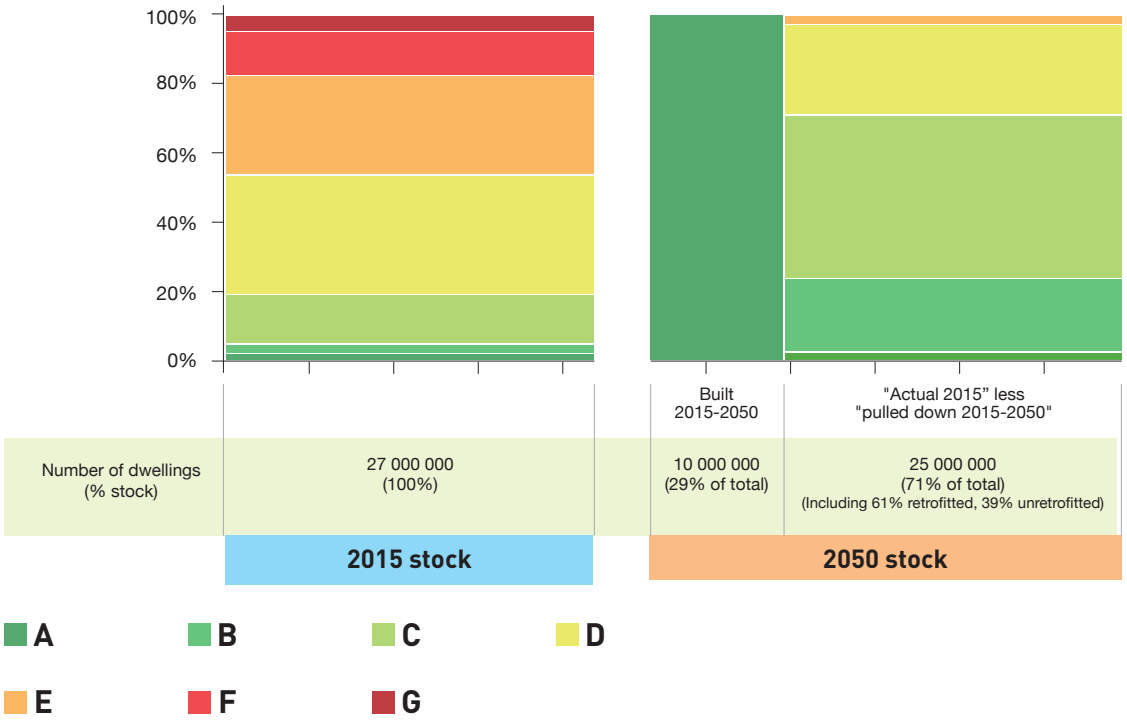
Retrofits will be preferred to pulling down/rebuilding in order to limit emissions. At cruising speed, from 2025 onwards 500,000 housing units and 50,000 office premises would be retrofitted every year.
At the same time, the deployment of energy management systems and home automation could result in 25% savings for about 20% of the housing stock.

In terms of new constructions or reconstructions (for densification), all the dwellings built will comply with energy regulation (< 50 kWh/m²). Office buildings will be built to "energy efficient" standards. 2 million housing units and 160,000 office premises will be pulled down when reconstruction makes more sense than retrofitting.

Figure 10

Number of dwellings and housing stock structure by energy label (main residences)

Carbone 4 method. ZEN 2050 Study, EpE



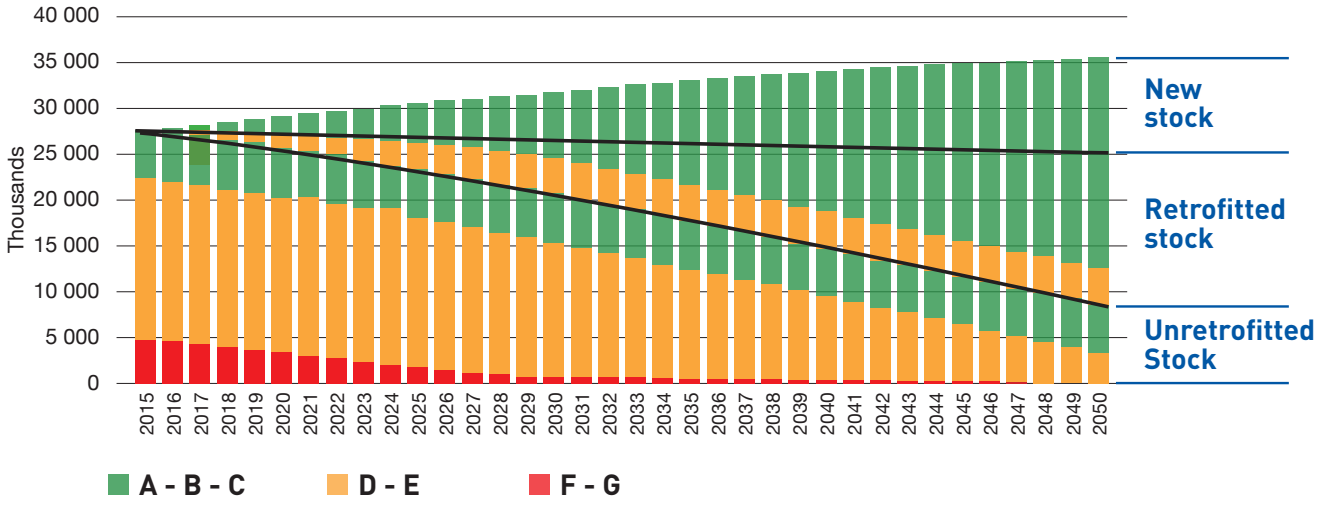
For the residential sector, housing stock will increase from 27 million today to 35 million in 2050, 30% higher than the rise in the number of households. The pace of construction chosen is that adopted in the Energy-Climate-Air scenarios till 2035, and takes into account the needs resulting from an increase in the number of households (+ 0.7%/year), as well as the reduction in the number of persons per dwelling from 2.3 in 2015 to 2 in 2050, among other things due to the increase in single-parent families (INSEE).

The energy performance of housing stock is described in Figure 11. This shows a slowdown in the growth of new housing stock, as priority is given to retrofitting heat sieves (energy labels F-G).
It should be noted that while the ambitious pace chosen results in buildings with A-B-C labels accounting for 80% of housing stock, 10% will require improvement after 2050.

Figure 11

Change in housing stock by energy label

ZEN 2050 Study, EpE



LEVERS

- Retrofit policy should be visible, stable and driven by an ambition which is consistent with climate objectives.
- Even if efficient communication on the overall improvement in thermal and sound comfort might be useful, the pace of retrofits mentioned above does not seem achievable without an obligation on owners to undertake improvement work when the circumstances are right, i.e.:
  - at the time of transfer of ownership of detached houses, whether they are occupied by the owner or leased;
  - on a scheduled basis for condominiums, as is the case with façade cleaning. Condominiums indeed have great difficulty in taking investment decisions even when the investment is cost-effective. A schedule combined with façade cleaning would help pooling of some costs. The carbon criterion ($CO2/m_2$) and the energy consumption criterion could become key criteria for all building policy.
- As with E+/C- labelling and future environmental regulations, retrofits and related public grants (CEE=Energy savings certificate, CITE=Tax credit for energy transition, Anah= National housing agency, etc.) could be subject to an energy/carbon criterion and not just energy as is currently the case.
- Households should receive support not only in the form of financial grants, but also information and assistance with the technical and administrative aspects of projects, particularly in the case of condominiums. In this respect:
  - companies could switch to solutions offering comprehensive retrofit packages with guaranteed performance without requiring occupant behaviour change. To do so, ongoing action would be required at national and local level to organise and ramp up the skills of companies and craftsmen involved in retrofits;

- the private sector could make integrated financing proposals (combining grants and loans). The responsibility for retrofits could also be linked to assets rather than owners (as in the United States);
- energy prices should be gradually increased, again in a predictable manner, to avoid the rebound effects of energy efficiency, so that energy's share of the household budget remains stable. In general, insulation should be installed before the heating source is changed to ensure it is correctly sized.

3.5 Mobility

Transport is the only sector whose emissions continue to increase totally out of line with national reduction targets[24]. Overall passenger transport increased by 27% (in pkm) between 1990 and 2015, up 1% per year[25]. Technology efficiency gains were largely offset by the increase in personal vehicle use (+19%) and freight (+69% in tkm). Public transport use (bus, coach, train, metro, tram) increased even more sharply (+42%), but was limited to the most densely populated urban areas.

Mobility is strongly influenced by town and county planning policies, social representations (ownership of a personal vehicle or a detached house in the suburbs), stage of life and income.

As commuting distances get longer due to urban sprawl, which continues to fuel private car use, most trends point to strong resistance to change. A range of factors account for this set of circumstances, including rising vehicle use, falling rail freight (-41%) and river freight (-6%), and soaring road haulage (+124%).

These negative mobility developments have other disadvantages than emissions (time loss, restricted mobility, increased weighting in pollution budgets, noise, stress), and call for more comprehensive solutions.

2050: growing mobility yet 90% fewer emissions

In the ZEN 2050 study, the transport sector (including 50% of emissions from flights entering and leaving France) will see its emissions decline tenfold from 155 $MtCO_2eq$ today to 15 $MtCO_2eq$ in 2050, thanks to a threefold decrease in its energy consumption and significant progress towards the decarbonisation of propulsion.

By 2050, people mobility will have risen by 17% compared to today. Half this increase will come from population growth and half from a rise in per capita mobility.

For passengers, public transport and bicycles will play a key role in ensuring a successful transition. Public transport will see a sharp rise, with bus and rail travel increasing by 36% and 50% respectively.

Soft modes, such as cycling and walking, will increase 300%, which in absolute terms remains low. Private vehicles will remain predominant, rising by 8% (see Figure 12).

Motor vehicle occupancy will increase, with the effect of limiting the energy consumption and footprint of vehicles, particularly in urban areas (2.2 passengers per vehicle in 2050 against 1.5 in 2015 over short distances). The momentum will be reinforced as people switch from the ownership of private vehicles to the consumption of services (self-driving, connected and shared vehicles).

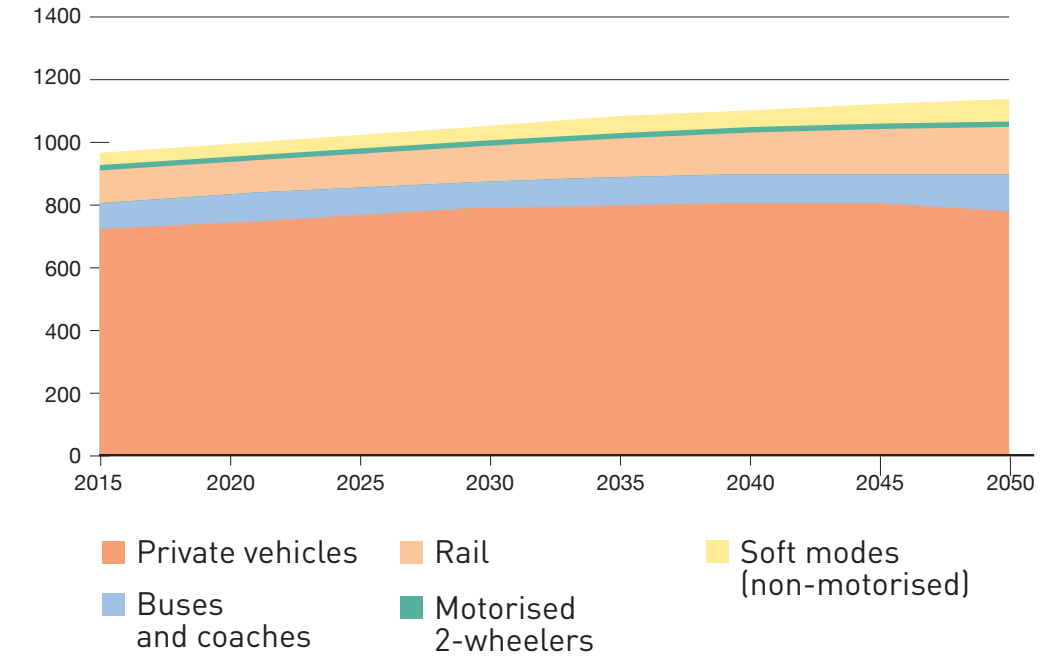
These changes are borne out in the portraits described above.

24 https://www.observatoire-climat-energie.fr/
25 Compte des transports - Annexe D - Transport et développement durable (Data from French Ministry of Ecological and Inclusive Transition

Figure 12

Passenger traffic (billion passenger kilometres)

ZEN 2050 Study, EpE



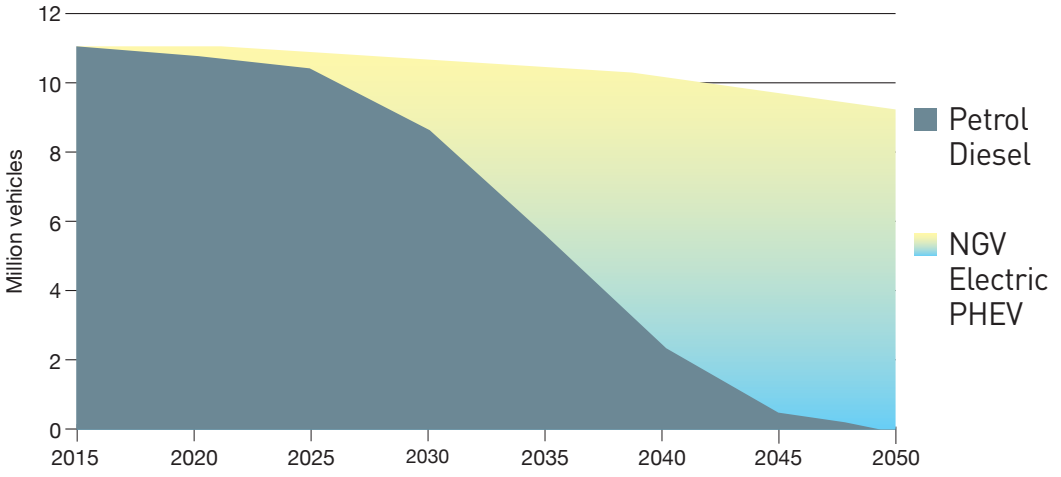
The replacement of internal combustion vehicles with zero-emission vehicles is the mainspring of transport decarbonisation (see Figure 13). The ZEN 2050 study does not select any particular zero-emission technology (electric, green gas or hydrogen). To streamline the energy model, we simply assume that vehicles run on electricity as green gas production is limited by biomass availability.

In the goods transport sector, traffic will increase by 30%, with commensurate increases in goods transported by road and rail. The increase in rail traffic will break with current trends, but remain low in volume terms. Overall, rail will benefit from the gradual shift from diesel to hybrid electrification, green gas and hydrogen.

Figure 13

Private vehicle fleet

ZEN 2050 Study, EpE



Aviation

The aviation sector will be marked by strong traffic growth. The annual number of passengers rose from marginal levels in 1950 to 2 billion in 2005, and 4 billion in 2017[26], mostly on the back of cost-reducing efficiency gains and the rapid rise of low-cost airlines[27].

The sector's other feature it the extraterritoriality of its operations, which largely exclude it from national climate policies and balances. Its borderless operations demand a systemic approach and global strategy overseen by the ICAO in view of the risk of carbon leakage between countries.

The industry has made strong international commitments involving all sector players in the fight against climate disruption. As overall traffic is expected to double in 20 years (3.5% global increase in passengers on average annually, according to IATA), the industry is committed to halving its emissions by 2050 compared to 2005 levels[28], under the CORSIA programme[29] for carbon-neutral growth from 2020 adopted by the ICAO.

On the premise that offset solutions will be limited in time and space, and that incremental gains in energy efficiency are inadequate on their own to achieve the required reduction levels (30), to meet its sectoral targets the industry is extremely reliant on speedier development and larger-scale production of breakthrough technologies (e.g. fuels meeting ICAO sustainability criteria, electric propulsion, hydrogen aircraft).

The ZEN 2050 study supports this conclusion: the inter-sector allocation of the 2050 carbon budget would involve quickly decoupling the aviation sector's required emission reductions from its growth. Due to the limited availability of biomass, the use of biofuels alone may not be sufficient to reach its reduction targets. France is reasonably well endowed with biomass, so the limited availability of biofuels will likely have repercussions across the world. In view of the anticipated growth in traffic (even if it is around +2.6% a year in Europe - source IATA), technological breakthroughs clearly become crucial if - other things being equal - the expectations of an ever more demanding global market are to be satisfied.

The ability of the sector to mobilize its resources and attract investments to support the required breakthrough technologies will thus be decisive, as will the implementation of ambitious and internationally compatible national public policies pointing in the same direction.

International shipping, excluded from the scope of this study, faces the same complex issues of emissions extraterritoriality, strong growth prospects and limited potential for incremental gains in energy efficiency.

LEVERS

- **Development of pedestrian, active and shared mobility:**
  - Suitable public transport options and integrated public-soft mode solutions;
  - Expansion of teleworking, and promotion of carpooling, car sharing, and zero emission two-wheel vehicles;
  - Urban densification and city centre/small town revitalization to bring inhabitants, services, shops and jobs together in closer proximity, and to reduce restricted mobility;
  - Management by local authorities of separate spaces in town for private cars and mobility services, as well as soft mobility infrastructure (cycling tracks, pedestrian areas).

26 https://www.air-journal.fr/2018-01-19-nouveau-record-avec-41-milliards-de-passagers-dans-le-monde-en-2017-5193395.html
27 https://www.challenges.fr/economie/hausse-du-trafic-mondial-aerien-en-2017-avec-les-compagnies-low-cost_560990
28 https://www.iata.org/pressroom/facts_figures/fact_sheets/Documents/fact-sheet-climate-change.pdf
29 Carbon offsetting and reduction scheme for international aviation
30 https://www.icao.int/environmental-protection/Documents/Resolution_A39_2.pdf

- **For goods, development of optimized logistics** in terms of energy consumption which matches needs, minimises distances travelled, facilitates pooling and sharing in urban centres, and adapts delivery standards. Substitution of domestic energy tax exemption (TICPE) for transport companies with an incentive mechanism to switch to low-carbon vehicles, enhance logistics efficiency, and turn to more local supply chains.

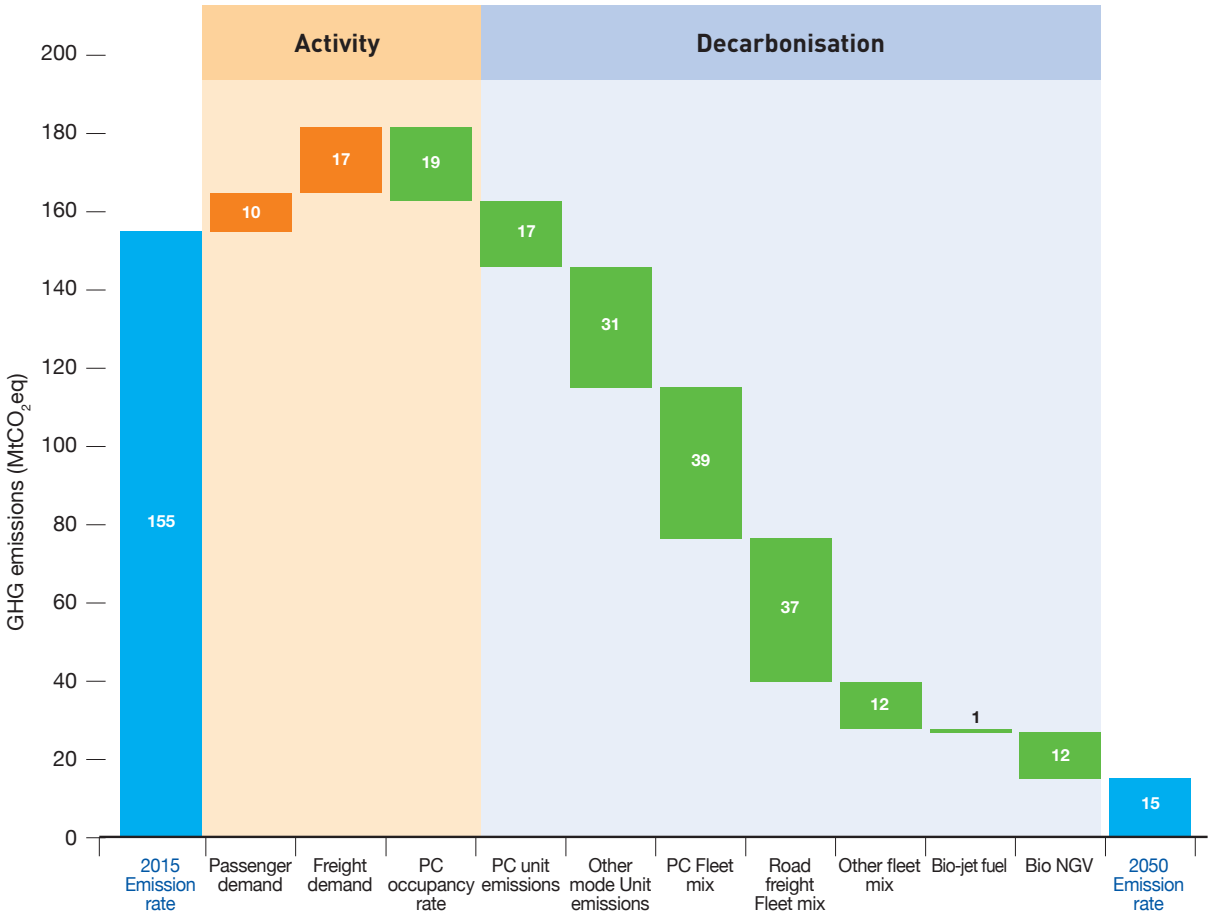
- **Promotion of transition to carbon-free mobility for passengers and freight:**
  - Advance planning for the decommissioning of all-ICE vehicles;
  - Improved application of the bonus/malus system to make it more transparent;
  - Targeting of grants at people with strong mobility needs linked to their work (i.e. those living in rural areas); people with strong mobility needs not related to their work can be encouraged to live closer to urban areas;
  - Development of territorial access to trains for travellers by putting in place a low-carbon feeder system (carpooling, bikes, etc.).

- **Development of a distribution network for electricity, hydrogen and gas:**
  - New refuelling infrastructure development and upscaling is critical for EVs, NGVs and hydrogen vehicles;
  - In-depth study of infrastructure requirements based on appropriate fleet deployment segmentation and timing.

Figure 14

Impact of different levers on transport emissions (2015-2050, $MtCO_2eq$)

ZEN 2050 Study, EpE



3.6 Industry

Since the late '90s, the energy intensity of industry has shrunk considerably. However, the untapped potential of energy efficiency remains significant and is expected to reach 20% by 2035[31].

Chemicals, steel, cement and glass alone account for some 65% of industry emissions and 50% of industrial energy consumption. The challenges needing to be addressed mainly concern these sectors.

60% of emissions come from energy combustion and 40% from industrial processes based on chemical reactions (mainly present in the production of chemicals, steel and cement-clinker).

Non-CO_2 GHG emissions (e.g. use of HFC for refrigeration or hydrogen production) account for around 10% of emissions.

The central issue for these four high-emitting industries is competitiveness. In the European and global market, emissions reduction policy in one country has to be consistent with the policies of other countries, failing which efforts to tackle carbon leakage could be jeopardised.

2050: revitalised, carbon-free and, to some extent, backshored industry and residual process emissions

By 2050, industry could achieve a fourfold reduction in its emissions (depending on the stability of volume and non-relocation assumptions), slashing emissions from 80 to 18 $MtCO_2eq$, or even 13 $MtCO_2eq$ if CCS is factored in. The conditions for this transformation (innovation, investment, jobs) will have to be properly determined.

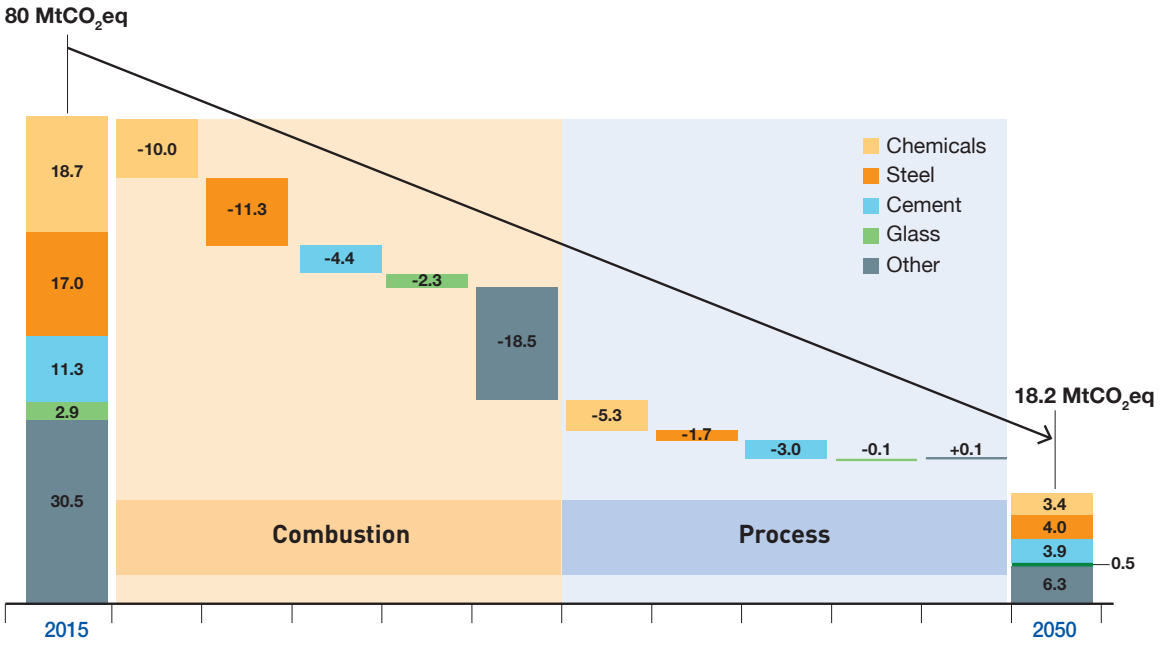
Emissions reduction across relevant sectors can be obtained by:

- cutting wastage and recycling secondary raw materials, steel, construction waste and plastics (estimated 50% untapped potential in the négaWatt scenario);
- increasing energy efficiency (10 $MtCO_2eq$);
- electrifying processes up to 50% of industry's final energy consumption;
- using biomass for energy and other decarbonised carriers (very high temperature heat pumps and heat networks, solid recovered fuels, biogas, hydrogen);
- improving process performance (hydrogen production, fluorinated gas leak reduction, CO_2 sequestration by concrete during production, etc.).

Figure 15

Change in greenhouse gas emissions by industry (2015-2050, $MtCO_2eq$)

ZEN 2050 study, EpE



Although based on GDP growth forecasts (provisional national low-carbon strategy, SNBC, December 2018), the study assumes that industrial production levels will be equivalent to current output levels in volume terms (as they are directly correlated to emissions). Output will fall slightly in some industrial sectors, mainly because of the shift to housing retrofits rather than new constructions, and falling demand for new housing.

While this scenario allows territorial emission targets to be reached, it requires industry to decorrelate value growth from production volume, or else reduce its share of GDP. A policy of maintaining or increasing this share could reduce emissions imported into France along with global emissions, but would slightly degrade France's emissions performance.

The technical and economic conditions specific to each sector of activity will be instrumental to the success of the ZEN 2050 study. Nevertheless, the reduction options to be deployed may be grouped into three categories (costs given as a guideline only[32] because the study did not undertake a detailed costing):

- at zero or negative cost (27 $MtCO_2$): less wastage, more efficiency, recycling, heat;
- at a cost below €100/tCO_2 (19 $MtCO_2$): secondary steel sector, gas decarbonisation, switch to electricity, biomass, fluorinated gas reduction;
- at a cost above 100 €/tCO_2 (11 $MtCO_2$): green hydrogen energy, steam recovery, green hydrogen process, biogas.

LEVERS Innovation and risk reduction

The implementation of industry decarbonisation projects is dependent on positive business models[33]. A European carbon price, which systematically promotes the deployment of low-carbon technologies as part of a mechanism that protects the competitiveness of French and European industry from competitors implementing less stringent climate policies, would therefore seem to be a crucial lever.

Other levers include:

- **Provision of large-scale finance for low-carbon technologies**
  - Across-the-board inclusion of internal carbon pricing into investment decisions, thus providing greater clarity on how prices are likely to evolve;
  - Provision of incentives via tailored financing arrangements and risk reduction measures for different sectors (role of professional associations);
  - Alignment of investment decision criteria with climate issues, particularly the carbon price set by the European market.
- **Support for technological innovation** and emerging or breakthrough solutions:
  - Anticipation of regulatory frameworks (e.g. for CCS utilisation);
  - Promotion of far-reaching international cooperation at European level, in view of the scale of research and deadlines for implementation (multiple processes and industrial sectors).
- **Promotion of best environmental practices**
  - Promotion of the circular economy at all levels, including lower overall consumption of resources. Environmental companies are already developing cutting-edge technologies, a sector in which France can play a leading role.
- **Material substitution**
  - More intensive forestry practices (50% increase in production) could create industrial opportunities if the downstream wood processing sector is developed well beyond its marginal role today.

31 ADEME, Visions 2035-2050
32 Trajectoires de transition bas carbone en France au moindre coût, MTES, November 2016
33 ENEA Consulting - Yannaël BILLARD 2016. Financement de projets industriels productifs sobres énergétiquement

3.7 Energy production

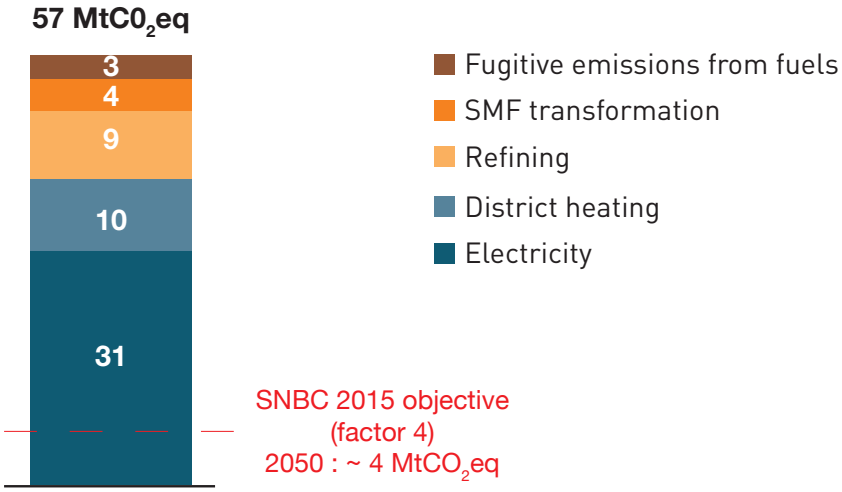
Due to the structure of its power generation, France already **produces very low carbon electricity**. Energy production accounts for a tiny fraction of its GHG emissions (7% from fuel oil, coal, gas in 2018)[34].

Emissions from heat networks depend on the energy resource that fuels them. Although fossil fuels accounted for 57% of production in 2013 (42% natural gas, 9% coal and 4% fuel oil), emissions are on the decrease with over 50% of heat now produced from renewable sources and recovery. Domestic emissions from refining activities have fallen sharply (-32% vs 1990), particularly following the closure of several refineries.

Fugitive emissions from fuels or from the transformation of solid mineral fuels (SMF) have also dropped considerably due to the decline in coke production.

Figure 16

Direct emissions of energy sector (2013, $MtCO_2eq$), National Low-Carbon Strategy (SNBC)



As part of the transition to net-zero emissions, electricity production will have to tackle a number of challenges:

- Proposing an energy mix free from dependence on fossil fuels, especially by supporting the development of decarbonised energies, whether or not intermittent;
- Maintaining a share of sufficiently manageable production to respond to daily and seasonal variations in energy consumption, including reduced use of thermal power plants through the deployment of alternative flexibility mechanisms.

The exact composition of the energy mix is the subject of substantive studies under the Multiannual Energy Programming System (PPE). The renewal of nuclear plants in particular is one of the issues being debated.

The ZEN 2050 study is compatible with the PPE and SNBC options and confined to highlighting the limitations and scope of the energy mix.

34 https://bilan-electrique-2018.rte-france.com/?lang=en#

2050 - Energy Savings and Electrification

The energy production sector in France accounts for only a small share of the country's GHG emissions (57 $MtCO_2$ or 12% of overall emissions). These would be cut to 9 $MtCO_2$ under the transition to net-zero emissions by 2050.

The electricity sector will continue to play a very important role when final energy consumption, all carriers included, is cut by half. Production would be shared between nuclear and renewable electricity, with such gas-fired power plants as are necessary supplied by renewable gas based on its availability.

The studies being conducted as part of the Multiannual Energy Programming System (PPE) and the National Low-Carbon Strategy (SNBC) provide a more detailed outlook of energy mix and consumption levels.

- Grid optimization and the development of flexibility mechanisms will play a significant role in achieving system balance, with 25-30 TWh obtainable (at a conservative estimate) through i) the reuse of EV batteries as second life batteries (~13 TWh) and ii) vehicle-to-grid inputs during charging of electric vehicle batteries;

- Flexibility mechanisms (demand management, stationary storage, water heater power control, etc.), in addition to nuclear, hydropower and gas-fired plants, would obviate the need for new fossil-fuel power stations in addition to those already scheduled.

Gas consumption will drop to between 220 and 300 TWh annually, compared to 490 TWh in 2016. Renewable gas will constitute the bulk of production at between 195 and 300-plus TWh (versus 0.7 TWh today), accounting for anything between 65%-100% of consumption, with:

- 120-130 TWh from methanisation;
- 65-130 TWh from gasification[35];
- 10-65 TWh from power-to-gas (methanation). Here too, detailed studies on changes to the energy mix have been carried out as part of the PPE and SNBC initiatives. The results vary according to the technologies considered and the actual share of gas from renewable sources.

Heat network production could rise to between 54 TWh and 75 TWh from 42 TWh in 2015. Their procurement will include a proportion of back-up gas, as well as geothermal energy and biomass energy available in line with the gradual increase in biomass production between 2015 and 2050.

Issues of scalability for biomass resources in the energy mix

The ZEN 2050 study highlights the limited quantity of biomass available for energy use in view of the decarbonisation needs of different energy sources (heat networks, biogas, boilers, etc.).

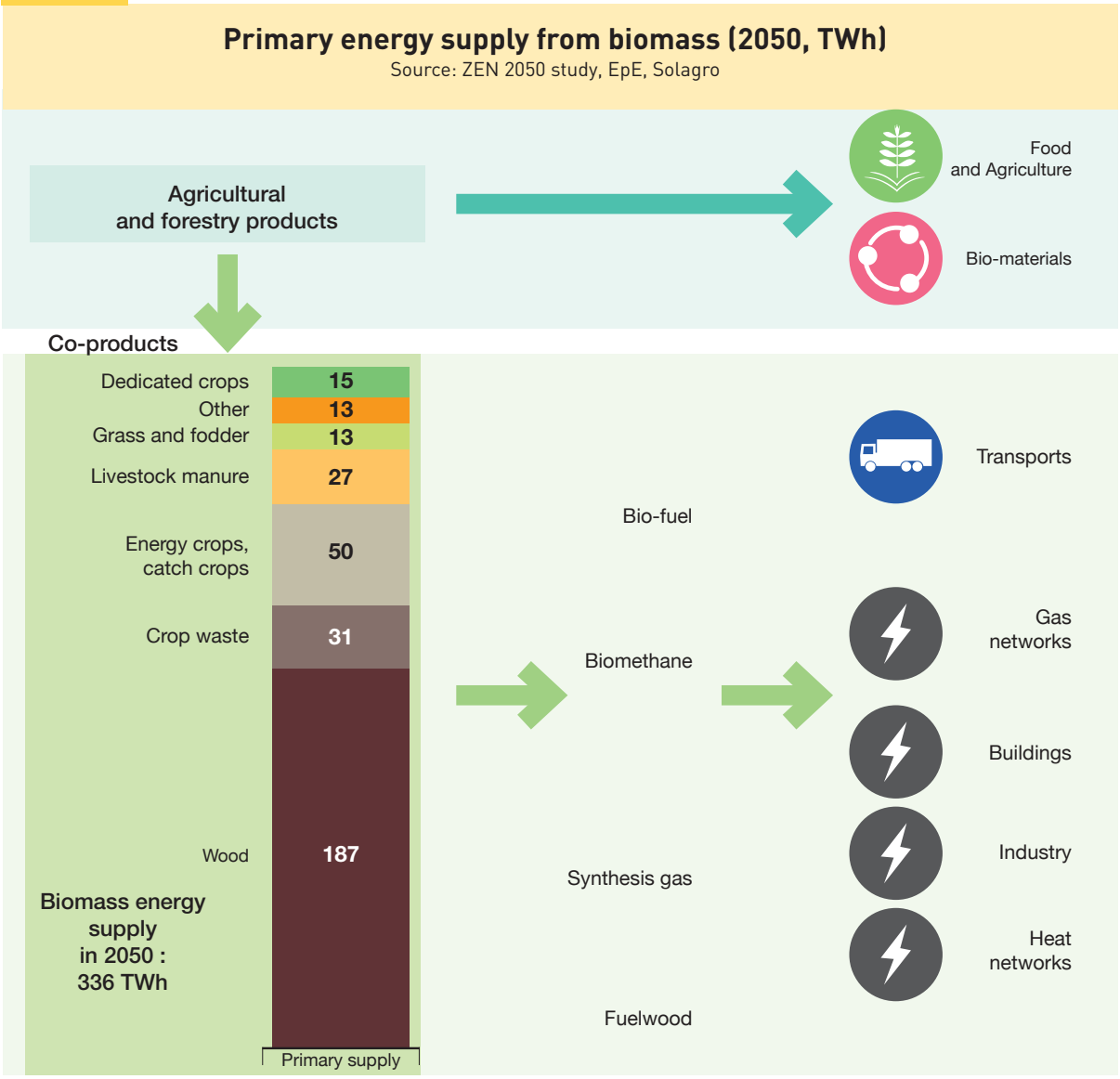
This finding raises two questions:

- Is it possible and desirable to increase biomass production? We have assumed the existence of a significant carbon sink that limits it.
- What governance rules should apply to achieving trade-offs between various competing biomass uses?

The study assumes that most energy uses leverage agricultural and forestry co-products and waste (intermediate crops, scrap) that are unfit for food. Governance tasks could be performed by an ad hoc institution since the market alone would be unable to deliver these trade-offs.

35 This technology is still at a preliminary stage of development and does not, for the time being, have an industrial deployment capability that would allow it to readily form part of the prospective energy mix.

Figure 17



LEVERS

Even if the choice of energy mix is undecided, a number of levers will be absolutely critical:

- Complementary uses of different energies;
- Widespread development of renewable energies (biogas, pyrogasification, geothermal energy, renewable heat, solar, wind, etc.);
- Strong ambition to secure an adequate volume of biomass and improve its production methods;
- Enhanced storage and flexibility capabilities, in addition to nuclear plants, hydropower and gas-fired plants, so as to obviate the need for new fossil-fuel production facilities; the use of renewable hydrogen, if economically viable, is promising;
- New business models for energy: an adequate carbon price would help pay for the investment in storage and renewable energies; new mechanisms should reward availability and flexibility rather than energy volumes sold. In general, energy will be more costly so as to encourage energy savings, with volume reductions offsetting the price effect and avoiding an increase in energy budgets.

3.8 Sewage and refuse

In 2015, France produced 298 Mt of waste, including 80% of low-emission, inert, easily recoverable waste (rubble, metals, glass), 15% of higher-emission organic waste primarily from households, and 5% of plastic waste.

Methane leaks from landfill sites are the main source of emissions, followed by emissions from incineration plants.

The French government's circular economy road-map sets objectives that include cutting in half non-hazardous waste dumped at landfills by 2025 (base 2010), shifting towards recycling or recovering 100% of plastics by 2025, and avoiding 8 $MtCO_2$ of emissions every year thanks to plastics recycling.

2050: no waste!

In the ZEN 2050 study, emissions from the refuse and sewage sector will be reduced by 76%, from 18.7 in 2015 to 4.5 $MtCO_2eq$ in 2050.

In line with the principles underlying the waste treatment hierarchy, waste emissions reduction would involve, first, decreasing the quantity of waste from 290 kt in 2015 to 240 kt in 2050.

This could be achieved by reducing the amount of packaging, increasing the role of ecodesign, and slashing wastage in general, including that of food (-50%). This will also enhance the reuse and life-span of various goods.

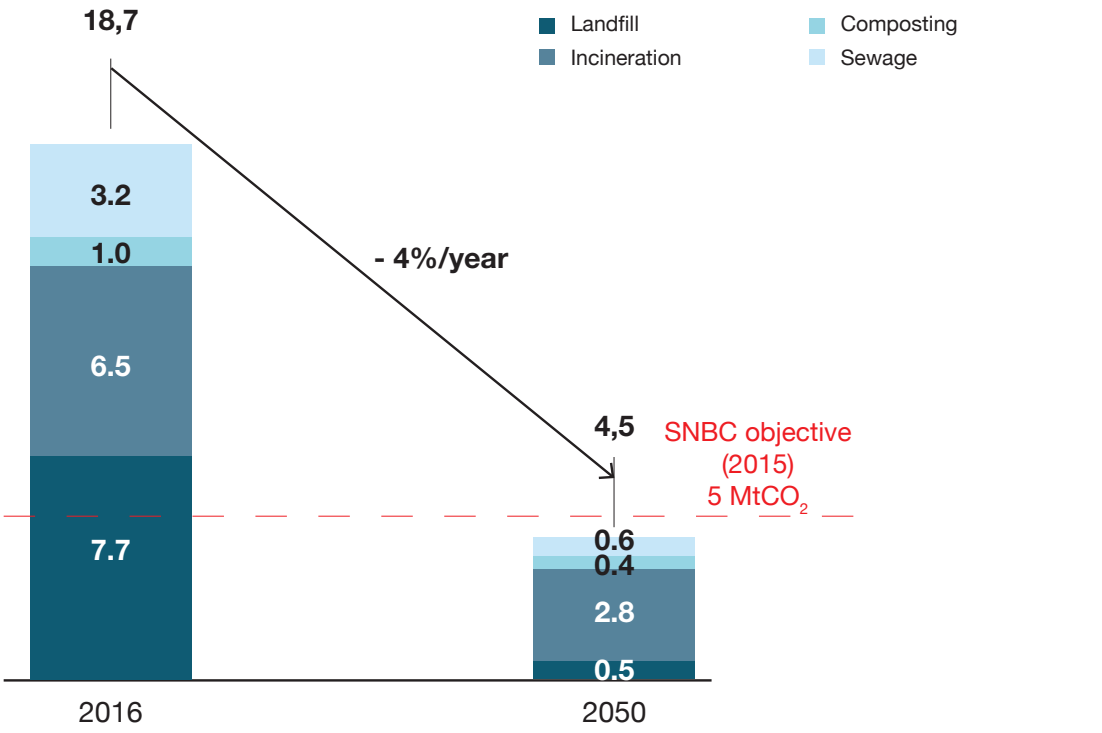
Secondly, it would involve increasing waste recycling from 50% in 2015 to 80% in 2050 so as to reduce incineration and landfills.

Lastly, it would involve electrifying processes (among others at wastewater treatment plants) and methane capture (80% in 2050 vs 45% in 2015), reducing emissions from waste treatment and recovery, and increasing the share of renewable energy in the gas mix.

Figure 18

Modelled change in GHG emissions from refuse and sewage (2016-2050, $MtCO_2eq$)

CITEPA, Carbone4



LEVERS Booming circular economy

The deployment of waste management levers, particularly from a long-term perspective, could rely on various pillars of the circular economy, defined by ADEME[36] as the evolution of supply towards sustainable procurement, ecodesign, functional economy, industrial ecology, waste management and recycling, and as the evolution of demand towards responsible consumption and longer periods of use. Accordingly, the following levers could also have a positive effect on emissions reduction:

- Limitation of household waste production and more sorting with simpler guidelines;
- Waste reduction, particularly of plastics, ecodesign and better recycling through:
  - Higher collection rates;
  - Incorporation of recycled plastics into products, including imported products;
- More robust recovery and recycling of inert waste, in particular building materials;
- Redirection of waste flows by increasing the cost of landfilling;
- Higher capture and recovery rates of biogas from landfill and sewage treatment plants;
- Improved reparability of goods, and greater consumers awareness of current warranty terms;
- Development of goods reuse: resale, gifts, pooling, reuse, repair, etc.

A review of the different sectors reveals many opportunities and a new economic and industrial momentum, with the exception of certain sectors heavily dependent on fossil fuels and faced with the challenge of radical transformation.
A net-zero 2050 France could therefore be an attractive proposition for the business community and not just consumers, as described in the beginning of this study.
Nevertheless, the success of this transformation is dependent on a number of conditions which are explained in the next chapter.

36 https://www.ademe.fr/expertises/economie-circulaire

4

CONDITIONS FOR A SUCCESSFUL TRANSFORMATION TO NET-ZERO 2050

4.1 Voluntary and fair transition

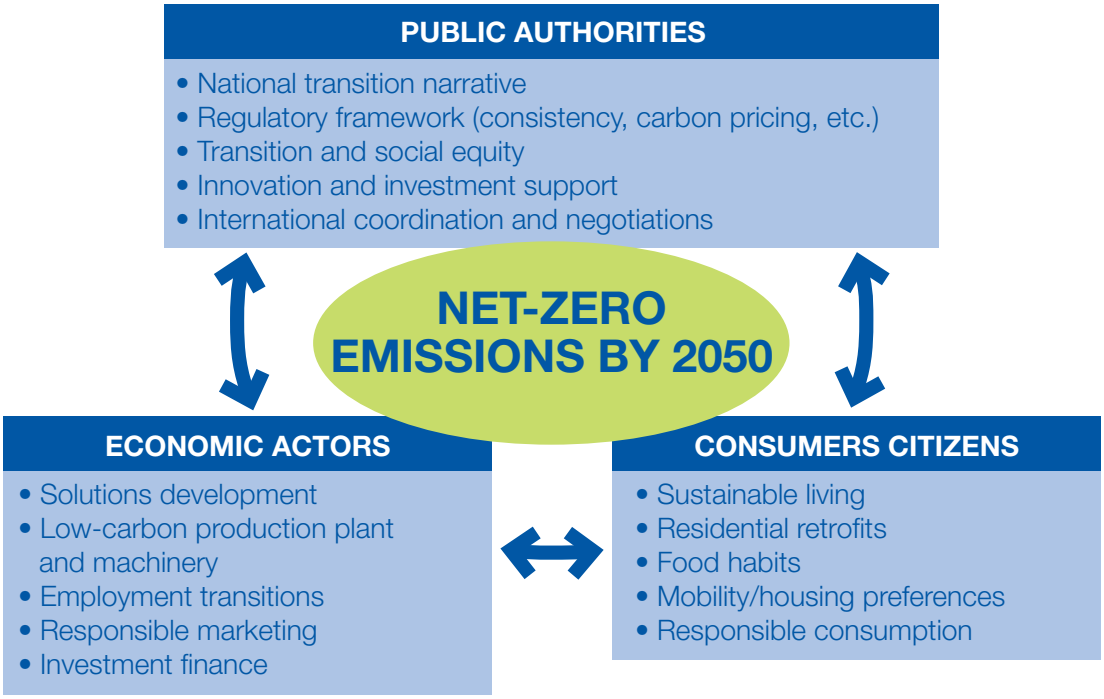
The main determinant of success appears to be the emergence of a shared vision of what constitutes a carbon-neutral France, and of the steps to be taken by the different stakeholders to get there.

The transition to long-term carbon neutrality calls for the reshaping of behaviours, infrastructures, technologies, organizations and institutions, thereby creating a wonderful opportunity for society. All stakeholders have a role to play in this process, and all can benefit if the transition is fairly organized and helps those most affected to adapt to the new reality. We also have a lot to lose if this transition fails: climate damage has already begun and will worsen.

We have seen in the previous chapters the many benefits the transition to net-zero emissions would bring to the people, the economy, and to France internationally. The study unequivocally shows that the stakeholders stand by each other in this transition – aware of the need to work together to make it happen - just as States stand by each other in the Paris Agreement. That is why a shared vision of the constituent elements of a carbon-neutral France and each person's role in getting there is of prime importance. The task will be much easier to fulfil if stakeholders share the work and focus on a common goal.

In our view, three categories of stakeholders should be capable of building together a carbon-neutral France by 2050: i) individuals who are also citizens, investors, working people, and consumers; ii) national, European and local public authorities; iii) businesses from all sectors, large and small. The respective contributions of these stakeholders to putting France on a net-zero emissions pathway by 2050, such as we have described in the preceding chapters, are summarised in the figure below and discussed in the sections that follow.

Contributions by each stakeholder



4.2 Much-needed citizen mobilisation

Citizen mobilisation will undoubtedly be a crucial determinant of success.
The lifestyles in Chapter 1 describe a desirable society which can deliver on the goal of net-zero emissions, while providing many benefits for inhabitants in terms of comfort and convenience, quality of life, health and prosperity. However, getting there will require a concerted effort to induce a change in individual behaviour and commitment: consumer citizens will indeed make or break the transition.

Adopting sustainable lifestyles

Food: changes already under way are laying the groundwork for a significant long-term shift in diets towards more vegetables, less animal proteins and more locally-sourced products.

Transport: new mobility modes - soft, public transport, shared - are on the rise and should offset the effects of aspiring to "ever more" mobility.

Housing: despite significant efficiency gains, further efforts are needed to surmount the difficulties besetting deep-energy retrofits caused mainly by huge investment requirements and the arduousness of collective decision-making, particularly in condominiums.

In fact, **efficiency gains are often nullified by rebound effects**, such as the tendency to increase heating temperature after a retrofit. Schemes aimed at bringing about a change in practices, such as the "Energy-Plus Family Challenge", show that it is possible to reduce, even cancel, this rebound effect.

Urban planning and development have become a cross-cutting and decisive issue in many of the fields mentioned above. Sprawled urban communities thus translate into forced mobility and poorer access to public transport.

The development by the private sector of a range of responsible products and services would likely be effective and feasible based on the need to meet real demand for such goods. Education, awareness-raising and training will enable people to address these issues, take individual responsibility for them and stimulate what is marginal demand at present.

A change in behaviour or lifestyle is easier to make if one has chosen to make it. The onus will therefore be on corporate stakeholders to deliver attractive solutions, just as it will be on public authorities to make those solutions desirable and accessible so that the emerging lifestyle choices are quickly adopted by most households.

The many digital services offering new consumption patterns - or even new criteria for describing what a "good life"[37] is - best exemplify the underlying trends and the growing appetite for a life in greater harmony with one's environment.

The collective representations and perceptions that shape consumer decisions are therefore of critical importance. They must change away from the high-carbon-footprint uses and consumption patterns that have largely driven economic growth and corporate profits until now.

37 See, for example, Good Life Goals, WBCSD

Social acceptance

The socio-technical feasibility of widespread deployment of renewable energies, especially wind and the energy products derived from biomass, is already arousing a great deal of public interest. There is strong attachment to the idea that the forest is a "natural" preserve, so much so that its intense commercial development is causing great concern (visual nuisance, noise, traffic, etc.).

Experience in different countries shows that in energy matters the fact that citizens can invest directly through cooperative schemes usually works as an important facilitator. This might well be a key success factor in France as well.

There are some cleavages between individual aspirations and the results of the ZEN study on the issue of urban development: 80% of the population dreams of living in a detached house (50% actually live in one)[38], whereas the study shows that urban sprawl must be curbed.

Solutions exist for reducing the perceived disadvantages of urban density, and include visual privacy, noise insulation, architectural quality, access to nature within the city, and thermal comfort in all seasons. Harnessed together they can help to revitalize city and town centres. But is it enough to change aspirations?

At the end of the day, consumers are citizens as well as voters; policymakers desperately need them to adhere to the collective project so that they can take the often difficult decisions to implement it.

Consultation with a citizens' panel (see attached recommendations) shows that to secure the planned transition's acceptance by citizens, it must be, and perceived to be, equitable, inclusive and conductive to social justice.

4.3 Ambitious and integrated public policies

National transition narrative

National and local authorities have a critical role to play in mobilising society towards the transition to net-zero emissions by 2050. We saw above that emissions are influenced by public policies in many fields, including taxation, town and country planning, infrastructure investment, research, development and innovation policies, public procurement, housing and mobility, agriculture, education, trade and industrial policy, and so on. For climate action to inspire such a wide variety of policies, the national climate transition narrative must have a broader appeal well beyond specialist environmental circles.

The first task of public authorities would therefore be to build and share, with civil society as a whole, a broad-based national narrative on what a carbon-neutral France might entail. The ZEN 2050 study only claims to be one contribution among many to this narrative. Beyond the political debate around the National Low-Carbon Strategy, the great national debate held in the first quarter of 2019 brought to the surface strong expectations as well as underlying issues.

At a subsequent stage, institutions such as France's High Council for Climate, set up at the end of 2018, could play a key role in enacting this national narrative and ensuring overall public policy consistency with this goal, well beyond the scope of traditional environmental policy.

38 Faire la ville dense, durable et désirable, ADEME, 2018

Supporting vulnerable populations

This task is clearly the responsibility of the local authority and falls within the scope of its social policy. The transition to net-zero emissions will lead to an increase in energy prices, requiring significant investment from households to reduce their emissions. It will be an especially difficult challenge for vulnerable populations, at risk from the effects of climate change, to take up on their own, even if they are usually small emitters.

As has been suggested for other policies, it will be necessary to incorporate climate into the social and welfare policies for vulnerable and needy populations already being widely implemented by the State and local authorities.

Policies could combine short-term transition support and assistance, including access to thermally retrofitted social housing instead of energy cheques, relocation grants to enable people to move closer to their place of work or to the place of delivery of essential services, and training in energy-saving behaviours. It could also involve training Social Action Community Centres (CCAS) and social landlords to support the least well-off in implementing energy restraint and efficiency management measures in their homes.

Action in this area seems essential if the transition to net-zero emissions is to be widely perceived as fair.

Economic incentives and carbon taxation

Among public policies, economic and tax policies are the most critical to all sectors since they create the economic models for agriculture, urban development, industrial innovation, mobility, the solidarity economy and the circular economy. All sectoral policies should therefore be reviewed to incorporate the needs and opportunities of the transition to net-zero emissions.

Among them, the emissions price signal could play a key role in shaping stakeholder behaviour, subject to a number of conditions:

- All stakeholders must have visibility of price signal changes in order to invest;
- All must be properly informed about the use of carbon pricing revenues (allowance or tax), whether as a grant for the transition of vulnerable households, or as financial assistance for the transition and/or as funding for the reduction of other costs particularly to address related carbon leakage;
- As fossil energy subsidies, primarily in the form of tax exemptions and assistance for some emitting sectors, are counter-productive for carbon neutrality, their reduction will be essential to freeing up significant resources for the transition, including that of the sectors concerned;
- The social value of mitigation activities (Valeur de l'Action pour le Climat), as defined by the Quinet Commission in February 2019, should continue to serve as a guide for all long-term public investment.

Investment and innovation support

Available studies on France[39] show a significant investment deficit in the French economy for a net-zero emissions pathway. The preceding chapters show that domestic investment should more than double from 30 billion euros a year to 75 billion euros a year from 2030. Local communities will have to bear the lion's share of investment in thermal retrofits for their buildings, public transport systems, appropriate infrastructures, and beautification of urban centres.

Several initiatives could be developed to speed up investment in the transition, increase funding and reduce the risk associated with transition-related investment. Such initiatives would stimulate both private and public investment.

Research and innovation policy. The transition will require a combination of behavioural, technological and institutional innovations:

39 Panorama des financements climats (Overview of climate finance), I4CE, 2018

• R&D policies in all sectors must include, from the earliest stages, the climate impact of planned innovations;

• social science research should be involved in this process, delivering innovation development insights to citizens-users-consumers, and building the new narrative.

Role of local authorities

The **role of local authorities in transforming key systems, housing, transport, and production** will be essential for the transition, as seen above. Ramping up the roles, responsibilities, jurisdictions and functions of local authorities on energy and climate issues is a sine qua non for the success of the transition.

Local authorities do indeed play a key role through:

• the inclusion of climate-energy practices, approaches and strategies in day-to-day work and the preparation of long-term land planning documents (SRADDET, PCAET, etc.);

• local schemes, such as Energy-Positive Territory (TEPOS);

• urban development policies, planning documents (SCOT, PLU, PLUI, etc.), tax incentives and their implications for urban sprawl, farmland conservation, and beautification schemes for city centres and small towns;

• their nearness to and contact with citizens, demonstrated inter alia by the success of local renewable energy development projects.

It is therefore important for local authorities to have the financial resources, expertise, service competence, skilled elected representatives and institutional and regulatory powers to make a meaningful territorial contribution to national carbon neutrality, while leveraging their geographical assets for a common purpose.

National strategies and policies will also be a driving force in the dissemination and implementation by most of them of regional best practices adopted by pioneering local authorities.

Lastly, some regions might be the losers in the transition because of their dependence on high-emitting sectors. National solidarity should be exercised to bring new activities to them and to organize their conversion in conjunction with business.

International cooperation

In 2015, France produced 0.9% of the 36 billion tonnes of GHGs emitted each year[40]. Beyond considerations of the responsibility, exemplarity and respective economic opportunities of countries, France's reduction effort is part of a European and global initiative.

Specifically, Europe is responsible for several policies critical for the climate: the common agricultural policy, external trade policy, a large section of R&D and climate policies, and major infrastructure policies. One of the determinants of success of carbon neutrality will be the conversion of those policies in line with climate ambitions.

With this end in mind, it will be essential to include environmental clauses in existing free trade agreements or those in the process of being negotiated, in particular the commitment to comply with the Paris Agreement and to work jointly for its implementation. These agreements could also provide an opportunity to facilitate the development and distribution of transition-friendly products and services. Europe could reward its partners for strengthening their climate ambitions with access to its vast market.

40 Chiffres clés du climat - France, Europe et Monde - Édition 2018, CGDD (Data from French Ministry of Ecological and Inclusive Transition)

Climate Paths for Germany Study

Germany has set itself the goal of reducing its emissions by 80%-95% by 2050 compared to 1990 levels, but discussions have been ongoing for years about how this should actually be done.
The BDI (Federation of German Industries) carried out a study[41] in 2017 with a view to proposing industrial strategies compatible with those objectives. The study took 10 months to complete and mobilised more than 70 member federations and 300 experts.
It concludes that existing measures would lead to a 65% reduction in GHG emissions, and that strengthening measures leading to a reduction of 80% is economically and technologically feasible for Germany, regardless of the behaviour of the rest of the world. A 95% reduction scenario would however be plausible only if the G20 countries coordinated their policies.
Aggregate additional investment amounts to an estimated €1500-2300 billion and net costs to €500-1000 billion. Effects on GDP would be neutral or slightly positive, while the opportunities created on the world market would be worth €1000-2000 billion/year by 2030.

While the carbon price appears essential for the deployment of low-carbon technologies, it also drives up costs (partially offset by energy savings), and so risks undermining the international competitiveness of French industry. On this issue, Europe is best placed to act: on the one hand by adopting provisions which prevent intra-EU distortions, and on the other by pursuing a determined and positive policy which combines emissions reduction and international trade development.

In some cases, therefore, it will clearly be necessary to make emissions reduction a greater priority than international trade development.

While border controls for all products seem difficult to implement, it is certainly possible to use access to the European market as a lever to reduce emissions, and to confer the customs advantages contained in bilateral or multilateral agreements on countries which adopt climate policies in line with the Paris Agreement. This would help raise the carbon price in Europe, and no doubt in other countries, to the levels needed for the deployment of low-carbon solutions without carbon leakage or jeopardising France's or Europe's economic activity.

The convergence of national strategies to combat climate change would moreover speed up the development of technologies by spreading development costs, generating economies of scale, and pooling learning gains.

In actual fact, a proportion of French emissions comes from using products manufactured abroad. As well as decreasing the global footprint, an improvement in the environmental performance of other countries would reduce the energy consumption of their products and carbon footprint in France.

If France and Europe are to play a significant role in greenhouse gas emission outcomes, they cannot confine their action to their territory alone.

To decide and carry out all these policies, public authorities would need the support of their citizens whose representatives vote laws and sometimes don't hesitate to take to the streets to be heard. They would also need the support of economic stakeholders who would have to bear the brunt of these policies, as well as the responsibility for delivering new solutions to their markets.

41 https://bdi.eu/themenfelder/energie-und-klima/klima2050/

4.4 The role of business

Developing solutions

While the study does not call for innovations in breakthrough technologies, it does highlight the deployment of many new products and services: electric vehicles, housing retrofit solutions, eco-designed and energy efficient products, functional economy, new energy services, etc. There would be an incentive for companies to develop such solutions and bring their cost down so that they are affordable for consumers and commercially more attractive in a fiercely competitive global market.

The financial and human investment needed will be significant, not to say risky despite the incentives offered by public policies. The technological race might lead to a dead-end, if some solutions prove more expensive - or have a smaller market - than anticipated. One thing is certain: we are talking about a technological and industrial revolution in which businesses will have to manage their risks and opportunities.

In this revolution, public confidence in climate goals is essential. Business needs consumers to successfully make the transition and consumers must have confidence in the solutions being proposed. One group of consumers - public authorities - will be key to the adoption of certain solutions. In fact, exemplary public procurement could be a prime driver in the transition.

Modernising production plant and machinery

Modernising production facilities, enhancing their energy efficiency, and decarbonising their energy sources will require significant investment. Mobilising employees on climate issues has in the past proved more difficult than expected, such is the pressure on companies core business. Climate and energy will need to be brought to the top of business's list of priorities, along with management's search for new solutions and suppliers.

Industrial and employment transition

The effects of transition will vary according to sector. Some, like those heavily dependent on fossil energies, will be hit particularly hard. Others, like renewable energies, building retrofits, and soft, shared and public transport, will see significant business growth. Others still, like automotive with its massive switch from internal combustion vehicles to electric vehicles, will see intra-sector transformations. Some activities will decline at the same time as opportunities for reindustrialisation arise.

This need for change will be felt by many employees: industrial transition will go hand in hand with employment transitions. Businesses will be required to anticipate, organize and promote these transitions.
Over and above the development of vocations specific to energy transition, many existing professions would need to acquire new skills (e.g.building craftsmen), as outlined in the jobs and skills programming plan (see box).

During the transition period, economic stakeholders would want to feel confident that their employees have understood and committed themselves to these changes, and so would require a range of often local, sometimes national, support and training measures to facilitate the transition for everyone, particularly the most vulnerable.

The biggest difficulty in speeding up the transition to a low-carbon economy would be the pace of transition itself: in the face of competitive pressures and shareholder demands, companies would have to ensure their own short-term profitability, based on high-carbon solutions, while investing in large-scale deployment of - initially low-profit - low-carbon solutions.

Jobs and skills programming plan

Spearheaded by Laurence Parisot and published in late February 2019, the plan aims to determine the conditions under which "employment, training and career development policies can be brought in line and synergy with the objectives set out in the energy and ecological transition strategy (TE)".

Seven of the eight prospective studies analysed forecast 160,000-600,000 net job creations, depending on assumptions about the intensity of energy transition. However, job losses and creations will not always occur at the same time or in the same area. The report therefore recommends assessing the opportunities and risks by sector and by region.

While the report highlights some new energy transition-specific occupations, it insists particularly on the "spectacular" scale of skills development in many existing professions, and on the need for comprehensive and cross-cutting skills in all professions, ranging from awareness-building, ecodesign, and skills pooling and coordination to convergence with the digital transition.

The report recommends running training schemes linked to energy transition, enhancing their visibility, attractiveness and alignment with the needs of professional branches, and emphasising interdisciplinarity and the digital transition process. The need for specific tools to monitor and manage job trends is also mentioned.

For businesses and financial stakeholders, being ZEN (or net-zero) means developing a vision of their own future in a carbon-neutral France and world by 2050, thinking and making the transition from business-as-usual to the model of the future, and creating the internal (technical, human and financial) as well as external conditions (dialogue with public authorities, customers and suppliers) for this transition (see recommendations of TCFD, Task Force on Climate-related Financial Disclosures). For them as for the other stakeholders, isolated voluntary action will not produce an adequate pace of transformation.

The transition to net-zero emissions described in this study should take place over a 30-year period, from 2020 to 2050. This is a very short time span encompassing just one generation of people, whereas lifestyles take longer to change.

A house, for example, changes ownership once or twice in thirty years, scarcely more. Cars are changed more often, but they last fifteen years, sometimes passing into other hands.

For business too, this time span is short: investments made today will still be operational in 2050; aircraft whose development is launched today will form the majority of aircraft by this date.

France more or less jettisoned coal between 1970 and 2000; farming and our food habits have undergone significant change since 1990; mobile phones and related lifestyles have spread even faster. A revolution in thirty years is therefore feasible.

Pathways starting from the current situation and leading to a carbon-neutral France by 2050 are very vulnerable to a late start. Reducing emissions by 4.5% a year is already very ambitious; having to reduce them by 5-6% a year, because we have delayed the transition only by a few years, would no longer be workable.

That is why our study concludes with a number of recommendations for action - measures that EpE members believe it advisable to implement at the earliest if we want a carbon-neutral France by 2050 to remain within reach.

5

RECOMMENDATIONS

1 / Mobilising French people by sharing awareness of the climate emergency and 'the carbon-neutral France by 2050' project

Collective ownership of the image of society we want in 2050 appears necessary. The consistency between the ZEN 2050 study, the new national low-carbon strategy, the new European strategy, numerous studies and the voice of citizens on social media inspires confidence in the emergence of this new vision.

To initiate this ownership and mobilise the concerted efforts of everyone, it will be necessary to conduct communication campaigns and local or sectoral debates with citizens, employees, consumers and public authorities.

This recommendation was strongly and spontaneously supported by the citizens' panel of the ZEN 2050 study.

The first recommendation is therefore directed at all stakeholders so that they quickly envision their role in this pathway, work out what actions they could take to fulfil it, forge alliances among themselves and understand their respective roles and responsibilities in order to create a net-zero emissions society.

Extending this narrative beyond national boundaries to a European or even international level would improve consistency and efficiency in the global fight against climate change. The United Nations, UNFCC and other global bodies could assume a coordinating role for this purpose.

2 / Acting internationally to use access to the European market as a lever for global decarbonisation, and the European carbon as a lever for competitive industrial transformation

The carbon footprint of the French and the Europeans is strongly dependent on the decarbonisation of imports, while businesses bearing the cost of the transition will find it harder to compete on the world market. Today's climate and industrial ambitions appear to be incompatible with the systematic priority given by Europe to free trade. It is therefore recommended that France urges Europe to reserve wider access to its market only for countries that share its climate ambitions and efforts: access to the European market will therefore act as a strong incentive for climate ambition.

In addition, carbon-free technologies and solutions (CCS, renewable hydrogen, biomass industries, energy storage, etc.) will be deployed in Europe or elsewhere only if an adequate carbon price makes them competitive over time compared to other technologies. The European carbon market should therefore be managed towards this end, providing a clear perspective for economic stakeholders on issues such as volume reductions and therefore prices increases, and the arrangements for preserving the international competitiveness of European players. Simultaneously, public authorities could add value and extend the scope of climate action by systematically setting carbon values consistent with their ambitions and investment policies and decisions.

Lastly, stepping up French exports, whose carbon footprint is much smaller than that of most other countries, would facilitate the reduction of global emissions.

3 / Giving a positive image of carbon taxation by explaining its purpose, pathway, revenue utilisation and accompanying social measures, so that it is perceived as fair and equitable

Strengthening emissions taxation and increasing energy prices will be a prerequisite for the transition, supported by economic regulations and price signals. Regulations to anticipate and limit price signals might help, but the signals themselves would be vital for preventing any increase in emissions through the rebound effect.

Taking into account the impact on households, especially the most vulnerable, would be another determinant of success.

Combating housing- and mobility-related energy insecurity could be delegated to social services in the search for solutions that combine temporary financial assistance and action aimed at reducing household dependence on emissions. This would involve training social services in global and sectoral issues related to the transition. Companies actively dealing with these issues could be associated with such an initiative. Households, especially the poorest ones, must be able to benefit from expertise and advice in order to make the relevant investments and adopt energy saving behaviours.

We propose to clarify the use of revenues from the climate-energy contribution and ensure that an amount equivalent to the contribution is dedicated to the transition in line with the following recommendations:

- Clearly plotting the climate-energy contribution path to guide individual investments (housing, mobility); over time, the final energy price rather than the tax amount could be shown, as is done for tobacco;

- Showing the use and impact of tax revenues within the broader context of a stabilisation or reduction of the tax burden. This should meet the combined requirements of societal acceptance, social equity and climate efficiency. Reductions in other expenses could be announced in advance to encourage low-carbon activities;

Cutting and subsequently stopping direct or indirect fossil fuel subsidies and informing the public of this reduction. Reallocating such savings to the transition;

- Factoring its social effects into social welfare policies, as mentioned above.

4 / Ensuring that transition-related investments mobilise both the private and public sectors and include employment and territorial transitions

The investment requirements for net-zero 2050 pathways will be significant: public and private investment in thermal retrofits of buildings, biomass development, private vehicle electrification and mobility development, especially public rail transport, and electricity grid expansion (and development of hydrogen, heat networks, public transport, etc.) should rise from €30 billion a year to over €75 billion a year from 2030 (bearing in mind the study does not cover all sectors). To get an overall picture, it would be necessary to add the as yet unquantified need for radical restructuring of industry, agriculture and forestry at about 10% of current national investment (approximately €500 billion). Some investments however would decrease, and the net additional investment would be much smaller.

A national public investment plan (with a leverage effect on private investment) would accelerate the transition, and would be easier to implement since the plan's financing would come from funds diverted from emissions-intensive activities as a result of carbon price hikes anticipated by stakeholders and the financial community at large, whether bankers or institutional investors.

The investment plan should be principally directed at regions strongly dependent on activities that would be impacted by the transition.

This would mean orientating vocational training towards ecological transition, in particular towards job conversion in negatively affected sectors or activities.

5 / Developing town and country planning projects in line with climate goals

Today's fast-spreading urban sprawl impacts not only agriculture, climate and biodiversity, but also access to many services. "Building a city in a city" (town or village), rehabilitating urban centres and concentrating local services there would deliver benefits in terms of comfort, time management, and convenience of access to public transport, infrastructure, services and shops, which are an integral part of today's quality of life. The dense city would be compatible with the significant presence of nature in urban spaces, whose valuable role in climate resilience and people's well-being is widely recognized.

We propose that the urban sprawl model (housing, shopping centres and business areas) be brought at the earliest into line with climate transition, by adapting local financing mechanisms and transforming social representations through public and private initiatives. We also recommend cutting land take rates by half.

6 / Developing, managing and valuing various biomass services

Biomass from waste, farming and forestry, as well as biomass products will play a key role in replacing fossil fuels, making biomass availability from non-imported sources a limiting factor for the economy, even in the event of a high degree of energy efficiency.

Forestry policies should double carbon sinks and maximize available resources, while leveraging varying territorial dynamics to promote the different services rendered by forests to local populations.

Biomass allocation, and synergy optimisation, between competing uses and services (food, animal feed, biodiversity, carbon capture, soil improvement, materials) should be regulated locally and nationally by means of intersectoral governance.

7 / Introducing building retrofit schemes based on binding obligation and financial support mechanisms

Retrofitting is one of the most important and difficult transition issues, in particular in view of the sheer number of policymakers involved. A mandatory low-carbon retrofit scheme adapted to different types of building (individual, collective private, public) should therefore be defined and enforced without delay. A mandatory obligation when transferring ownership or entering into a long lease seems to us the preferred option for individual housing; similarly, a mandatory obligation staggered over time seems to us the preferred option for condominiums (for example, it could be linked to the façade cleaning obligation, where such exists).

The investment plan referred to above should be widely implemented by public and private stakeholders to finance this transformation, and grants should be made conditional upon the scale of the retrofit.

8 / Switching to non-emitting mobility and phasing out fossil fuel engines

The transformation of mobility must go hand in hand with the rapid introduction of low-carbon modes, soft modes, public transport, electric mobility, biogas and green hydrogen, as well as the phasing out of GHG and local pollutant emissions-intensive options.

To ensure that the goal of net-zero emissions by 2050 is achievable, internal combustion vehicles must only have a marginal presence in the total fleet, with the marketing of all-ICE vehicles having stopped well before. The size of the plug-in hybrid vehicle fleet will be restricted by the limited availability of biofuels.

9 / Modernising industry by promoting low-carbon investment

Because rising carbon prices are a necessary but not sufficient condition for guiding corporate decisions down the right path, low-carbon investment (energy efficiency, circular economy, process electrification) should be encouraged by appropriate mechanisms, including industrial and social conversion and innovation grants, carbon leakage prevention, risk reduction, and arrangements for preserving the international competitiveness of French economic actors. Posting carbon price trends for both industry and consumers should facilitate the funding of these investments.

Given the ambition of carbon neutrality, all paths need to be explored and developed, because a combination of solutions will be necessary. Some sectors appear particularly transition-friendly: energy efficiency, energy storage, circular economy (in return for reduced requirements for new materials), CCUS, timber and biomass industries, carbon-free vehicles and mobility systems, including for aviation, and biomass-based chemicals.

10 / Assisting the transition of agriculture to a quality-based model

We see an urgent need to rethink Europe's agricultural economic model, rural management and agricultural policies, currently based on integration into an undifferentiated global market. The development of quality production and supply chains, both upstream and downstream, to address the challenges of the agricultural economy, nutrition and health, productivity, environment, diversification of farm products and services (food, bioeconomy, biomass, carbon sinks, etc.), and their fair valuation would deliver many benefits, including net job creations, strengthened resilience, agricultural emissions reduction, biodiversity conservation, reduction of imports and imported deforestation, and soil conservation.

Grants should be channelled towards farms applying these new practices, and customers (public or private mass catering establishments) promoting this new offering through a change in specifications.

11 / Eating better by promoting healthy eating habits for humans and the climate

A change in food consumption patterns is already under way and is conducive to emissions reduction and health. It should be stepped up and sustained by food & health policies, initiatives in public and private mass catering, and reduction of food wastage.

Such policies would also drive the transformation of the agricultural model by opening bigger and more profitable markets for products generated by the new agricultural model (fewer inputs, mixed farming, product diversification). Food wastage should be cut in half along with meat consumption.

12 / Educating all young people about our environment and climate.

Many of today's younger generations in school or university will dedicate their professional lives to this transition and must be prepared for it. Dedicated curricula will have to be developed and taught from primary schooling to higher education, and teachers will have to be trained in the subject across all disciplines, from natural sciences to technical and human sciences.

13 / Shifting advertising towards sustainable consumer habits and lifestyles

Through advertising, business plays a key role in shaping consumers' representations of desirable lifestyles. However, this stream of communication often overrates high-emitting equipment and services.
Product communication should increasingly underline the positive role of material and resource savings in the satisfaction of needs, for example by relying more on services.

Companies could voluntarily act in two ways:

- By using promoting new underlying role models advertising sustainable lifestyles;

- By encouraging alignment of consumption habits with desirable pathways and ensuring that product advertising is more consistent with net-zero pathways.

14 / Anticipating impacts of climate change and adaptation needs of regions

The effects of climate change (heat waves, coastal erosion, water scarcity, increasing rainfall and droughts, etc.) can already be seen and will get worse by 2050, even if the world follows a pathway compatible with the Paris Agreement.

Although the study touches on this issue only briefly, we recommend taking steps today to anticipate those impacts and strengthen regional resilience. This regional approach is adopted in the second National Plan for Adaptation to Climate Change (NAPCC), published in late 2018.

Where do we begin?

What we have said so far could form the basis of a wide-ranging programme promoting a new model of societal and economic development involving many stakeholders. The study itself is in fact only a starting point, a contribution by companies to a shared project to be undertaken together in keeping with the SNBC and the European Union's long-term strategy. In the short term, this would mean, as a minimum:

- Laying the groundwork with employers' organisations as well as public authorities in European countries for promoting climate-friendly EU policies (R&D, Common Agricultural Policy, and in particular external trade policy). A net-zero pathway is viable only as part of a Europe-wide drive, with several European countries running similar coordinated programmes;

- Ensuring that these elements are taken into account in any future carbon neutrality law;

- Exploring further opportunities of drawing up roadmaps that federate companies and other stakeholders and set out costs, financing, support arrangements, stages, etc.

- In-depth discussions within sectors and regions that might feel particularly concerned by a profound transformation.

The solutions are there, as are the corporate commitments. The ZEN 2050 study offers an ambitious and demanding vision of a common destiny that will be fulfilled by businesses, citizens and public authorities acting together. Businesses are ready to throw in their lot with this movement if the nation collectively takes the decision to drive it.

ANNEXES

Citizens' panel

The aim of the public consultation, organized using IPSOS methodology, was to obtain from a panel of citizens their reactions and opinions on the proposed recommendations with a view to assessing their acceptability and, where appropriate, amending them.

The panel was composed of 23 citizens who had been selected to represent the diversity of the French population in terms of age, gender, profession, geographical origin, type of housing, level of studies, etc. None was a specialist on environmental issues or policies, or an activist. The interviewees were not asked to take a stand on the feasibility of the recommendations made by the panel, or on all the recommendations.

The consultation took place over two weekends.

The first was used to present the context and issues of the study. Various experts and organizations[42] discussed the subjects of climate change, collective and individual behaviours, housing retrofits, mobility, taxation, and so on.

The last day was devoted to a discussion between citizens behind closed doors on the pathways suggested by the ZEN 2050 study and on the drafting of a citizens' statement in which the panel was invited to express its feelings, differences of opinion, points of agreement, and concerns.

The additional analysis carried out by IPSOS highlights a change in the group's perception of the subject: the participants went from initially feeling they were neither involved, nor aware, nor responsible, nor stakeholders in the face of a global problem, to viewing the issues with some bemusement:

"*When I read these lines, I thought to myself: now there's a beautiful utopia*"; this shifted after a number of discussions to an awareness of the role they could also play: "*All of us - companies, citizens and politicians - are concerned and responsible*".

The gap between this initial indifference and their subsequent awareness of the issue and involvement at the end of the consultation is emphasised by the panel at the beginning of their statement as one of the principal lessons learned.

That said, the participants did not reach a consensus on all the solutions. All shared the observation that communicating in a transparent and compelling manner is necessary both to increase understanding of the issues and, above all, to get each and every person to do their share of the collective effort.

42 Jean Jouzel, Stéphane Labranche, CITEPA, Réseau Action Climat, Association des Maires de France, Ministère de la transition écologique et solidaire, Rodolphe Meyer, Patrick Criqui, Total, EpE

Citizens' proposals

Carbon-neutral France

The citizens' panel insisted on giving its initial reaction to the very title of this citizens' conference "a carbon-neutral France", since the expression "carbon-neutral" was understood by practically no one in the panel. The entire panel thought that by the end of the second weekend they had a pretty clear understanding of what the expression meant, in sharp contrast to what they felt when the consultation began.

This being the case, the entire panel was highly aware at the end of this conference of the need, indeed urgency, of tackling the issue head on. Moreover, everyone agreed that at the start of the proceedings they were unaware of the scale of the problem, leading some to say that it called for nothing short of a revolution.

Here are the reactions of the panel to some of the recommendations made by the ZEN 2050 study.

▲ Recommendation 1

Mobilising French people by sharing awareness of the climate emergency and the "carbon-neutral France by 2050" project.

At the end of the discussions, the entire panel wholeheartedly agreed with this recommendation, since they all realized that initially not one of them subscribed to it. This recommendation seems all the more necessary because some panel members believed that their generation (30-50 years) is indeed less aware of the issue than their own children. On the other hand, some believed their children are mired in rampant consumerism.

▲ Recommendation 3

Giving a positive image of carbon taxation by explaining its purpose, pathway, revenue utilisation, and accompanying social measures, so that it is perceived as fair and equitable.

The panel fully agreed with this recommendation that gives a positive image of carbon taxation, subject to the following explicit conditions:

- Essential transparency with regard to the collection, use and redistribution of revenues, which must be fully allocated to the cause;
- taxation proportional to income.

The panel was divided on the feasibility of a petrol price at €2 a litre in three to five years. While the majority believed it would be effective, easy to implement and inevitable, others rejected it if consumers had no reasonable alternative. Those who agreed, nevertheless, laid down conditions for this tax, particularly as regards petrol:

- again absolute transparency regarding the use of funds;
- the creation of a green fund financed by this tax, free public transport.

The panel suggested in connection with the issue of carbon taxation:

- the creation of a specific VAT rate based on the carbon footprint of the product or service;
- the creation of a bonus-malus system to reward the use of alternative transport versus privately-owned internal combustion vehicles, wherever possible;
- the selection of local and environmentally-friendly companies in public procurement tenders.

▲Recommendation 4

Ensuring that transition-related investments mobilise both the private and public sectors and include employment and territorial transitions.

The panel acknowledged that the consultation had made it aware of the scale and speed of the employment and territorial transitions required by the energy transition. Nevertheless, the panel was uncomfortable with this recommendation because it did not feel specifically concerned by its implementation.

In the circumstances, the panel suggested:

- diversifying businesses in poorly diversified industrial regions;
- promoting teleworking when companies relocate;
- anticipating training requirements.

▲Recommendation 5

Developing town and country planning projects in line with climate goals.

The citizens' panel was in favour of stopping urban sprawl and densifying cities and villages subject to the following conditions:

- city centres are regenerated and urban den sification is intensified;
- city centres are made more attractive and a range of initiatives are taken, including revegetation, new types of architecture to maximize available space, shared gardens, neighbourhood shops, health services, and provision of residential housing by corporate stakeholders and local authorities;
- the creation and expansion of business estates on the outskirts of towns is prohibited;
- intermunicipal services are offered and delivered to rural communities;
- railway stations are rehabilitated and the railway network is expanded;
- access to property is facilitated through financial assistance schemes so as to limit peri-urban housing;
- owners (private and public) are encouraged to place empty housing on the market.

▲Recommendation 7

Introducing building retrofit schemes based on binding obligation and financial support mechanisms.

The panel was in total agreement with this recommendation. Nevertheless, opinions strongly diverged regarding a retrofit obligation, with some believing this should be compulsory and others preferring incentives. All agreed to attach the following conditions to this recommendation:

- financial assistance is provided in the form of subsidies from the Green Fund, tax benefits, financing at attractive low-carbon rates from banks, reduction of death duties / land tax in the event of retrofitting, and tax credits;
- better training is given to certifiers who are deemed untrustworthy;
- local retrofit companies are certified;
- priority for energy retrofits is given to the least well off.

▲ Recommendation 8

Switching to non-emitting mobility and phasing out fossil fuel engines.

The panel agreed with this recommendation but was divided on its implementation.

- Some felt that internal combustion vehicles still had a future, particularly as a result of biofuel innovations.
- Others felt efforts should be stepped up to expand car sharing and every type of electric transport (scooters, bicycles, urban cable cars, etc.) so that all-ICE vehicles die out.

The panel agreed on the need to develop public transport, some even suggesting they should be free. They also suggested a deterrent tax on vehicle licences for gas-guzzlers, and using this money to finance the Green Fund.

The panel further suggested establishing a financial contribution levied on foreign lorries crossing France. Some members of the panel had reservations about this recommendation and instead advocated a Europe-wide incentive system.

▲ Recommendation 11

Eating better by promoting healthy eating habits for humans and the climate.

The panel was in total agreement with this recommendation. It recommended good eating from the nursery to retirement homes, including one meatless day, seasonal products, local producers, short supply chains, and low-carbon labelling on products. It recommended lowering VAT on basic necessities and the aforementioned products, which would offset the additional costs.

It also suggested expanding urban agriculture and training to enable farmers to switch to HEV* crops.

▲ Recommendation 12

Educating all young people about our environment and climate.

The panel unanimously approved this recommendation. It suggested, inter alia, that all school children from the youngest age be given opportunities to visit farms, as well as courses on climate, the benefits of home-grown products, and the environment.

It also suggested explaining to young people the very concept of carbon neutrality.

▲Recommendation 13

Shifting advertising towards sustainable consumer habits and lifestyles.

The panel was unanimous that this was a vital necessity. In this connection, it suggested:

- regulating advertisements for CO_2-emitting products and services;
- regulating energy-intensive advertising media (Illuminated panels / LCD);
- conducting high-impact campaigns on the subject of carbon neutrality;
- better explaining, by way of clear illustration, CO_2-impact labels and notices on everyday products and services;
- encouraging businesses to communicate more about their carbon-neutrality initiatives (such as Total's actions as described to the panel).

In conclusion, the panel emphasized the need for each stakeholder (consumer/citizen, business, government) to take part in this transition.

* High Environmental Value

Acronyms

ADEME	Agence de l'environnement et de la maîtrise de l'énergie (Environmental and Energy Management Agency)
BECCS	Bio-Energy with Carbon Capture and Storage
CAP	Common Agricultural Policy
CCAS	Centre Communal d'Action Sociale (Social Action Community Centre)
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Usage
CIRED	Centre International de Recherche sur l'Environnement et le Développement (International Centre for Research on the Environment and Development)
CITEPA	Centre Interprofessionnel Technique d'Etudes de la Pollution Atmosphérique (Interprofessional Technical Centre for Studies on Atmospheric Pollution)
CREDOC	Centre de recherche pour l'étude et l'observation des conditions de vie (Research Centre for the Study and Observation of Living Conditions)
DNTE	Débat National sur la Transition Energétique (National Debate on Energy Transition)
EMS	Energy Management Systems
EpE	Entreprises pour l'Environnement
ETS	Emission Trading Scheme
FREC	Feuille de route Economie Circulaire (Circular Economy Roadmap)
GHGs	Greenhouse Gases
GWP	Global Warming Potential
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization (UN institution)
IPCC	Intergovernmental Panel on Climate Change
HP (electricity)	Heat Pump
PCAET	Plan Climat Air Energie Territorial (Climate Air Energy Territorial Plan)
PES	Payments for Environmental Services
PHEV	Plug-in hybrid vehicle
Pkm	Passengers per kilometre
PLU	Plan Local d'Urbanisme (Local Town Plan)
PLUI	Plan Local d'Urbanisme Intercommunal (Intermunicipal Local Town Plan)
PNACC	Plan National d'Adaptation au Changement Climatique (National Climate Change Adaptation Plan)
PNNS	Programme National Nutrition Santé (National Health and Nutrition Programme)
PPE	Programmation Pluriannuelle de l'Energie (Multiannual Energy Programming)
PV	Photovoltaics
SCOT	Schéma de Cohérence Territoriale (Territorial Coherence Scheme)
SNBC	Stratégie Nationale Bas Carbone (National Low-Carbon Strategy)
SRADDET	Schéma Régional d'Aménagement, (Regional Planning, Sustainable Development and Territorial Equality Scheme)
TEPOS	Territoire à énergie positive (Energy-Positive Territory)
TICPE	Taxe intérieure de consommation sur les produits énergétiques (Domestic tax on consumption of energy products)
Tkm	Tonnes per kilometre
UNFCCC	United Nations Framework Convention on Climate Change

Glossary

Biomass	Biodegradable part of household, agricultural, livestock, forestry and industrial waste.
Bio-NGV	Renewable natural gas for vehicles used as fuel and produced from biomass.
Carbon neutrality	Defined by the Paris Agreement as "the balance between anthropogenic emissions by sources and absorption by sinks of greenhouse gases".
Carbon sink	All systems, natural or artificial, where carbon is stored in a sustainable manner.
Climate action value	(Formerly shadow carbon value) Price of a tonne of carbon defined by the State, different from the market value of carbon. It is used to assess public policies and investment by factoring in the relevance of emissions reduction.
Decarbonisation	Partial or total reduction of greenhouse gas emissions.
Digestate	Residue from the methanisation of organic material.
Ecodesign	Design of a product or service intended to limit the environmental impact it will have over its life cycle.
Electrolysis	Production of hydrogen from water by using electricity. It is therefore a potential way of storing electricity.
Fuel cell	Electricity production by a redox reaction, typically between hydrogen gas and oxygen.
Heat network	System for supplying centrally generated heat to several users via buried pipes, mainly for industry, heating and domestic water heating.
Industrial ecology	Principle of environmental management and one of the components of the circular economy which aims to limit the impacts of industry by exchanging resources between companies.
Land take	Conversion of farmland, forest land or natural land into built, paved or stabilized land, which makes it partially or totally impermeable.
Livestock manure	Waste from livestock, consisting mainly of slurry and manure, recoverable as organic fertilizer or by methanisation.
Methanation	Production of methane through a reaction between hydrogen and CO_2.
Methanisation	Degradation of organic matter into CH_4 and CO_2 (anaerobic digestion).
Negative emissions	Combination of the use of biomass-based solutions and CO_2 capture methods (CCC/CCU). Example BECCS.
Offset (carbon)	Technical or financial mechanism for counterbalancing greenhouse gas emissions resulting from an activity or project by reducing other emissions or storing an equivalent quantity of carbon.
Power-to-gas	Process by which gas is produced from electricity, particularly for storing the electricity produced from renewable energy sources. It consists of water electrolysis to form hydrogen gas, which may be followed by a methanation reaction with CO_2 to produce methane.
Pyrogasification	Process by which synthesis gas (or syngas) is produced by heating waste at temperatures between 900 and 1200°C in the presence of a small quantity of oxygen.
Vehicle-to-grid	Use of electric or hybrid vehicle batteries during charging to store energy or reinject it into the network as required.

About EpE and the ZEN 2050 study

Entreprises pour l'Environnement (EpE), a French association set up in 1992, is a forum for dialogue between business leaders and environmental managers and policymakers who share the vision of the environment as a source of progress and opportunity, exchange their best practices and work together to take better account of the environment in their strategies and operations.

EpE's Climate Change Commission began work on carbon neutrality in the aftermath of the signing of the Paris Agreement in late 2015.

In 2017, the launch of the Climate Plan by Nicolas Hulot announced the new goal of carbon neutrality by 2050. EpE subsequently decided to undertake the ZEN 2050 study in order to explore what a carbon-neutral society means in 2050. How do the French live? How do they get around and eat? What do our cities, jobs and economy look like? Are they sustainable? Under what conditions?

The 27 members involved in the EpE study monitored it with the support of a group of experts (the consortium), as well as numerous academic experts, and business and civil society stakeholders with whom they had established contact.

A panel of stakeholders, known as the Circle of Inspiration, met at three key stages of the study to provide critical insights and express opinions and recommendations.

Circle of Inspiration

ADEME, Afep, Association des Maires de France, CFDT, Confédération Paysanne, Conseil Economique pour le Développement Durable, Cour des comptes, FNH, FNSEA, Forum Français de la Jeunesse, HEC, INRA, Institut de l'Elevage, Institut de la transition environnementale (Sorbonne Université), I4CE, IDDRI, INRA, Institut de Médecine Environnementale, Institut de l'élevage, MEDEF, NUMA, Pole Emploi, Réseau Action Climat France, Sidièse.

Claire Tutenuit, CEO of EpE and director of publication, thanks the many representatives of the companies involved in the steering committee, the consortium, Circle of Inspiration members, participants and citizens who took part in the consultation, together with all the stakeholders met during the study.

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EpE members:

AIR FRANCE • AIR LIQUIDE • AIRBUS GROUP • AXA • BASF FRANCE • BAYER FRANCE • BCG • BNP PARIBAS • CAISSE DES DÉPÔTS • CHANEL • CIMENTS CALCIA • CREDIT AGRICOLE S.A / AMUNDI • DELOITTE • ÉCONOMIE D'ÉNERGIE • EDF • ENGIE • ERM FRANCE • GROUPE ADP • HERMES • IMERYS • GROUPE INVIVO • KERING • GROUPE LA POSTE • LAFARGEHOLCIM • MARSH• MICHELIN • PAPREC GROUP • PRIMAGAZ • RENAULT • REXEL • RTE • SAINT-GOBAIN • SANOFI • SCHNEIDER ELECTRIC • SÉCHÉ ENVIRONNEMENT • SIACI SAINT HONORE • SNCF • SOCIÉTÉ GÉNÉRALE • SOLVAY • SUEZ • TOTAL • VALLOUREC • VEOLIA • VESUVIUS • VINCI •

The consortium

Enerdata
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Carbone 4
Specialises in energy transition and long-term forecasts.
Supports many French corporate actors in their transition to a low-carbon economy.
Led by Alain Grandjean,
Chairman of DNTE's committee of experts.
www.carbone4.com

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www.solagro.org

Stéphane La Branche
Sociologist
Expert, IPCC member for his studies on the social, political and institutional aspects of energy transition and climate (values, lifestyles, practices).

CIRED - SMASH
Philippe Quirion, Economist, Research DIrector at CIRED.
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