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ADEME
AGENCY FOR ECOLOGICAL TRANSITION

HORIZONS

TRANSITION(S) 2050

DECIDE NOW ACT 4 CLIMATE

Executive Summary

An unprecedented, structured forward-looking exercise

Ambition and goals of the Transition(s) 2050 exercise

Carbon neutrality by 2050 is now part of the common language of international, European and national climate policies. While its definition is more or less agreed on, the way to reach it is still unclear, if not totally unknown for most decision-makers and citizens. However, given the climate emergency, the changes to be made are of such magnitude that **it is essential to accelerate discussions now, given the time required to make decisions in a democratic framework, as well as the time required to implement them.**

Four "type" paths, consistent and contrasting, to lead France towards carbon neutrality.

ADEME does not intend to propose "the" right pathway, because the route that will be decided is the result of political choices to be made in the face of multiple uncertainties and in line with a project for society as a whole. Therefore, on the eve of the 2022 presidential election and ahead of the collective deliberations on the French Energy and Climate Strategy, ADEME has chosen to submit for debate **four coherent and contrasting "type" scenarios to take France towards carbon neutrality**. These four carbon neutrality pathways are compared with a Business As Usual (BAU) scenario that sees current trends continuing to 2050.

Forecast for mainland France, the scenarios are based on the same macroeconomic, demographic and climate change data (+2.1°C in 2100). They all lead to carbon neutrality for the country, but take different routes and correspond to different societal choices. The logic of the four scenarios is inspired by the four IPCC scenarios presented in the 1.5°C Special Report of 2018.[1]

The goal of this exercise is therefore:

- to build **"outline scenarios"** that are internally consistent;
- to illustrate the **range of possible long-term options** for achieving carbon neutrality and explore the various implications;
- to inform **essential short-term decision-making**.

Two years of cross-disciplinary expert work

To facilitate the move to action, ADEME has carried out this unprecedented forward-looking exercise based on two years' work and the involvement of about a hundred ADEME employees as well as regular discussions with a scientific committee. The assumptions and models were refined and enhanced through in-depth discussions with a hundred or so partners and external service providers, specialists in different fields, as well as two webinars organised in May 2020 and January 2021, each of which brought together nearly 500 participants to discuss the intermediate results.

Method

For each scenario, ADEME built a coherent narrative, broken down by each economic and social sector, using structuring variables; these narratives were then transformed into quantitative assumptions in existing models or models created for the occasion; several successive iterations were necessary to verify, cross-reference and refine these quantifications.

This work has highlighted the interdependencies between sectors and helped to give each scenario a solid and coherent structure. In addition, it incorporates analytical advances in areas that until now have been little or poorly studied in climate forecasts. For example, evaluation and availability of biomass, evaluation of biological and technological carbon sinks, and changes in industrial production induced by changes in consumption.

The scenario descriptions cover the construction sector, passenger and freight transport, food, agriculture, forestry, industry, waste and energy services (fossil fuels, bioenergy, gas, hydrogen, heat and electricity).

In particular, the parameters studied cover:

- energy demand;
- consumption of irrigation water, building materials, agricultural inputs and land use;
- waste generation and management;
- energy production and the composition of the energy mix;
- imports and exports;
- the greenhouse gas balance and biological and technological carbon sinks.

This first publication presents the major findings of the work, but some results of modelling that could not be started until after the final results from the sectoral scenarios will be presented in the form of a series of publications between January and March 2022. This is the case for the electricity mix, materials and greenhouse gas footprints, and macroeconomic impacts, which are only presented qualitatively in this publication.

1 https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf.

9 key messages

01

The four pathways presented, each internally consistent, enable France to achieve carbon neutrality in 2050. **But all are difficult and require orchestrated planning of changes, involving the State, regions, economic players and citizens.**

02

Achieving neutrality is based on overcoming some major challenges, both human (behavioural changes) and technological (carbon sinks in particular). All scenarios therefore involve a degree of risk. But not all of them have the same environmental, social and economic consequences.

03

For all scenarios, it is imperative to act quickly. The socio-technical transformations to be carried out are of such magnitude that they will take time to produce their effects. During this decade, a profound transformation must be planned and undertaken in our consumption patterns, land use planning and development, technologies and productive investments.

04

Reducing energy demand, itself related to the demand for goods and services, is the key factor in achieving carbon neutrality. This reduction ranges from 23% to 55% compared with 2015 depending on the scenario, each scenario being based on a different balance between reduced consumption and energy efficiency.

05

Industry will have to transform itself, not only to adapt to a profound change in demand but also to decarbonise its production. This will require large-scale investment plans and an effort by all of society to support the regions undergoing change and to train employees in new professions.

06

The biosphere is one of the main assets in this transition, combining three strategic levers: carbon storage, biomass production and greenhouse gas reduction. It is therefore essential to maintain a balance between food and energy use of biomass, with preservation of ecological functions such as biodiversity and carbon storage, through a comprehensive approach to the bio-economy.

07

Adaptation of forests and agriculture is therefore becoming an absolute priority in combating climate change. The resilience of ecosystems is all the more crucial as they are increasingly being affected by the impact of climate change.

08

The pressure on natural resources varies considerably from one scenario to another. This is particularly the case for irrigation water or building materials, where the volumes consumed vary by a factor of two between certain scenarios.

09

In all scenarios, more than 70% of the energy supply in 2050 is based on renewable energy and electricity is the main energy carrier. However, to limit the pressure on resources, this can in no way justify wasting energy.

	 S1 FRUGAL GENERATION	 S2 REGIONAL COOPERATION	 S3 GREEN TECHNOLOGIES	 S4 RESTORATION GAMBLE
LIFESTYLES				
Society	• Search for meaning • **Frugality chosen but also imposed** • Preference for local sourcing • Nature protected	• Sustainable changes in lifestyles • **Sharing economy** • Fairness • Preservation of nature enshrined in law	• **New technologies rather than reduced consumption** • "Green" consumerism for the benefit of well-off populations, connected society • Services provided by Nature are optimised	• **Mass consumption** lifestyles safeguarded • Nature is a resource to be exploited • Confidence in the ability to repair damage to ecosystems
Food	• Meat consumption reduced by a factor of 3 • **Share of organic: 70%**	• **Meat consumption halved** • Share of organic: 50%	• 30% reduction in meat consumption • **Share of organic: 30%**	• Meat consumption almost stabl (10% decrease), supplemented by **alternative synthetic or plant proteins**
Housing	• Massive and rapid renovation • **Strong limits on new construction** (conversion of vacant housing and second homes into primary residences)	• Massive renovation, **gradual but profound changes in lifestyle** (growth in cohabitation and the size of housing adapted to household size)	• **Large-scale demolition and rebuilding** of housing • All homes renovated but not efficiently: only half undergo deep renovation	• New construction **maintained** • Only half of the housing stock renovated. When renovated, houses undergo deep renovation • **Appliances multiply**, combining technological innovation and energy efficiency
Personal mobility	• **Strong reduction in mobility** • Distance travelled per perso reduced by one-third • Half of all journeys on foot or by bicycle	• **Managed mobility** • Distance travelled per person reduced by 17% • Nearly half of all journeys on foot or by bicycle	• Mobility managed with State suppo infrastructure, widespread telework car-pooling • **+13% in distance travelled per person** • 30% of journeys on foot or by bicycle	• Strong increase in mobility • +28% in distance travelled per person • People prioritise **speed** • 20% of journeys on foot or by bic
ECONOMY				
Technical Relationship to progress, digital, R&D	• Organisational and technical innovation • **Prevalence of low-tech**, reuse and repair • Digital collaboration • **Stable data centre consumption** due to stabilisation of flows	• Massive investment (energy efficiency, renewable energy and infrastructure) • Digital technology in support of regional development • **Stable data centre consumption** due to stabilisation of flows	• Targeting of the most **competitive technologies to decarbonise** • Digital technology in support of optimisation • Data centres consume 10 times more energy than in 2020	• Innovation on all fronts • Capture, storage or use of captured carbon essential • Pervasive presence of the Internet of Things and Artificial Intelligence: data **centres consume 15 times more energy** than in 2020
Governance Decision-making ladders, international cooperation	• **Local decision-making**, little international cooperation • Regulation, prohibition and rationing via quotas	• Shared governance • **Environmental taxation** and redistribution • National decisions and European cooperation	• Minimum **regulatory framework** for the private sector • Government as planner • Targeted carbon tax	• Supply-side support • Strong and targeted international cooperation in a few key sectors • **Centralised planning of the energy system**
Region Rural-urban mix – land degradation	• Important role for the region in terms of resources and taking action • **"De-urbanisation"** in favour of medium-sized cities and rural areas	• **Demographic recovery of medium-sized cities** • Cooperation between regions • Regional energy planning and land policies	• **Urbanisation**, competition between regions, functional cities	• Low involvement by regions, **urban sprawl**, intensive agriculture
Macro-economy	• **New prosperity indicators** (income gaps, quality of life, etc. • Contraction in international trade	• Qualitative growth , **"re-industrialisation"** of key sectors in conjunction with the regions • Regulated international trade	• **Green growth**, innovation driven by technology • Regional specialisation • International competition and globalisation of trade	• **Carbon-based economic growth** • Minimal and targeted carbon tax • Globalisation of the economy
Industry	• **Production as close as possible to needs** • 70% of steel, aluminium, glass, paper, carboard and plastic sourced from recycled materials	• Production of value rather than volume • **Dynamic local markets** • 80% of steel, aluminium, glass, paper, carboard and plastic sourced from recycled materials	• **Energy decarbonisation** • 60% of steel, aluminium, glass, paper, carboard and plastic sourced from recycled materials	• Decarbonisation of industry relying on **carbon capture and storage** • 45% of steel, aluminium, glass, paper, carboard and plastic sourced from recycled materials

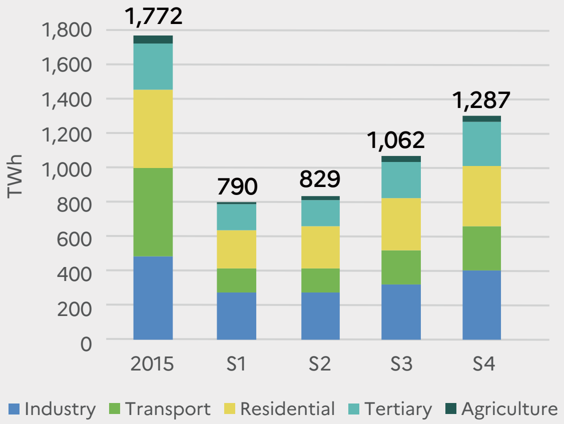
OVERVIEW
of the 4 scenarios

S1 Frugal Generation | **S2** Regional Cooperation | **S3** Green Technologies | **S4** Restoration Gamble

ENERGY
4 different energy mixes for 2050

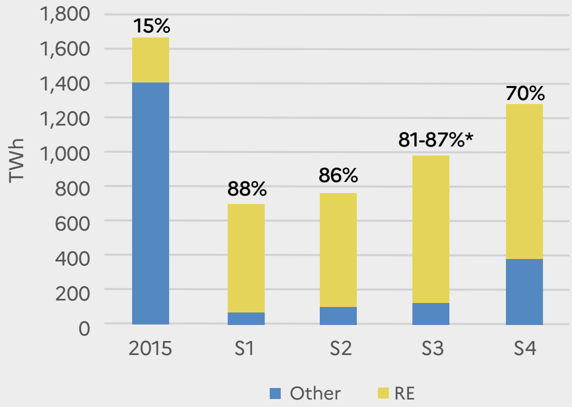
REDUCED ENERGY DEMAND

Final energy consumption by sector in 2015 and 2050 (including non-energy uses and excluding international bunker fuel)



MORE THAN 70% RENEWABLE ENERGY IN ALL SCENARIOS

Energy consumption and share of RE of gross final energy consumption in 2015 and 2050



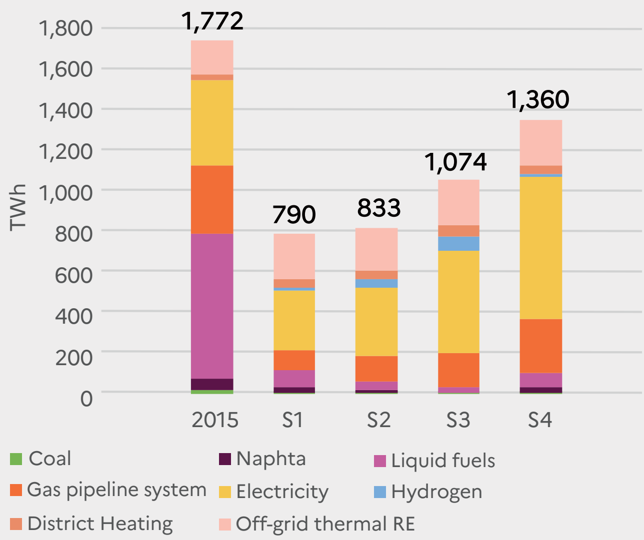
*Values dependent on industrial policy choices for development of floating wind or nuclear power.

A GROWING SHARE FOR ELECTRICITY

VIRTUAL DISAPPEARANCE OF FOSSIL-FUEL ENERGIES

SOME RESIDUAL GAS CONSUMPTION REMAINS

Final energy demand by vector in 2015 and 2050 (with non-energy uses and excluding international bunker fuel)

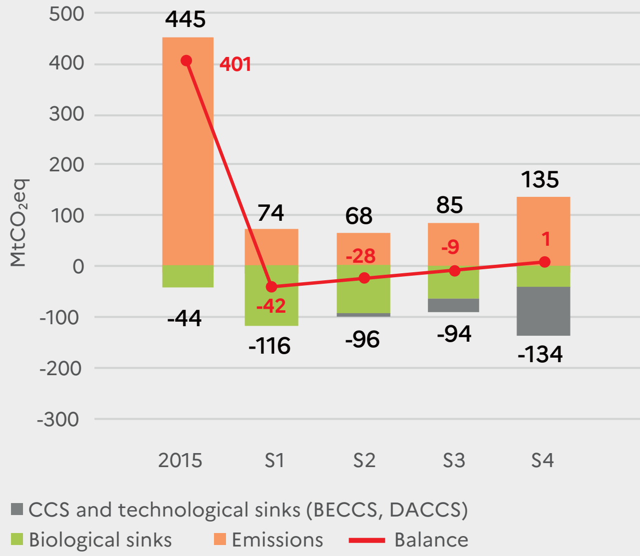


Note: final energy consumption does not take into account energy used as an intermediate in the manufacture of other energy or non-energy carriers such as hydrogen. By way of illustration, the electricity consumption (not shown in this graph) used to manufacture hydrogen for energy use is 62 TWh, 135 TWh, 65 TWh and 33 TWh respectively in S1, S2, S3 and S4. The difference between consumption demand and the graph of energy demand by sector is due to consumption by technological carbon sinks, which is not allocated to a specific sector. The difference with gross final energy consumption results from consumption for non-energy uses.

CLIMATE
The major role of biological sinks for achieving neutrality in 2050

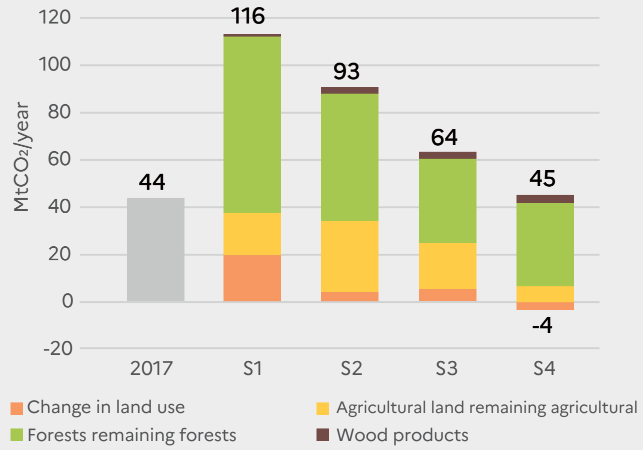
FOUR NEUTRAL SCENARIOS IN 2050, WITH VARYING DEGREES OF RELIANCE ON CARBON SINKS

Balance of CO_2 emissions and sinks in 2015 and 2050



GROWTH OF BIOLOGICAL SINKS IN S1 AND S2 DUE TO GROWTH OF FORESTS AND CHANGING AGRICULTURAL PRACTICES

Natural carbon sinks in biomass and soils in 2017 and 2050

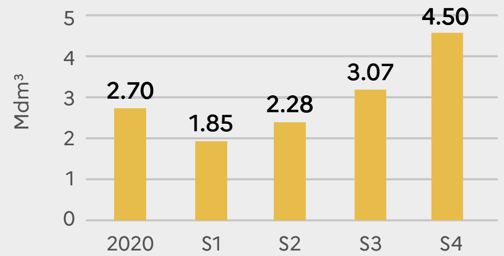


Note: the 2017 sink value is given as the benchmark, though it was not calculated in the same way as for the scenarios: it used values from the national inventory carried out by CITEPA, adding carbon sequestration to forest soils and forest deadwood.

RESOURCES
Differing pressure on resources

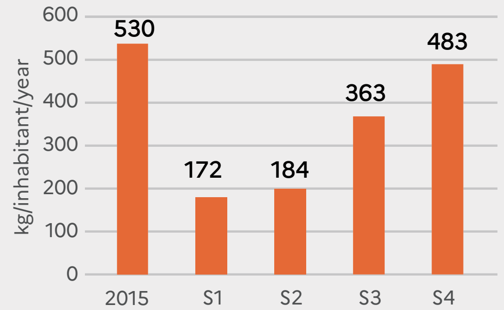
2 SCENARIOS LIMITING THE USE OF IRRIGATION

Water requirements for irrigation in 2020 and 2050



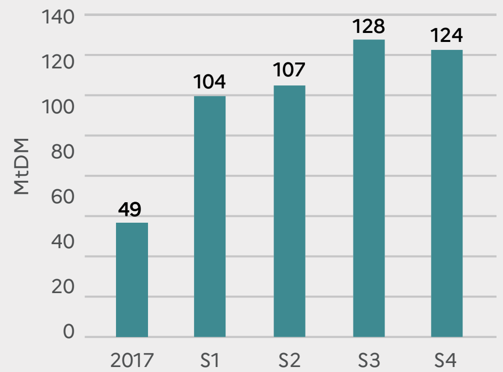
LESS HOUSEHOLD AND SIMILAR WASTE

Household and similar waste collected in 2015 and 2050



USE OF BIOMASS DOUBLED OR MORE

Use of biomass for non-food uses in 2017 and 2050



5 ISSUES for debate

S1 Frugal Generation | **S2** Regional Cooperation | **S3** Green Technologies | **S4** Restoration Gamble

ISSUE #1 Sufficiency: how far should it go?

The lower the demand, the easier it will be to decarbonise energy. However, reduction in demand is determined by two factors: sufficiency, i.e. re-examining lifestyles and consumption patterns to control the demand for goods and services; and energy efficiency, which makes it possible to reduce the amount of energy required for their production. But the potential for energy efficiency comes up against physical limitations and especially the limits of available technologies.

So we cannot escape the question of sufficiency.

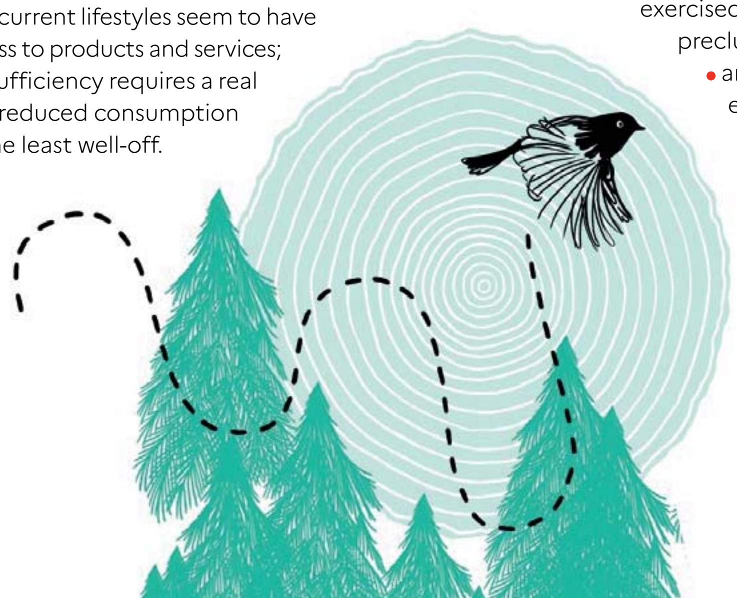
S4, the only scenario not to incorporate this lever, leads to a headlong rush that seems risky: unable to decarbonise energy production, society is reduced to using huge amounts of energy to remove CO_2 from the atmosphere. The technological and economic gamble is enormous.

S3, which is an extension of our current lifestyles, relies on technologies to increase the potential for energy efficiency, so that we can make do with only moderate sufficiency. This implies achieving an effective balance between development of these technologies and increased consumption. But the time taken to develop these technologies delays emission reduction, leading to a high overall emission balance during the transition period.

In S1 and S2 there is greater adoption of sufficiency by changing the principles of socio-economic development: reduced consumption, more rational lifestyles that prioritise social links over the accumulation of material goods, aspirations that are being expressed increasingly in our societies. S1 and S2 thus develop sufficiency in energy use (walking or cycling, preferring local shops), size sufficiency (reducing the weight of vehicles) and cooperative sufficiency (communal housing, renting equipment that is used infrequently rather than buying it). This sufficiency secures the achievement of carbon neutrality: residual emissions are more easily offset by natural carbon sinks and the drop in emissions is fast enough to ensure that total emissions during the transition period remain moderate.

However, sufficiency is at odds with the dominant way of thinking in the consumer culture of the modern world. It is often perceived as a hardship and proves to be divisive: what seems to be a hardship for a given generation or individual may be accepted as a matter of course by another. However, implementing policies of sufficiency on a large scale requires rapid and major social transformation, which may meet with strong resistance. S2 overcomes this difficulty by seeking a social consensus through open governance, but this slows down the pace of transformation. S1, with much stronger goals for sufficiency in a much shorter time, inevitably has to resort in parallel to coercion via regulation or rationing via quotas, requiring a lot of explanation and compensation to gain acceptance. The difficulty in achieving these goals runs the risk of strong or even violent divisions within society.

Finally, **sufficiency cannot be considered in isolation from inequality**: on the one hand, current lifestyles seem to have adapted to inequality in access to products and services; on the other, the choice of sufficiency requires a real effort for a fairer society, as reduced consumption cannot be expected from the least well-off.



ISSUE #2 Can we rely only on natural carbon sinks to achieve neutrality?

The four scenarios show that achieving carbon neutrality cannot be achieved without natural carbon sinks (plants, soils and forests) because their potential is very high compared with technological sinks (carbon capture and storage).

In the scenarios with the most sufficiency, S1 and S2, these agricultural and forestry biological sinks can be maximised and are sufficient (or almost sufficient in S2) due to low energy demand, which allows biomass harvesting to be limited (forests in particular). It is therefore possible to maintain a balance between exploitation of biomass to decarbonise, provision of services to people (recreation, materials, etc.) and low exploitation of forests to preserve the services provided by nature (biodiversity, water quality, etc.). Agriculture, with the development of agroecology and "sequestration practices" (agroforestry, grasslands, etc.), as well as the very low level of land degradation due to controlled urbanisation, also preserves the "sink" function of soils. But this requires changes in our lifestyles that may not be consensual.

In S3 and S4, the level of emissions to be offset increases and the greater exploitation of natural environments reduces the potential of sinks: technological sinks therefore become necessary.

But their potential is limited: while S3 achieves a satisfactory balance between natural and technological carbon sinks, keeping their cost under control, S4 is forced to deploy technologies for direct capture of CO_2 from the air. This consumes a lot of electricity, is not yet mature, and its cost is unknown even if it were to become mature in time. In both these scenarios, some or all of the captured CO_2 must be stored underground, which raises questions of acceptance.

Sufficiency, biomass management and natural sinks are therefore intimately related. But natural sinks are fragile and vulnerable to climate change. Without the enormous sufficiency exercised in S1, the other scenarios should not therefore preclude reflecting on the need for:

- an active policy to develop agricultural and forestry sinks to increase their resilience, with likely co-benefits for biodiversity and climate change adaptation;
- the development of carbon capture, utilisation and storage technologies, to avoid relying solely on natural sinks whose development potential remains uncertain.

ISSUE #3 What is a sustainable diet?

Food is one of the world's major challenges, with an expected doubling in food requirements by 2050. In France, food is responsible for a quarter of the carbon footprint and is at the centre of multiple health and environmental issues, particularly preservation of biodiversity, and water and soil quality. Finally, food is also at the heart of our social practices.

The proportion of animal protein in the diet is one of the most important factors in the environmental impact of food production. As an example, feeding the average French citizen with a meat-rich diet requires four times more agricultural land (in terms of footprint) than a purely plant-based diet.

The four scenarios show that diet cannot be considered in isolation from other issues affecting the biosphere: what contribution is expected from biomass for material and energy production? What role do we want natural carbon sinks to play? How can agriculture adapt to climate change, which is already affecting it?

Apart from scenario S4, which relies on technological capture of CO_2 from the air, all the other scenarios require a move towards less consumption of animal protein while prioritising quality meat in the average French diet. This has multiple co-benefits: freeing up agricultural land in France and outside France, facilitating conversion to organic farming and favouring less intensive systems (grassland systems), relocalisation of production and encouraging regional resilience, and reducing our impact on ecosystems (imported deforestation). The first three scenarios show, nevertheless, that different agricultural and food models are possible, provided they are developed in conjunction with the other dimensions of the transition.

ISSUE #4

Land degradation, fuel poverty, renovation: can the construction sector adopt a different economic model?

Residential and tertiary buildings now account for nearly half of national energy consumption and nearly a quarter of GHG emissions. Their construction consumes 51 million tonnes of materials per year and directly contributes to land degradation. On the social level, accommodation represents 30% of the household budget, fuel poverty affects more than 5 million households and poor housing affects around 4 million people.

In addition, **recent trends have led to the proliferation of household equipment and an increasing use of building space** (reduction in cohabitation, vacant housing and offices, growth in second homes).

In S1 and S2, it is possible to limit the impact of buildings not only by widespread and efficient renovation but also by abandoning the dream of the individual house in favour of flats or shared living spaces, respecting each person's privacy but in a friendlier environment; developing the sharing of rooms or equipment (e.g. washing machines) between several apartments; conversion of second homes into main residences; or sufficiency in the use of electrical and digital equipment. But these changes in society are not easy. S3 and S4 rely more on technology and new construction (especially S3, which is a "Haussmannian" scenario of demolition and rebuilding) but with very high consumption of materials and energy (production of cement and materials), requiring new quarries or extensions that are increasingly unacceptable to the surrounding population.

The choices made for the construction industry have consequences for the industrial model: massive consumption of cement and steel strongly increases construction industry emissions. S1 and S2, based on renovation, go hand in hand with a more restrained industrial model based on the circular economy. In social terms, jobs created for the mass renovation of housing could more than make up for the loss of jobs in the new construction industry.

ISSUE #5

Towards a new industrial model: is sufficiency harmful for French industry?

In contrast to the past 30 years, it is now widely accepted that **relocalisation of industry to France is vital for our economy and its resilience. However, this relocalisation will not happen by itself in a globalised world and will not be without impact.** The competitiveness of industry will be developed using two levers, activated to a greater or lesser extent depending on the scenario: a new industrial model that favours quality over quantity and is based on the circular economy (S1 and S2); and a more quantitative model, but using decarbonised energy and processes (S3 and S4).

In S1 and S2, industry has to rethink its business model, with production of reduced tonnage of materials and consumer goods (-38% for S1 and -26% for S2) due to the sufficiency shown by consumers (individuals, companies and local authorities). This will be achieved through high-quality products, more expensive but durable, eco-designed, repairable, reusable and recyclable. But also through the development of an economy based on functionality, i.e. sale of a service rather than a product, in which material and energy savings come together in favour of a more circular economy. These scenarios also limit the risk of "carbon leakage", avoiding the off-shoring of heavy industry to countries with lower carbon taxes. In S2, this goes as far as re-industrialisation (improving the trade balance) for certain targeted sectors with decarbonised production.

In S3, industrial production is slightly down (-14% in tonnage). It remains stable in S4, but with a worsening trade balance in heavy industry sectors, potentially leading to "carbon leakage". The industrial challenges are then in energy efficiency and energy decarbonisation (renewable energies or carbon capture and storage).

In all cases, these developments must be accompanied by:

- large-scale investment plans both for widespread introduction of mature technologies and the emergence of breakthrough innovations in industrial processes. Energy efficiency and decarbonisation are becoming key competitive factors;
- ambitious employment and training policies and support for regions affected by industrial change.

This raises the question of what role public policies should play in supporting these transformations, whether in terms of support mechanisms or regional planning.

Limitations and prospects for further study

As with any forward-looking exercise, certain limitations remain:

- **The effects of climate change** on the operation of infrastructure, systems and organisations as well as on behaviour are mainly taken into account for the agriculture, forestry, construction and electrical energy sectors, due to a lack of benchmarking work or modelling tools for other sectors;
- The juxtaposition of scenarios built on very different driving forces may suggest that they benefited from the same **level of expertise and feedback**. However, knowledge of sufficiency or carbon sinks is much less developed than that of energy efficiency or renewable energy, which have been studied and researched for several decades.
- **The assessment of the consequences on biodiversity** posed methodological difficulties due to a lack of knowledge and the fact that the source of the data for the exercise is not precisely located geographically. Nevertheless, concern for biodiversity is not absent from the work;
- **The "rest of the world" is considered as a whole** which takes the same route as mainland France and, for this reason, is not modelled in a detailed way.

Next steps in this work

This work is just the first part of a series of publications that will be published between January and March 2022. The collection will then form a whole, which will be put into perspective during the Grand Défi Écologique (the "Great Environmental Challenge"), an event organised by ADEME on 29 and 30 March 2022 in Angers.

This series of publications will cover the following subjects:

- Analysis of the electricity generation mix
- Materials for the Energy Transition
- Macroeconomic assessments including employment and investment
- Analysis of changes in lifestyle, conducted through a qualitative study of views and perceptions of the scenario narratives by 31 French people from different backgrounds
- Footprint of materials, greenhouse gases, resources and consumer goods
- Land use and soil quality
- Adaptation to climate change
- Analysis of the impact on some key sectors, in particular: "new construction", "energy systems", "proteins" and "last mile logistics"
- Robustness and vulnerability to shocks
- Air quality
- Regions (in the form of a guide to help regions with forward planning)
- Digital

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EXECUTIVE SUMMARY TRANSITION(S) 2050

"**Transition(s) 2050. Decide now. Act 4 climate**" is a forward-looking exercise describing four consistent and contrasting pathways to carbon neutrality in France in 2050. The pathways aim to link the technical and economic aspects with consideration of the societal transformations that they assume or provoke.

The following sectors are considered in detail: those related to consumption (land development, building, mobility and food); those forming the production system (agriculture, forestry and industry), those forming the energy supply (gas, cooling and heating, biomass, liquid fuels and hydrogen); those that constitute resources (biomass and waste) and carbon sinks. Wherever possible, these sectors are also analysed for their impact on water, soils, materials and air quality.

This publication is the result of more than two years' work by ADEME, in interaction with external partners, to inform decision-making in the coming years. For the aim is not to propose a political project or "the" right pathway, but rather to bring together technical, economic and environmental knowledge to raise awareness of the implications of the societal and technical choices that the chosen paths will entail.

This document is published by ADEME.

Find the ADEME scenarios online at www.transitions2050.ademe.fr/en

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