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The energy transition: which transition for which objectives?

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The **energy transition** (**ET**) seeks to respond to an environmental constraint, which stems from the depletion of our carbon budget, responsible for **climate change** (**CC**). This transition is complex, costly, but necessary. Climate scientists agree that the future benefits of the transition far exceed its short-term costs; in other words, the cost of taking action is significant, but the cost of climate inaction is likely to be insurmountable.

While operating costs for decarbonised energy and technologies are following a decreasing trend thanks to technical progress, which would justify postponing the ET, the damage caused by stockpiling **carbon dioxide** (**CO_2**) in the atmosphere would also increase, probably to a much greater extent. The macroeconomic losses are already significant, estimated at 10 billion euros for France in 2022[1], and are likely to increase considerably, if we do not reverse the emissions trend. An ET is therefore urgent and has three objectives: carbon neutrality by decoupling GDP growth from that of CO_2 emissions, industrial competitiveness by stimulating new forms of economic activity that emit less, and finally a fair distribution of costs.

Issue n°1: Carbon neutrality by 2050

The goal of **carbon neutrality** by 2050 is probably the most important one, as the first consequences of CC are already weighing heavily on societies. But it is a global goal and carbon neutrality in an isolated region (such as France or even Europe) will not be sufficient to combat CC. Nevertheless, local objectives must be maintained, as they have some virtues and benefits.

Lower CO_2 emissions also has joint benefits in terms of local pollution and maintaining biodiversity. It would set an example, allowing us to boost our international legitimacy in the fight against CC and for the protection of the global commons (such as forest resources or deep-sea resources, for example).

Carbon neutrality aims to decouple growth from CO_2 emissions. This decoupling can be expressed in relative (economic growth increases more than CO_2 emissions) or absolute (CO_2 emissions decrease) terms. Decoupling the two is obviously all the easier to achieve since growth drivers are initially the most polluting. How can the ET enable this decoupling? The breakdown of interactions between economic growth and CO_2 emissions, as proposed by Grossman and Krueger (1995), shows that the growth of CO_2 emissions can be explained by the combination of three factors: scale, composition and technology. The scale effect, which is positive, reflects the increase in CO_2 emissions generated by the increase in production, all other things being equal. The composition effect, which

[1] According to the President of France Assureurs (*Le Monde* newspaper, 26 January 2023, "The cost of natural disasters in France reached 10 billion euros in 2022, a level not seen since 1999").

is more ambiguous, adds a different element by taking into account the specificities of the goods produced and the factors of production involved; lastly, the technology effect, which is negative, highlights the virtuous role of an increase in (1) income in the social acceptability of stricter environmental regulation, (2) technology and (3) knowledge. Thus, the ET should mainly target the technological effect channel, i.e. social acceptability and green innovation. This is a necessary condition for sustainability, which emphasises the role of education, human capital and technological progress. The ET should therefore enable the implementation of strategies to boost technological progress (R&D) and direct it towards the fight against CC, increase social demand for environmental protection through awareness-raising campaigns, education and also through climate policy. More generally, the ET aims to reduce undesirable public bads while increasing public goods; the composition effect is therefore important. This is the necessary condition for separation that could be global.

But the ET must also encourage negative emissions, by adapting agricultural practices, facilitating reforestation and the deployment of investments in carbon capture and sequestration, linked to the carbon price. If carbon were to be seen as a profitable market resource to be eliminated, there would need to be a value set for each ton not emitted that is sufficiently incentivising.

There are many avenues to accelerate the ET. For example, we should encourage the production of renewable energies by removing obstacles such as their poor acceptability in certain environments, increase their financial profitability, guarantee the long-term availability of the mineral resources necessary for these infrastructures (autonomy over the primary resource and/or access to recycled resources), regulate carbon content more strictly, possibly in a progressive manner depending on the economic situation or the context (such as certain 'super-emitting' international events or irresponsible behaviour, which generate more emissions than alternative solutions with the same characteristics and costs).

A final objective of carbon neutrality is to reduce our dependence on fossil fuels.

The benefits are twofold: (i) increase energy independence (security of supply, energy bill, exposure to the fluctuations of the energy and financial markets), according to mechanisms that have been well known since the oil shocks of the late 20th century, (ii) avoid the carbon curse (Chiroleu-Assouline et al., 2020).

Empirical measurements show that countries with abundant fossil resources emit more CO_2 per unit of output than countries where these resources are scarce. Three specific mechanisms of the carbon curse are at work. On the one hand, the abundance of resources could lead to a composition effect due to the predominance of fossil fuel sectors in the economy, which are high emitters of CO_2; on the other hand, this abundance could go hand in hand with eviction effects in the energy sectors, resulting in barriers to the development of renewable energies; lastly, it could lead to knock-on effects of polluting behaviour to all sectors of the economy (including services), combined with lax environmental policies and specialisation in electricity generation. These effects hamper the development of new green sectors, like the resource curse.

Carbon neutrality is scheduled for 2050. In the meantime, it is likely that economies

will continue to extract and use fossil fuels. But it would be appropriate to take greater account of the climate impact of each of these fossil resources. Overall, the hierarchy is now well established: gas is preferable to oil, which has less impact than coal. However, within the same resource, i.e. oil, extraction sites themselves have different climate impacts depending on the extraction and refining technologies, chemical characteristics and transport methods (Coulomb et al., 2021) used. Ultimately, there is a climate hierarchy specific to oil, and if this hierarchy were to be respected when operating wells, significant quantities of emissions could be avoided. However, economies would remain dependent on these fossil resources, by curse, but could remedy this by starting to better control or even limit the permits granted for new fossil fuel explorations.

Issue n°2: ET: towards a new industrial revolution for better competitiveness

The 19th-century industrial revolution saw the rise of machines that lightened physical labour but at the cost of considerable use of fossil energy.

This revolution took place when natural resources were relatively abundant and the environment relatively healthy. It was not until the end of the 20th century that a high economic and social dependence on resources began to be observed, with concerns about the risk of depletion and a slowdown of growth and development drivers. The two oil crises (1974 and 1979), the ensuing macroeconomic crises and price effects accelerated the pace of innovation and technical progress, allowing for an increase in energy efficiency, while making the exploration and operation of new deposits profitable and therefore possible. The depletion of fossil fuels predicted in 1970 did not occur.

More than 40 years later, the issue has shifted. From a stock depletion constraint, we have moved to a carbon budget depletion constraint, measured by the saturation point of a reservoir (the atmosphere). According to Henriet and Schubert (2021), resource depletion is not the issue at stake with fossil fuels, for which recoverable known reserves are between four and eight times larger than the available carbon budget.

Just as the 20th century oil shocks were drivers of energy innovation, the 21st century carbon budget constraint could be a catalyst for climate innovation, by encouraging the emergence of new forms of energy, new needs and lifestyles, and new production or abatement technologies.

This carbon budget constraint, if internalised correctly (through regulatory or industrial strategies for example) and early enough (i.e. before competitors), could be a source of competitiveness and a growth driver. The first to innovate gains market share and maintains it. This hypothesis was formulated by Porter (1995): the environmental constraint weighing on companies has a lower cost than it seems. Even if this hypothesis is not completely confirmed by data yet, it will be all the more likely when the carbon budget constraint becomes a heavy and unavoidable burden.

These innovations will inevitably lead to industry shifts, for example by replacing a combustion-engine car with an electric one, by using different mineral resources or by developing the role of hydrogen.

There will be winners and losers in this transition. But the net benefits, if positive, can help to remove the barriers to the ET by providing compensation for the losers, such as the holders of stranded assets[2] and the most fragile actors (households, companies, regions).

Issue n°3: A social transformation for a fair distribution of costs

In order to better capitalize on natural resources and take into account their contribution to well-being and GDP (ecosystem services, air and water quality, etc.), negative externalities, particularly carbon, must be regulated (and priced) more strictly. How can we put a price on carbon that reflects its social value: quotas or taxes? The two tools are not incompatible, and can even be complementary, as shown by the situation in most European countries, which apply a carbon tax decided at the national level, combined with a European carbon trading market.

With the carbon budget running out, and damage from CC rising, the necessary increase in the cost of carbon poses a risk of loss of purchasing power for the most exposed households and could exacerbate inequalities. Removing barriers to the ET also means tackling inequalities. As shown by Douenne and Fabre (2020, 2022) and Chancel et al. (2022), this is a complex but pervasive issue that determines the chances of success of an ambitious climate policy. One section of society is confronted with great vulnerability to cold, drought and transport difficulties, while another section is better off, where abundance is reflected in behaviours that are less and less responsible with regard to climate issues and the efforts required. Climate policy must therefore take into account social acceptability, the fair distribution of its costs and redistribution. The fight against vast income inequality could become an objective of the ET, but it will remain an additional tool because it is unlikely to solve the climate problem on its own. Income redistribution will only have a significant impact on global emissions if the climate impact of marginal consumption is found to be significantly different between rich and poor households. Nevertheless, enabling the most vulnerable households to adapt to the needs of the ET, without compromising their standard of living, and even improving their economic conditions as much as their natural environment remains an essential objective.

This issue matters at the national level, but even more so at the international level. Wealth inequalities between countries are considerable, as are the historical responsibilities for the concentration of CO_2 in the atmosphere. The relative short-sightedness of developed and/or polluting countries likely hampers international negotiations. Taking into account the distribution of the costs of the fight against CC between regions, as part of a more global reflection on transitions, could accelerate the ET and the international fight against CC. Financial markets and

[2] Refers to assets devalued as a result of an environmental or institutional constraint.

interactions with sovereign debt could be catalysts for change.

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