The transition to carbon neutrality: An unusual type of structural reform

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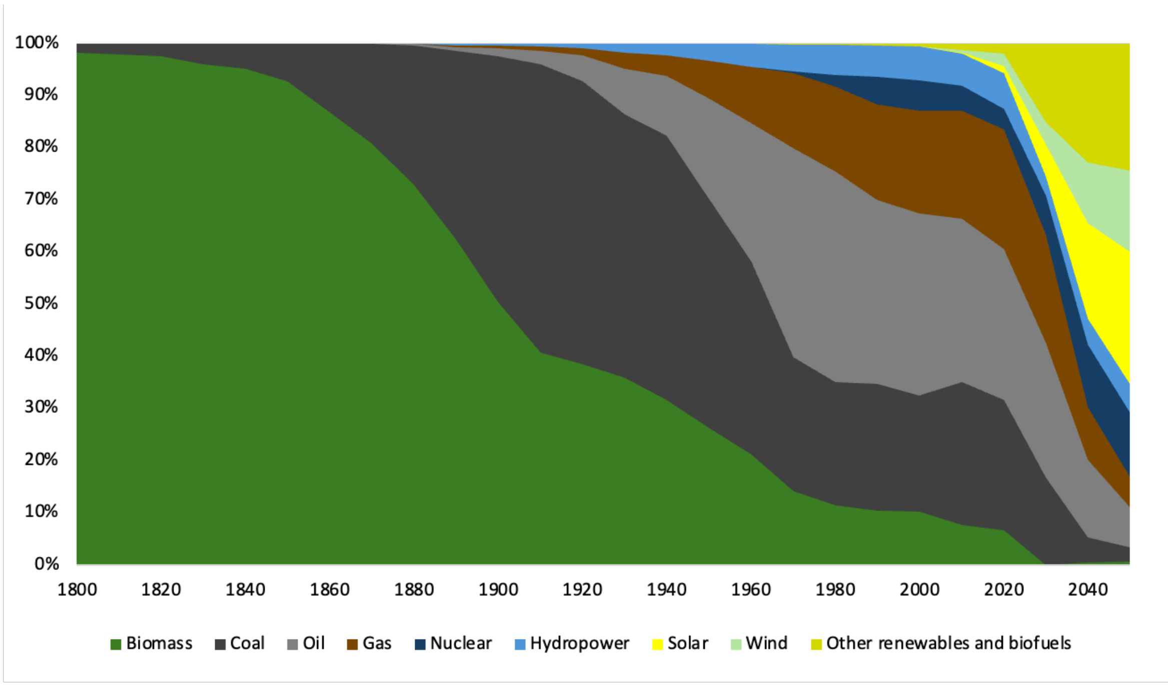
We are not used to thinking of the green transformation as a structural reform. But in fact we should, because it is essentially triggered by policy actions and because the questions it raises, be it about the range of available policy instruments, about their relative effectiveness, or about the political economy of this transformation, are familiar ones when designing structural reforms. Seen in this light it is indeed, as Olivier Blanchard says in his chapter, the most radical worldwide structural reform in the history of mankind.

An industrial revolution at warp speed

Let me start by illustrating the magnitude and speed of the transformation ahead of us. We know from history that changes in energy sources have been associated with industrial revolutions. In the 19th century, the emergence of coal as a major energy source contributed in a central way to the first industrial revolution. In the 20th century, the rise of hydrocarbons (oil and gas) contributed to unleashing the second. What we are speaking of now, the substitution of carbon-free energy sources for fossil fuels, will trigger another industrial revolution.

Figure 1 gives the composition of the world energy from 1800 to 2050, assuming (which is an ambitious assumption) that the world reaches Net Zero by 2050. Let us use simple thresholds to assess the speed and extent of these transitions. If we consider that a source of energy is globally marginal as long as it amounts to less than 10 percent of the global energy supply, and dominant once it has passed the 50 percent bar, what the data tell us is that it took five decades, from the mid-19th century to the early 20th century, for coal to transition from marginal to dominant; and that it took about four decades, from the late 1920s to the late 1960s, for hydrocarbons to reach the same status. But what is ahead of us is a faster and more radical transition: whereas the 10 percent bar was reached in the mid-1980s already, the share of modern carbon-neutral technologies in global energy supply stagnated around 12.5 percent until it eventually took off in the 2010s. By 2050 it is expected to reach the 80 percent bar. In the course of three decades, this would amount to a complete overhaul of the global energy system.

Figure 1: Composition of world energy supply, 1800-2050



Sources: Smil (2016) for the historical data; Energy Institute (2024) for 1965-2020; IEA (2023) for 2030-2050.

Moreover, there is something more than speed: unlike the energy revolutions of the past, largely triggered by the discovery of new carbon-rich natural resources and with momentums driven by technological advances, the current one is primarily steered by policy. More precisely, it was initiated by policy and continues to be mostly driven by policy, although the technology momentum is becoming increasingly self-sustained. When, how, and in which sectors green technologies reach a stage where they have become efficient enough to displace brown technologies without the support of policy is key to the irreversibility of the transformation. In some fields this point is behind us already; in some, it is within reach; in some others, it is still far off. By 2050, however, most technologies are expected to have reached that point.

The mechanisms behind the green transformation

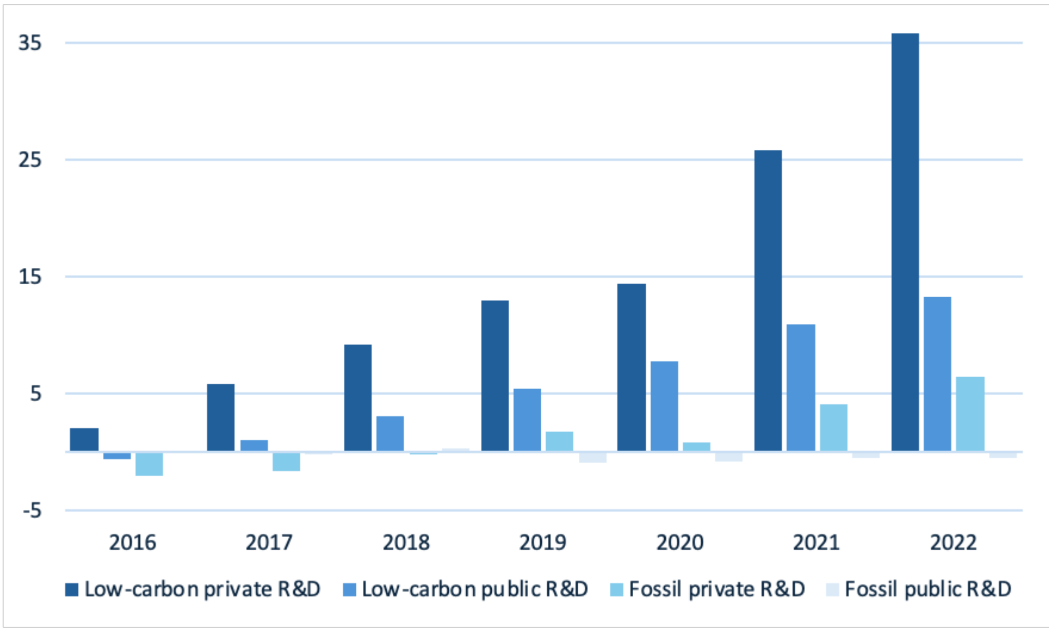
Because it can be triggered by various instruments and involves several technologies, it is easy to get confused about the economic mechanisms at the origin of the green transformation. They are fundamentally of three types.

The first type is a change in the lifestyle of consumers. In the same way the second industrial revolution cannot be dissociated from the rise in mass consumption, the coming transformation will likely be accompanied by behavioral changes. Cycling to work, eating less red meat, or turning off the air conditioning when the outside temperature is moderate are just three examples, among many, of such behavioral changes. The reasons for them can be of several types: for example, very few dare cycling to work, even if they would wish to, if there are no bike lanes, so triggering this change in behavior requires public investment. Behavioral change may alternatively result from better information, for example about the individual health benefits of a lower intake of red meat. Even though “sufficiency,” as it is sometimes referred to, is bound to play a secondary role in the overall reduction of emissions, it is an important dimension of the transformation of the economy, because it gives individual citizens agency in it. Be it through public investment, through disseminating information or through nudges, policy has a role to play in helping trigger behavioral changes.[1]

The second mechanism is a redirection of technical progress toward green technologies. Over the long term, it has a fundamental role to play. As argued by Daron Acemoglu and Philippe Aghion in a series of papers, whose main conclusions are summarized in Acemoglu, Aghion, Barrage, and Hémous (2024), path-dependency initially puts green technologies at a disadvantage in comparison with brown technologies, which benefit from accumulated innovation efforts. In the absence of policy action, this path-dependency prevents green technologies from taking off, even if they are intrinsically superior to brown ones. Carbon pricing contributes to correcting this initial handicap, but a full offsetting of it would require an excessively high price that would have detrimental economic effects.

There is consistent evidence that the redirection of technical progress is at work and that it is delivering. Figure 2, from Fries (2024), gives changes since 2015 in the allocation of private and public R&D investment in the energy sector. It indicates that a massive reallocation of R&D toward low-carbon technologies is at work in the private sector.

Figure 2: Change relative to 2015 in global private and public energy-related R&D investment, 2016-2022



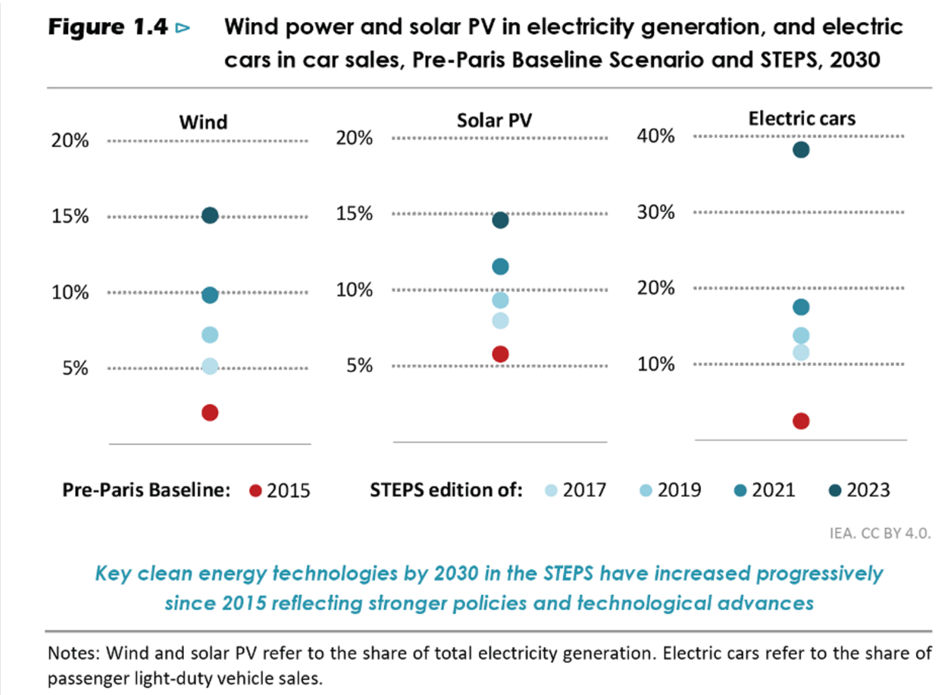
Source: Fries (2024)

Indications on the extent to which the reallocation of R&D spending is delivering benefits can be found in evidence from the International Energy Agency (IEA). Every two years, the IEA

[1] For a more detailed analysis of the potential contribution from behavioral changes, see Pommeret (2023) and European Commission (2024).

releases forecasts for the uptake of key green technologies. The comparison of forecast vintages is indicative of the surprises regarding the speed of deployment of these technologies. Figure 3 provides comparisons of forecasts for 2030 made in 2015 (before the Paris agreement) with subsequent ones (2017, 2019, 2021 and 2023). Each dot represents an individual forecast for a given technology. For example, the 2030 share of wind in global electricity generation was expected in 2015 to be about 2 per cent. It has consistently risen and was assumed to reach 15 per cent in the 2023 forecast, even assuming stated policies.[2] Similar evolutions have been observed for solar photovoltaics and the share of electric vehicles in total car sales. The fact that green technologies have consistently surprised on the high side is indicative of their potential.

Figure 3: IEA forecasts for the global deployment of green technologies



Source: IEA (2023)

Finally the third, and certainly the most important mechanism at a 5 to 10 year horizon is the substitution of capital for fossil fuels. A common characteristic of all clean electricity production technologies (wind, solar and nuclear) is that even abstracting from backup and electric grid costs, they are at least twice as capital intensive as fossil-fuel-powered ones (coal and gas).[3] The same actually applies to other fossil-fuel-saving technologies such as heat pumps, the retrofitting of buildings or, at current prices, the replacement of internal combustion engine cars by electric vehicles.

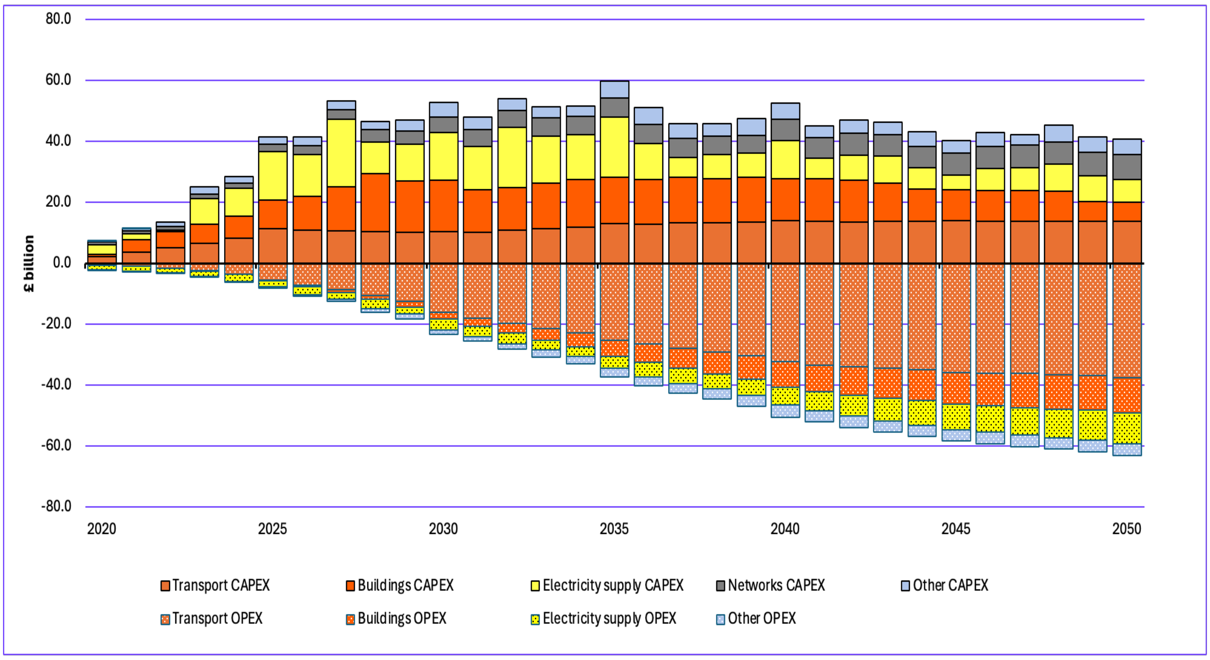
Decarbonization therefore requires incurring high upfront investment, offset by eventual

[2] The IEA's Stated Policies Scenario (STEPS) is based on a detailed review of the current policy landscape. It provides a granular, sector-by-sector evaluation of the policies that have been put in place to reach stated goals and other energy-related objectives. The STEPS provides a more conservative benchmark for the future than the alternative Announced Pledges Scenario (APS).

[3] See Figure 2 in Pisani-Ferry and Mahfouz (2022).

savings on operation costs. This is well illustrated by projections of annual additional CAPEX and OPEX reductions made by the British Climate Change Committee (Figure 4). As shown in the figure, reaching Net Zero in 2050 requires a steep ramp-up of additional investment, up to about 2 per cent of GDP in 2030 (above-the-line bars), while savings on OPEX (below-the line bars) arise much more gradually.

Figure 4: Investment Requirements and OPEX Expenditures in a Net Zero Scenario for the UK, 2020-2050



Source: The CCC 2021

Eventually, lower OPEX may possibly ensure a more efficient energy system than the current one – or not. In the meantime, however, additional investments likely imply a drag on potential output growth. To understand why, think of a production function with three factors (capital, labor, and energy), where energy can be produced either with fossil fuels or with clean technologies. Assume that the production of a megawatt-hour of clean energy requires more capital than one of brown energy. If the investment required to diminish the reliance on fossil fuels (call it type 2 investment) is taken away from traditional efficiency-enhancement investment (call it type 1 investment), the overall efficiency of capital and labor is reduced. If type 1 investment remains unchanged ex ante, additional type 2 investment requires an increase in the overall level of investment. Restoring the savings-investment balance implies an increase of the equilibrium interest rate and therefore a reduction in the level of type 1 investment. One way or another, type 1 investment takes a hit, which implies a temporary productivity slowdown.

So where do we stand with this investment? According to the Institute for Climate Economics, which tracks climate-related investment in the European Union, the European climate investment shortfall was still €406 billion, or 2.5 percent of EU GDP in 2022. Much remained to be done to ramp up climate investment and put it on the path required to reach carbon neutrality by 2050 (I4CE 2024). Even accounting for discrepancies in methodology, this large figure suggests the challenge we face.[4]

The right choice of policy instruments

As mentioned in the chapters by Blanchard and Kim Clausing, a key question is the choice of policy instruments for triggering the transformation. In a single-externality world with exogenous technical progress, where policies are perfectly credible and where their distributional and efficiency effects can be fully separated, the answer is simple: policy should go for a Pigouvian tax or an equivalent cap-and-trade system, knowing that the proceeds from carbon pricing could be redistributed to modify, or neutralize, the distributional effects from carbon pricing. Unfortunately, however, we are not in such a world. As often for structural reforms, real-world considerations may lead policy to depart from the first-best optimum and go instead for a mixed strategy that combines pricing with subsidies, nudges, and outright regulation.

Even if carbon pricing was shown to be the first-best instrument, three considerations would argue against relying on this instrument alone.[5]

The first case for a mixed strategy is the one put forward by Acemoglu et al. (2024): a single instrument, namely carbon pricing, could only correct two externalities, one for climate and one for knowledge, if the desired first-best carbon prices happen to coincide, or at least if they happen to be sufficiently close to each-other. This is unlikely to be the case, especially because correcting the knowledge externality exclusively through the pricing of carbon would require putting that price at an excessively high level. In practical terms, carbon pricing will need to be complemented by subsidies to green technologies.

The second argument has to do with credibility. Investors will only start betting on the greening of the economy if they are certain that the future price of carbon will be high enough to ensure these investments are profitable. In other words, what matters to them is not only today's carbon price but its outlook at a 10- or 15-year horizon. In this respect, the announcement that only carbon-neutral vehicles can be put on the market after a certain date is likely much more credible than the announcement of a future trajectory for the price of carbon. This is a second reason for combining carbon pricing with another instrument, in this case, regulation.

The third argument is at its core a political economy argument. The investments needed to transition away from fossil fuels represent a significant burden not only for lower-income households but median-income ones. For the latter, investments required for the purchase of an EV or for home renovation and the change of heating system easily represent a year of income. As argued by Pisani-Ferry, and Mahfouz (2023) and confirmed by Vailles, Ousaci, and Kessler (2023), these can only be made affordable through means-tested subsidies to households. Again, this is a reason for considering a mixed strategy whereby carbon pricing is combined with subsidies.

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[4] I4CE's methodology is based on an exhaustive census of climate-friendly investments, whereas the CCC methodology focuses on the additional investment required to reach carbon neutrality.

[5] Eléonore Soubeyran and Nicholas Stern also discuss the rationale for multiple instruments in their chapter.

The downside of a multiple-instruments strategy is however substantial, because it requires assigning efficiently instruments to objectives. As pointed out by Furman (2024) and Mehrotra (2024) in their discussion of Acemoglu et al. (2024), policies are prone to errors or to capture, and multi-instrument strategies can result in much higher abatement costs, at least in the short term. In turn, these higher costs easily translate into public sector budgetary costs if, as for the US Inflation Reduction Act, the approach relies primarily on subsidies. In an environment where political economy considerations prevail over strictly economic ones, there is a high risk of adopting an inefficient strategy.

Europe in this regard faces a difficult conundrum as it intends to accelerate the transition away from fossil fuels while keeping public spending within strict limits. As a new, tighter fiscal framework has been put in place, the question is if it leaves enough fiscal space for the financing of the transition.

The political economy of climate action and its fiscal implications

It was long believed that carbon pricing would yield revenues and that these revenues could be used to lower distortionary taxes. According to the "double dividend" hypothesis, carbon taxation was expected to contribute to reducing emissions, while lower taxes on labor would help reduce the tax wedge and thereby contribute to improving employment or the income from labor. The fallacy of this hypothesis was vividly illustrated in 2018, however, when the French Yellow Vests revolted against a (fairly modest) increase in the carbon duty and against the very principle of relying on taxation to steer the transition away from fossil energy. The episode made clear that at least in the French case, and probably beyond it, carbon taxes were politically toxic, unless their proceeds were entirely, visibly, and convincingly redistributed to those directly affected by it.

Empirical research by Stephanie Stantcheva and co-authors (Dechezleprêtre et al. 2022) helps understand the political economy of climate action. The gridlock blocking structural reforms generally results from the fact that their benefits are widely spread whilst their costs are concentrated on a narrow group of potential losers. Entrenched resistance from the latter is strong enough to prevent reform from being carried through, even if the aggregate benefits vastly outweigh the costs. Large-scale international surveys conducted by Stantcheva and co-authors indicate that the same logic is at work in the case of climate action, but that another factor enters into play: the perceived fairness of the policy.[6] Indeed, responses indicate that survey respondents care about the effectiveness of policy and about how it affects their own interests, but more generally also about equity in the distribution of the corresponding burden.

The most straightforward conclusion from these findings is that the transition is bound to be fiscally costly. Public finances will incur direct fiscal costs (for example, for public infrastructure and the retrofitting of public buildings), as well as indirect ones (especially for the relocation of displaced workers). The government will also have to subsidize low- and

[6] In the words of the authors, "The policy lessons emerging from these international surveys and experiments are, first, that the specific policies proposed need to be distributionally progressive and that citizens need to be made aware of this. A corollary is that carbon pricing can be widely supported, as long as it is accompanied by transfers to vulnerable households and low-carbon investments."

median-income households in order for them to be able to afford the necessary investments, and it will suffer revenue losses due to the temporarily lower level of activity that the productivity slowdown implies.[7]

Estimates of the fiscal consequences of climate change mitigation vary, but even the fairly optimistic assessment by De Mooij and Gaspar (2024) starts from the observation that there is a trilemma among reducing greenhouse gases emissions, satisfying the political constraints, and preserving public debt sustainability. Whether or not an appropriate balance can be found among these three imperatives is a matter for discussion. Policy choices in different countries actually exhibit different revealed policy preferences: especially, the United States implicitly ranks political constraints very high compared with emissions reduction or debt sustainability. By contrast Europe's choices reveal that in its hierarchy of objectives, the reduction in emissions and debt sustainability rank above the objective of satisfying political constraints. Whether or not these rankings survive the test of reality is a major question going forward.

A key issue in this respect is whether climate investment can be financed by public debt. In principle it should be because, as alluded to by Blanchard in his chapter, investment in climate change mitigation can be regarded as a productive one-off expenditure that does not affect debt sustainability. At the very least, some categories of public investment should be deemed acceptable from a debt sustainability viewpoint, subject to proper conditionality and provided future OPEX savings can be earmarked for debt reduction.

Unfortunately, this is not a direction taken by the European policy discussion. The new economic governance framework that entered into force at the end of April 2024 does not make room for climate investment. Inflexibility in the implementation of much-needed fiscal discipline risks jeopardizing the climate transition.

References

Acemoglu, Daron, Philippe Aghion, Lint Barrage, and David Hémous. "Green Innovation and the Transition toward a Clean Economy." In *The Green Frontier: Assessing the Economic Implications of Climate Action*, edited by Jean Pisani-Ferry and Adam Posen, chapter 3. Peterson Institute for International Economics, 2024.

Climate Change Committee. *Sixth Carbon Budget: Updated Dataset*. December 2021.

De Mooij, Ruud, and Vitor Gaspar. "How Does Decarbonization Change the Fiscal Equation?" In *The Green Frontier: Assessing the Economic Implications of Climate Action*, edited by Jean Pisani-Ferry and Adam Posen. Peterson Institute for International Economics, 2024.

Dechezleprêtre, Antoine, et al. *Fighting Climate Change: International Attitudes Toward Climate Policies*. Mimeo, Harvard University, July 2024.

Energy Institute. *Statistical Review of World Energy*. 2024.

European Commission. *Impact Assessment on a 2040 Climate Target*. February 2024.

[7] My discussion does not count the loss of tax revenues arising from a shrinking fossil fuels tax base and supposes that alternative resources can be found.

Furman, Jason. “Comment on Acemoglu et al. and on Fries.” In *The Green Frontier: Assessing the Economic Implications of Climate Action*, edited by Jean Pisani-Ferry and Adam Posen. Peterson Institute for International Economics, 2024.

Institute for Climate Economics (I4CE). *European Climate Investment Deficit Report*. February 2024.

International Energy Agency. *Net Zero Roadmap: 2023 Update*. 2023.

Mehrotra, Neil. “Comment on Acemoglu et al. and on Fries.” In *The Green Frontier: Assessing the Economic Implications of Climate Action*, edited by Jean Pisani-Ferry and Adam Posen. Peterson Institute for International Economics, 2024.

Pisani-Ferry, Jean, and Selma Mahfouz. *L’action climatique: un enjeu macroéconomique*. Note d’analyse No 114, France Stratégie, November 2022.

Pisani-Ferry, Jean, and Adam Posen. *The Green Frontier: Assessing the Economic Implications of Climate Action*. Peterson Institute for International Economics, June 2024.

Pommeret, Aude. *Sobriété*. Special report, France Stratégie, May 2023.

Smil, Vaclav. *Energy Transitions: Global and National Perspectives*, 2nd ed. Praeger, 2016.

Vallies, Charles, Samir Ousaci, and Léa Kessler. “An Analysis of French State Aid for Investment in Deep Energy Retrofits and Electromobility.” I4CE Blogpost, October 2023.