Alessio Terzi and *Roger Fouquet*

The Green Industrial Revolution: Lessons from the History of Past Energy Transitions*

KEY MESSAGES

- **The challenges associated with today's green transition echo dynamics during past energy revolutions**
- **Improvements in energy efficiency and sobriety can be part of a decarbonization strategy but with muted impact**
- **An effective and credible climate policy must be chiefly targeted at accelerating a Green Industrial Revolution**
- **Governments have many tools to do so, including taxation, regulation, public investment, and industrial policy**
- **Cushioning blows to income and consumption of low-income households will be important in avoiding social backlash, slowing decarbonization**

"What experience and history teaches us is that people and governments have never learned anything from history, or acted on principles deduced from it."

Georg Wilhelm Friedrich Hegel

Climate change is upon us: 2023 is virtually certain to be the warmest year since records began in the mid-1880s, and likely in the millennia before (Hausfather 2023). This has already resulted in unprecedented wildfires, droughts, floods, and hurricanes across the globe. In order to avoid even worse consequences, political leaders in over 110 countries have agreed to reach climate neutrality by mid-century. This is no minor feat given that we currently effectively live in a fossil fuel civilization, meaning that directly or indirectly, close to everything we do relies in one way or another on burning fossil fuels and emitting greenhouse gasses.

Becoming climate neutral will require a complete transformation of energy generation, transport, housing, agriculture, manufacturing, and more (Terzi 2022a) – all to be achieved in only three decades. When framed this way, the societal challenge seems daunting, if not impossible. And yet, it gives us some comfort to note that structural transformations on a similar scale have happened before, notably during past Industrial Revolutions (Terzi 2022b).

In this short essay, we draw a set of lessons from past energy transitions to help design credible and efficient strategies to achieve climate neutrality in the 21st century. By observing and analyzing the rapid uptake of technologies and energy sources for the provision of energy services,[1] an understanding can emerge of when and why radical change in the energy system occurred. Doing so will require understanding the contribution of various channels in breaking previous technological lock-ins and catalyzing an accelerated switch to new energy sources. When thinking about decarbonization strategies, the focus on energy seems particularly appropriate as power, transport, and heat are collectively responsible for over two-thirds of global greenhouse gas emissions (Liu et al. 2023).

THE VALUE OF A HISTORICAL PERSPECTIVE

Ever since the goal of achieving climate neutrality was established, policymakers, private sector leaders, and academic experts have been constantly discussing the many challenges associated with the green transition. These include:

- the successful uptake or failure of a specific technology;
- problems of technological lock-ins and path dependency;
- the importance of market structure;
- the appropriate degree of government involvement in the economy;
- the role of incumbents, such as Big Oil, often trying to slow down the transition, including through lobbying; and
- security of energy supply, particularly in the aftermath of Russia's invasion of Ukraine.

These problems are all very important and represent fundamental challenges. They also feel like unique predicaments of our era, and yet each of these elements has parallels with past energy system transformations. For instance, in 1865, William Stanley Jevons published *The Coal Question* to shed light on the risks of exhaustion of coal resources that were cen-

* The authors would like to thank Simone Tagliapietra, Riccardo Rovelli, Niko Jaakkola, and participants to the University of Bologna's Shared Perspective seminar. All remaining errors and omissions remain the sole responsibility of the authors. Moreover, the views expressed here are those of the authors and not necessarily those of the institutions to which they are affiliated.

[1] Following an energy economics approach, it is worth highlighting that in this piece we speak of energy services, which encompasses both goods and services used to satisfy an energy demand or need. After all, as Alfred Marshall noted: "in one sense all industries provide services" (Fouquet 2008, 8).

tral to Britain's economic supremacy (Missemer 2012). At the same time, smoke abatement societies were forming across Britain with the aim of encouraging local authorities and the national government to introduce legislation to reduce air pollution (Fouquet 2012). Meanwhile, industrialists were lobbying policymakers to either not introduce legislation or water down any laws such that they were unenforceable. As a result, civil society, industrialists, and government battled over air pollution policies for around a century.[2] Eventually, after the dramatic experience of the Great Smog of London, which was associated with thousands of additional deaths (Fukushima 2021), the Clean Air Act of 1956 was the first legislation in Britain that genuinely enforced air pollution standards, marking the beginning of the transition to cleaner energy sources (Fouquet 2012).

Explorations of historical patterns are central to anticipating developments in future energy systems and their environmental impact (Grübler et al. 1999). Considering very long-run trends allows us to see technological revolutions as recurring events, cycles of economic transformation, rather than unprecedented discontinuations of business-as-usual scenarios (Freeman and Louçã 2002). While the usual lament goes that history never repeats itself, it does often rhyme, to quote Mark Twain. The reason it rhymes is because the fundamental forces at play across various technology transformations are essentially the same, as we will detail shortly. Even the First Industrial Revolution responded to the recursive logic of an evolutionary process (Galor 2022; Perez 2009). As Wrigley (1988) famously noted, the processes surrounding it were the result of "continuity, change, and chance."

SOBRIETY AND ENERGY EFFICIENCY IMPROVEMENTS

Attempts at devising a strategy to achieve climate neutrality have typically encompassed a mix of at least three elements (Pisani-Ferry and Mahfouz 2023): (i) voluntary reductions in energy use beyond gains from efficiency (sobriety); (ii) improvements in energy efficiency; and (iii) technological progress toward carbon-free energy sources and services.

Placing these various tools in historical context already provides some food for thought. First, Fouquet (2008) details how past experience with declines in energy consumption are uncommon, and rarely happen as a consumer choice. This suggests that the main channel for decarbonization in the 21st century is unlikely to be "sobriety," i.e., consumers voluntarily giving up energy services in the name of a greater good (Vogel and Hickel 2023). This might work over short periods of time, and in conditions that have been framed as war-like (as happened in Europe in 2022), but will be difficult to maintain over prolonged periods of time. Likewise, without sustained public support, it will be challenging for a government to impose a reduction in energy services on its citizens, especially within democracies. Nevertheless, when managed, temporary and sporadic reductions in consumption (as occurred during Covid-19 restrictions) combined with effective substitution policies can help realign economies onto lower energy-intensity pathways and minimize vulnerability to energy price shocks, inflation, trade balance deficits, political pressures from energy companies, and environmental pollution associated with energy intensive economies (Fouquet 2016; O'Garra and Fouquet 2022). Indeed, the International Energy Agency expects sobriety, as part of behavioral changes, to be responsible for just 8 percent of CO_2 reductions in its roadmap toward net zero by 2050 (International Energy Agency 2021).

Second, efficiency improvements have occurred frequently throughout energy history. The efficiency of steam engines was transformed by a series of scientific and technological innovations over more than one hundred and fifty years (Crafts 2004; Fouquet 2008). Similarly, a whole set of innovations led to efficiency improvements in the transport sector. Advances in the energy efficiency of lighting have been underway since the late 1700s, improving efficiency more than one thousand-fold. However, the savings from efficiency improvements are often modest due to so-called "rebound effects," which lead to increases in the consumption of energy services (Chitnis et al. 2020). Nevertheless, there is evidence that these rebound effects decline with economic development, implying that some energy savings can be achieved, all other things being equal (Fouquet 2014). However, in the long run, rising income and the associated increasing demand for energy services tend to outpace any energy savings. This is because "when prices rise and resources become scarce, ingenuity will be directed towards discovering more resources and developing ways to use them more efficiently. When resources are abundant, creativity will be aimed at offering ways to use them" (Fouquet 2008, 380).

[2] The Sanitary Act of 1866, the Public Health Act of 1875, and the Public Health (London) Act of 1891 were weak policies avoiding impact on industrialists – as an example, the term "black smoke" was placed in the text to ensure that it could be argued that the smoke was not black, and it took until 1926 for legislation to legislate against non-black smoke, but any enforcement required the go-ahead from the Ministry of Health (Thorsheim 2018, 131).

Alessio Terzi

is an Economist at the European Commission and an Adjunct Professor in climate economics at Sciences Po. His first book *Growth for Good* was one of Foreign Affairs' Best Books of 2022.

Roger Fouquet

is a Senior Research Fellow at the Energy Studies Institute at the National University of Singapore, and a Vising Senior Fellow at the Grantham Research Institute at the LSE.

Effectively, what this implies is that sobriety and energy efficiency could very well be pursued as part of a decarbonization strategy, but their effect will be contained in scale and limited in time. They might be worthwhile pursuits in order to buy some time, but, on their own, sobriety and energy efficiency improvements will have limited impact as a strategy to contain catastrophic climate change. They should therefore be seen as complements while fast-tracked technological transformation unfolds. Put differently, a switch to carbon-free energy sources and services should be seen as the main realistic strategy to achieve long-run climate neutrality.

ROLLING OUT GREEN TECHNOLOGIES

In light of the considerations above, it becomes evident that a successful climate policy should focus squarely on accelerating the development and deployment of carbon-free energy sources and services. In other words, it should spark a new Green Industrial Revolution. In order to understand what set of policies can accelerate the rollout of renewables, and green technologies more broadly, it is worth considering the mechanism through which, historically, most energy transformations took place. In this section, we will do so first in general terms and then through a few examples.

As discussed in Fouquet (2010), new energy sources or technologies generally provided the same service (i.e., heating, power, transport, or lighting), but in a way that offered superior or additional characteristics (e.g., easier, cleaner, or more flexible to use). Frequently, the high price of the service (i.e., the combined energy price and efficiency) made it initially accessible to only a few consumers. The energy price, or its inefficiency at converting energy into the service, limited its market to a niche of consumers willing to pay a premium for those characteristics.

This niche of early adopters was however important because it allowed the energy sources and technologies to "survive" at a higher price than the incumbent sources and technologies. Economies of scale, learning by doing, and technological refinements could then take place in a relatively protected market. Early adopters were typically either relatively well-off private consumers, or governments, very often for military reasons. Military expenditure was particularly well positioned for this purpose, given that broader security considerations typically allow for spectacular budgets that go beyond the logic of the cheapest available alternative.

Eventually, lower prices meant that the new technology crossed the threshold of price parity with the incumbent technology, allowing for it to spread to the wider population. In all of the 14 major energy transitions that took place over the last 1,000 years, cheaper or better services were key to the switch. In a majority of cases, the initial driver was better or different services. In all cases, a lower energy service price was necessary to achieve the energy transition (Fouquet 2010). Without a lower service price, the new energy technology is simply unlikely to be adopted by most of the population, preventing it from replacing the incumbent technology. The price of the service is therefore crucial (Fouquet 2008). Incidentally, this explains why successful technologies are known for following a so-called "S-curve," meaning they spread slowly at the beginning (thanks to early adopters), at some point they reach price parity and spread at an exponential rate, only to flatten out once they reach full market capacity.

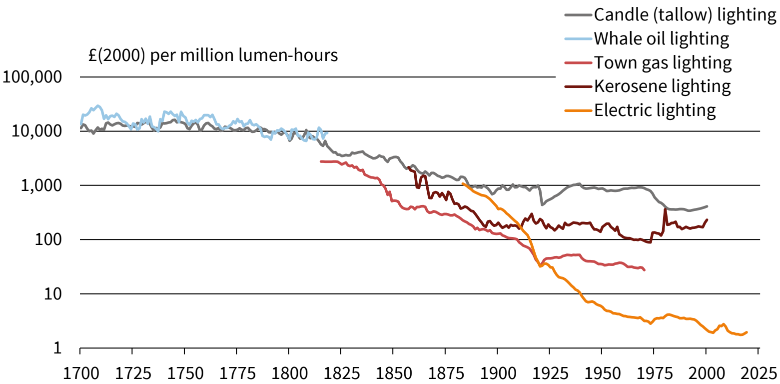
Let us showcase this dynamic with two specific historical examples related to the transitions in lighting and in transport.

Candles had been providing lighting at least since 3,000 BCE (Nordhaus 1996). However, they were extremely expensive, to the point that centuries later they were occasionally used as status marker to signal wealth.[3] Alternative technologies and energy sources were tested. Whale fat made modest inroads (see Figure 2), as it was a technological alternative that could not scale due to the biological limits of the whale population and, ultimately, the ecological and energy inefficiency of converting solar power into plankton into whales into a lighting fuel. As a result, the price never became competitive in a way that allowed the full rollout across society, and it fluctuated greatly as a population of whales was decimated and a new population was found further afield (see Figure 1).

In nineteenth century Britain, town gas (derived from coal) became the dominant source of lighting (Fouquet and Pearson 2006). This success was the result of the combination of a large source of energy supply and improvements in lighting technology. In 1830, a town gas lamp would have generated 130 lumen-hours per kWh; by 1916, the "Welsbach Mantle"

Figure 1

Price of Lighting by Energy Source in the UK, 1700–2019



Source: Fouquet and Pearson (2006); Chitnis et al. (2020).

[3] This can be inferred for instance from the old Neapolitan expression: "Un nobile che vale due candele" (an aristocrat worth two candles), based on the fact that the aristocracy would place candles in front of their balcony seats at San Carlo theater, to signal status and wealth.

gas lamp generated 870 lumen-hours per kWh, roughly six times more light (Nordhaus 1996). Combining the energy efficiency with the gas prices provides an estimate of the price of lighting – the price of gas lighting in 1830 was £2,700 (in 2000 money) for one million lumen-hours (equivalent to leaving-on a 100-watt incandescent bulb for 30 days) and, in 1920, it was £40 (see Figure 1).

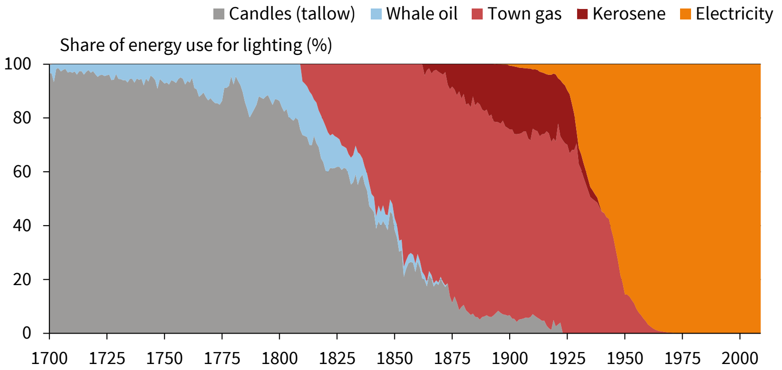
It is worth noting that, because of the relatively large capital investment associated with installing gas pipes in a residential building, gas lighting tended to be used first in affluent and, a few decades later, in middle-class homes. In poorer accommodation, kerosene lamps were used instead. As shown in Figure 1, the price of kerosene lighting was greater than that of gas lighting, implying a substantial variation in the cost and (undoubtedly) consumption of lighting according to income. Roughly eighty years after the introduction of gas lighting, poorer homes were fitted with pipes, as gas companies felt the competitive threat from electric lighting (Fouquet and Pearson 2006).

Electric lighting was initially very expensive compared to the prevailing alternative – in the 1880s, it cost the same as generating light using a candle (see Figure 1). The initial switch constituted an extreme example of the fact that superior characteristics lead some consumers to adopt a technology in spite of a higher price. Large-scale gas lighting, for example in theaters, created heat and depleted oxygen. Simply flicking a switch to turn on the electric lamps made lighting up a room much easier. It also reduced the amount of preparation, maintenance, and cleaning required, as well as the smell of burning tallow candles, animal or vegetable oil, or gas (Fouquet and Pearson 2006). As a result of these considerations, certain customers – especially restaurants, theaters, and wealthy house owners – were therefore willing to pay many times more for the exclusive features of electric lighting (Fouquet 2010). Only later, thanks to significant efficiency improvements and price reductions did electric lighting scale up. By 1960, virtually all lighting in the UK was electric (see Figure 2). Today, with LED lighting, generating 66,000 lumen-hours per kWh, it costs around £1 per million lumen-hours.

The story of transport is similar. New technologies were adopted by the affluent, then by the middle class, and, decades later, by the poor. Before the mid-nineteenth century, land transport was either by foot or, for the affluent and middle classes, horse-drawn stagecoach. Meanwhile, sea travel was dependent on wind power to push sailing ships (Fouquet 2008; Smil 2017). The introduction of the railways on land and steam ships on the sea ensured faster and (generally) more reliable services. The success of these technologies led to the transition to coal as the dominant energy source by the late nineteenth century (see Figure 3).

Figure 2

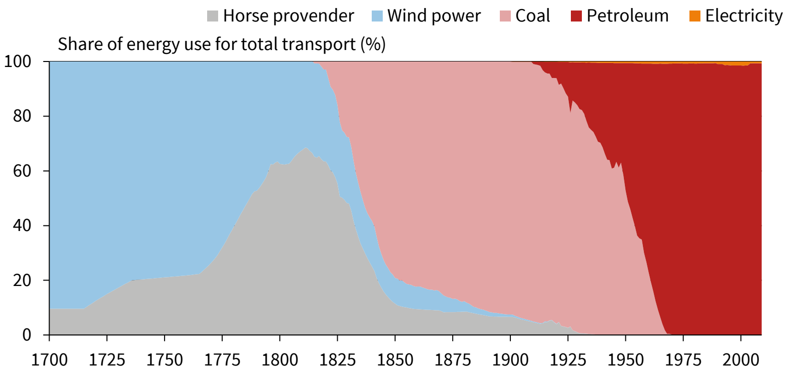
Share of Energy Consumption for Lighting in the UK, 1700–2019



Source: Fouquet and Pearson (2006); BEIS (2020).

Figure 3

Share of Energy Consumption for Land, Sea, and Air Transport in the UK, 1700–2019



Source: Fouquet (2008); Chitnis et al. (2020); Fouquet and O'Garra (2022).

Again, for the first two decades of the twentieth century, the car existed as a niche technology, with the rich willing to pay substantially more for the pleasures of racing and touring (Fouquet 2010). Car prices fell thanks to the famous Ford Model T, setting the scene for more widespread adoption. High population density made the horse, which for hundreds of years had played a crucial role, an inferior transport technology. Improvements in the car's engine made the technology more reliable, and an option for long-distance travel.

We can expect green technologies to follow a similar path. Let us take electric vehicles (EVs) as a transport service example that provides for easy parallels with the car era.[4] In the early stages, EVs entered the market as a more expensive technology, but one that was seen by some early adopters as superior. This created a niche market for early movers (e.g., Tesla). The realization that there were large gains to be made in such markets attracted new producers, which entered into a price competition war. They then strived to further increase the quality of the product offer, with longer range, faster recharging, greater in-vehicle experience, and more. This process drove the quality of EVs up, and their price down. Price par-

[4] Terzi (2023b) traces a similar path ahead for carbon-free aviation.

ity is now expected to be reached within the coming 1–2 years, paving the way for widespread adoption along the S-curve.

ROLE OF CONSUMERS AND GREEN VALUES

Technological progress is often pictured as a way to address societal issues with a minimal toll on people and their habits, particularly vis-à-vis energy sobriety. While this is broadly true, it should be evident from the section above that consumers do play a fundamental role in energy transformations. In particular, the previous section showed how a subset of early-adopting consumers effectively pave the way for wider society. This however requires initially paying a higher price for the new technology. Bill Gates refers to this as the "green premium" (Gates 2021). This extends to governments both in their role as consumers and their willingness to use public funds to incentivize green options, for instance through subsidies for renewable energy sources.

The more willing consumers are to pay for climate stability, the greater the protection will be for the niche market enabling low carbon energy sources and technologies to be developed and refined (Fouquet 2010). Recent academic research has carefully modeled how consumer preferences and technology crucially influence each other (Besley and Persson 2023; Mattauch et al. 2018). Specifically, green technologies are more profitable when the share of the population holding green values is broader, and green values are more attractive when green technologies are (cheaply) available. We would specifically maintain that recurrent extreme weather events associated with climate change already baked into the atmosphere will only accelerate this process of green value shifting, leading the green option to be seen as superior (Terzi 2020) along the lines of what happened in the aftermath of the Great Smog of London.

More broadly, from a historical perspective, the superior characteristics offered by a new technology can vary substantially: "the steam engine offered a more reliable source of power (compared with water); the car allowed personal control; electric lighting provided exclusivity. For these superior attributes, certain customers were willing to pay more" (Fouquet 2008, 369). For example, in 1900, above what they had to pay for these services (i.e., the price) and the value of the incumbent energy technology and source, consumers were willing to pay roughly 6 percent of GDP for gas lighting and 15 percent of GDP for railway travel, and in 1950, around 5 percent of GDP for electric lighting and 10 percent of GDP for car use (Fouquet 2018). In other words, these new energy technologies and sources dramatically improved consumers' lives and people were willing to pay significant proportions of their income for these superior characteristics.

Likewise, some consumers in our era will be willing to pay more for green products because they offer some superior characteristics, such as less noise pollution or zero emissions at the point of use. The fact that they are expensive and associated with modernity also primes them for being status-signaling devices among the elite. A warm-glow effect of helping fight climate change can also not be excluded (Taufik et al. 2016). From there, emulation of the consumption patterns of richer cohorts can also be expected along the lines of well-documented human psychological emulation behaviors (Henrich 2016).

ROLE OF GOVERNMENT

When reflecting on the role of government with regard to the green transition, the standard economics answer is to implement carbon prices aimed at aligning personal and social benefits / costs of greenhouse gasses and therefore energy uses (Stern and Stiglitz 2017). While this consideration continues to hold its wisdom, there are reasons to expect political economy limits to what can credibly be achieved with them (van Reenen 2023) given that taxing carbon (beyond low levels) remains unpopular in several jurisdictions (Blanchard et al. 2023; Tagliapietra 2020).

The other classic role cut out for government when thinking about the green transition is regulation – specifically prohibiting or setting quantitative limits on some polluting production or practices (Blanchard et al. 2023). Once again, a historical perspective suggests a degree of caution in this respect. Specifically, Fouquet (2012) shows in detail how regulation typically arrives at the end of an energy transformation process, rather than serving as a spark. The history of the car is instructive in this respect (Standage 2021). As touched on above, cars were initially adopted by the rich as a form of entertainment or status-signaling device. Eventually, they were considered a more practical alternative to the horse in densely populated cities. This, combined with increased affordability, paved the way for their adoption. Regulation typically arrived only at the end of this process, to eventually ban the coexistence of horse and cars on urban streets at the expense of the former. In other words, regulation served as a final coordination device aimed at laggards, rather than as a mandate for a transportation revolution. To an extent, current bans to cars with internal combustion engines, as adopted in California, the EU, or the UK, follow a similar trend insofar as they are set for 2035, when EVs will already be the cheaper, better, and most widely spread personal transport technology.

In other words, while maintaining an important role, there are reasons to suspect that there are limits to what can be achieved by governments through carbon taxation and regulation. In light of the realization that an effective and credible climate policy will entail unleashing a Green Industrial Revolution, the best course of action to leverage and maximize the impact of government resources is to keep the focus on accelerating the technology transformation process (Aghion et al. 2009). In the words of Fouquet (2008, 366–367): "Market forces will push us on to the next [energy] system, and beyond. The best that governments can seek to achieve is to direct these forces in the long-term interest of the public."

Specifically, in all the 14 energy transitions that took place over the last 1,000 years, possibly with the exception of the switch from the ox to the horse, the method of energy supply needed to be changed. This generally involved new producers, distributors, and retailers – often (and particularly since the Industrial Revolution) requiring major infrastructure investments such as the gas, railway, or electricity networks. Existing energy infrastructure contributes to technological lock-in effects and path dependence, making public investment aimed at their renewal a particularly useful avenue for government intervention. A current example of this is the large-scale effort to expand the electricity grid or install EV charging points.

Likewise, governments can use substantial industrial policy tools to accompany the development and deployment of green technologies (Rodrik 2014), along the lines of measures taken under the US Inflation Reduction Act or the EU's Net-Zero Industrial Act (Terzi 2023a; Terzi et al. 2023).

Finally, it is worth underscoring that all major technological transformations have to some degree shattered previously existing professions, industries, and value systems. Analyzing over 600 years of technology history, covering innovations including the printing press, electricity, farm mechanization, mechanical refrigeration, and more, Juma (2016) shows that when large sections of the population fear that the benefits will be reaped only by a small cohort, they will oppose them. In our context, it implies that governments must earmark a portion of their limited financial resources to accompany the green transformation, helping poorer citizens and cushioning any potential blow to their income and consumption. The alternative would be to face mounting opposition that would impede a rapid rollout of green technologies, and therefore a speedy decarbonization process.

POLICY CONCLUSIONS

The scale of the challenge of abandoning fossil fuels and achieving full climate neutrality by mid-century to avoid a climate catastrophe seems daunting. However, a long-term reading of history reassures us that energy systems are in constant flux. The challenge is therefore to accelerate this economic transformation to align it with political targets set in agreement with climate scientists. Here again, history offers scope for hope. The fastest energy transitions of the past, from horse to railway and from steam to electricity, took place over periods of roughly 30 years, despite requiring an infrastructure to accommodate the new energy source or technology (Fouquet 2010). It has happened in the past and it can happen again.

In this essay, we have considered the three main avenues that governments are considering to fast-track decarbonization, namely energy efficiency, sobriety, and the speedy development and deployment of carbon-free energy sources and services.

Historical experience suggests that voluntary energy reductions (sobriety) and improvements in energy efficiency can surely play an ancillary role and will inevitably buy some time given their short-term effectiveness. This implies that a successful climate policy will essentially have to focus primarily on accelerating technological transformation. In other words, a policy bent on fast-tracking a new Green Industrial Revolution.

To accompany this process, governments can surely implement carbon pricing and environmental regulation, in line with standard policy recommendations. Going beyond that, we highlight an important role for public investment aimed at developing the infrastructure network for a new green economy, contributing to the breaking of technological lock-ins and path dependence. On top of this, industrial policy should also play a role, together with social policies aimed at spreading the benefits of the new green economy and cushioning any potential hit to low-income households' earnings and consumption during the transition process. Failing to do so will lead to social backlash and an inevitable slowdown in the decarbonization process.

REFEENCES

Aghion, P., D. Hemous and R. Veugelers (2009), "No Green Growth without Innovation", *Bruegel Policy Brief*, 1–8.

Besley, T. and T. Persson (2023), "The Political Economics of Green Transitions", *Quarterly Journal of Economics* 138, 1863–1906.

Blanchard, O. J., C. Gollier and J. Tirole (2023), "The Portfolio of Economic Policies Needed to Fight Climate Change", *Annual Review of Economics* 15, 689–722.

Chitnis, M., R. Fouquet and S. Sorrell (2020), "Rebound Effects for Household Energy Services in the UK", *Energy Journal* 41, 31–59.

Crafts, N. (2004), "Steam as a General Purpose Technology: A Growth Accounting Perspective", *Economic Journal* 114, 338–351.

Fouquet, R. (2008), *Heat, Power, and Light: Revolutions in Energy Services*, Edward Elgar Publishing, Cheltenham.

Fouquet, R. (2010), "The Slow Search for Solutions: Lessons from Historical Energy Transitions by Sector and Service", *Energy Policy* 38, 6586–6596.

Fouquet, R. (2012), "The Demand for Environmental Quality in Driving Transitions to Low-Polluting Energy Sources", *Energy Policy* 50, 138–149.

Fouquet, R. (2014), "Long-Run Demand for Energy Services: Income and Price Elasticities over Two Hundred Years", *Review of Environmental Economics and Policy* 8, 186–207.

Fouquet, R. (2016), "Path Dependence in Energy Systems and Economic Development", *Nature Energy* 16098.

Fouquet, R. (2018), "Consumer Surplus from Energy Transitions", *Energy Journal* 39, 167–188.

Fouquet, R. and P. J. G. Pearson (2006), "Seven Centuries of Energy Services: The Price and Use of Light in the United Kingdom (1300–2000)", *Energy Journal* 27, 139–177.

Fouquet, R. and T. O'Garra (2022), "In Pursuit of Progressive and Effective Climate Policies: Comparing an Air Travel Carbon Tax and a Frequent Flyer Levy", *Energy Policy* 171, 113278, https://doi.org/10.1016/j.enpol.2022.113278.

Freeman, C. and F. Louçã (2002), *As Time Goes by: From the Industrial Revolutions to the Information Revolution*, Oxford University Press, Oxford.

Fukushima, N. (2021), "The UK Clean Air Act, Black Smoke, and Infant Mortality", *CAGE Online Working Paper* 587.

Galor, O. (2022), *The Journey of Humanity: The Origins of Wealth and Inequality*, Dutton, Boston.

Gates, B. (2021), *How to Avoid a Climate Disaster: The Solutions We Have and the Breakthroughs We Need*, Random House, New York.

Grübler, A., N. Nakićenović and D.G. Victor (1999), "Dynamics of Energy Technologies and Global Change", *Energy Policy* 27, 247–280.

Hausfather, Z. (2023), "'Greater Than 99 percent Chance' 2023 Will Be Hottest Year on Record", Carbon Brief, 16 October, https://www.carbonbrief.org/analysis-greater-than-99-chance-2023-will-be-hottest-year-on-record/.

Henrich, J. (2016), *The Secret of Our Success: How Culture Is Driving Human Evolution, Domesticating Our Species, and Making Us Smarter*, Princeton University Press, Princeton, NJ.

International Energy Agency (2021), *Net Zero by 2050: A Roadmap for the Global Energy Sector*, Paris.

Juma, C. (2016), *Innovation and Its Enemies: Why People Resist New Technologies*, Oxford University Press, Oxford.

Liu, Z., Z. Deng, S. Davis and P. Ciais (2023), "Monitoring Global Carbon Emissions in 2022", *Nature Reviews Earth & Environment* 4, 205–206.

Mattauch, L., C. Hepburn and N. Stern (2018), "Pigou Pushes Preferences: Decarbonisation and Endogenous Values", *Grantham Research Institute on Climate Change and the Environment Working Paper* 314.

Missemer, A. (2012), "William Stanley Jevons' The Coal Question (1865), beyond the Rebound Effect", *Ecological Economics* 82, 97–103.

Nordhaus, W. D. (1996), "Do Real-Output and Real-Wage Measures Capture Reality? The History of Lighting Suggests Not", in T. F. Bresnahan and R. J. Gordon, eds., *The Economics of New Goods*, Chicago University Press, Chicago, 29–66.

O'Garra, T. and R. Fouquet (2022), "Willingness to Reduce Travel Consumption to Support a Low-Carbon Transition beyond COVID-19", *Ecological Economics* 193, 107297.

Perez, C. (2009), "Technological Revolutions and Techno-Economic Paradigms", *Cambridge Journal of Economics* 34, 185–202.

Pisani-Ferry, J. and S. Mahfouz (2023), "*Les incidences économiques de l'action pour le climat*", https://www.strategie.gouv.fr/publications/incidences-economiques-de-laction-climat.

Rodrik, D. (2014), "Green Industrial Policy", *Oxford Review of Economic Policy* 30, 469–491.

Smil, V. (2017), *Energy and Civilization: A History*, MIT Press, Cambridge, MA.

Standage, T. (2021), *A Brief History of Motion: From the Wheel, to the Car, to What Comes Next*, Bloomsbury Publishing, London.

Stern, N. and J. E. Stiglitz (2017), *Report of the High-Level Commission on Carbon Prices*, Washington DC.

Tagliapietra, S. (2020), *Global Energy Fundamentals: Economics, Politics, and Technology*, Cambridge University Press, Cambridge.

Taufik, D., J. W. Bolderdijk and L. Steg (2016), "Going Green? The Relative Importance of Feelings over Calculation in Driving Environmental Intent in the Netherlands and the United States", *Energy Research & Social Science* 22, 52–62.

Terzi, A. (2020), "Crafting an Effective Narrative on the Green Transition", *Energy Policy* 147, 111883.

Terzi, A. (2022a), *Growth for Good: Reshaping Capitalism to Save Humanity from Climate Catastrophe*, Harvard University Press, Cambridge, MA.

Terzi, A. (2022b), "A Green Industrial Revolution Is Coming", *VoxEU*, 28 June, https://cepr.org/voxeu/columns/green-industrial-revolution-coming-0.

Terzi, A. (2023a), "Green Industrial Policy: The Necessary Evil to Avoid a Climate Catastrophe", in S. Tagliapietra and R. Veugelers, eds., *Sparking Europe's New Industrial Revolution: A Policy for Net Zero, Growth and Resilience*, Bruegel Blueprint, Brussels, 106–121.

Terzi, A. (2023b), "Enrolling Capitalism in the Fight Against Climate Change", ProMarket, https://www.promarket.org/2023/03/03/enrolling-capitalism-in-the-fight-against-climate-change/.

Terzi, A., M. Sherwood and A. Singh (2023), "European Industrial Policy for the Green and Digital Revolution", *Science and Public Policy* 50, 842–857.

Thorsheim, P. (2018), *Inventing Pollution: Coal, Smoke, and Culture in Britain since 1800*, Ohio University Press, Athens, OH.

Van Reenen, J. (2023), "The Case for Green Industrial Policy", ProMarket, https://www.promarket.org/2023/02/14/the-case-for-green-industrial-policy/.

Vogel, J. and J. Hickel (2023), "Is Green Growth Happening? An Empirical Analysis of Achieved versus Paris-Compliant CO_2–GDP Decoupling in High-Income Countries", *Lancet Planetary Health* 7, e759–e769.

Wrigley, E. A. (1988), *Continuity, Chance, and Change: The Character of the Industrial Revolution in England*, Cambridge University Press, Cambridge.