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Why combating climate change is so challenging

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Climate change is perhaps the most pressing challenge faced by humanity. It causes not only environmental degradation but also impacts whole ecosystems, societies, and global political stability. This paper explores the obstacles to implementing climate-change policies, emphasizing the complex interplay of economic, social, and political factors. It highlights the need to integrate economic, environmental, social, and political dimensions. It stresses that policies must be socially equitable, as demonstrated by the "Gilet Jaune" protests in France. Effective climate action requires balancing financial and non-financial factors and addressing unintended consequences such as job losses, regional economic disparities, and potential social unrest. Ultimately, a multifaceted, interdisciplinary, and inclusive approach is vital for achieving sustainable and socially responsible solutions to combat climate change.

Key words: climate change, green energy, inaction, sustainability, political economy, acceptability

JEL: D62, H, Q42, Q54, Q56

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1 INTRODUCTION[6]

Climate change is perhaps the most urgent and polarizing policy issue facing the world today. Most scientists agree that climate change is mainly due to human activity[7] and having observable effects that are likely to grow in the future. Heat waves, droughts, extreme rainfalls, floods, and severe storms are increasingly being attributed to a changing climate (Kalmus 2017). Climate change has especially severe consequences in densely urbanized areas due to the concentration of human activities and vulnerable infrastructure. Rapid urbanization, particularly in large cities across Asia and Africa, will exacerbate the impact of extreme weather events. Furthermore, the growing strain on roads, buildings, energy networks and other infrastructure increases maintenance and adaptation costs. In this context, the combined effects of demographic[8] and economic growth, along with urban sprawl, amplify environmental risks (United Nations Human Settlements Programme 2020).

Climate change is largely due to emissions of Greenhouse Gases (GHGs) including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). While Europe and the USA have reduced their emissions, global emissions continue to rise, driven primarily by demographic and economic growth in emerging and developing countries. At the same time, the capacity of natural sinks such as forests to absorb CO_2 is decreasing due to clearcutting of land, droughts, and fires.

Action against climate change relies on the quality of scientific research, the effectiveness of large-scale applications of scientific findings, the availability of reliable information, the robustness of institutions, and public acceptability of policies. These dimensions are inherently imperfect for distinct reasons and uncertainty prevails as a result. Additionally, fostering a culture of sobriety—encouraging more sustainable consumption and production patterns—plays a crucial role in reducing environmental impact and ensuring long-term resilience. Despite numerous proposed policies, humanity remains undecided about the best course of action in the face of this uncertainty. Stern (2007) argues for immediate action to mitigate the impacts of climate change. Others resist on various grounds. Some deny or minimize the scientific evidence (Rich 2019). For decades, others have called for more scientific evidence before committing to decisive action. Still others argue for a "wait and see" approach, hoping for future technologies like carbon capture or fusion energy to offer solutions. Overall, inaction remains widespread.

Optimists have pointed to the success of environmental policies such as the 1970 US Clean Air Act that led to a drastic reduction in automobile emissions, or the 1987 Montreal Protocol which

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[6] This paper originates from a three-day symposium in Munster, France (June 12-15, 2024) organized by the *Action versus Inaction facing Climate Change* (AICC) association. Symposium participants included business representatives and scholars from economics (public, welfare, industrial organization, political economy), law, philosophy, and physics. The main findings from three parallel sessions were presented at the second AICC conference at the European Parliament on June 17, 2024 (https://aicc2.sciencesconf.org/).

[7] Lynas *et al*. (2021) analyzed 88,125 climate-related studies and found that over 99.9% of peer-reviewed scientific papers agree that human activity is the primary driver of climate change.

[8] According to United Nations projections, the global population is expected to peak at approximately 10.3 billion toward the end of this century (https://ourworldindata.org/un-population-2024-revision).

addressed CFCs (chlorofluorocarbons). However, combating climate change has proven far more complex, largely because of its global scope and long time horizon.[9]

Large strides have been made in expanding the supply of green energy and reducing its costs. However, capital investments in green energy such as electric vehicle batteries require large quantities of rare earth elements and critical metals. Extraction of these resources is energy-intensive, often exacerbating the very problems green technologies aim to solve. Extraction and processing often contribute to land artificialization, further exacerbating environmental degradation. The Draghi report (2024) highlights how developed nations (and especially Europe) have outsourced the environmental and human costs of this green transition to developing countries. The shift makes the transition appear cheaper to wealthier countries while imposing external costs on developing countries which also disproportionately bear the brunt of climate change. The net effect is to exacerbate inequalities both between and within regions. The shift also increases reliance on countries like China, which controls much of the world's supply of rare earth elements.

Natural resource constraints thus exist, but concerns have shifted from running out of fossil fuels.[10] Indeed, many scholars and other observers now view over-exploitation of carbon-based fuels as a greater threat than inability to extract enough of them. The transition to green energy also poses risks of lost jobs and stranded assets in fossil-fuel sectors, complicating policy acceptance due to concerns about economic inequality and fairness. Moreover, electrification of industry, transportation, and other sectors materially reduces GHG emissions only if the electricity is generated by green energy. Yet, in some countries, the mix of primary energy is such that driving an electric car produces more CO_2 than a conventional vehicle.[11] Although the relative share of fossil fuels in the energy mix has declined slightly due to the expansion of renewable energy, absolute fossil-fuel consumption has continued to grow, driven by rising global energy demand.[12]

An overriding question is whether climate change can be tackled at reasonable cost with a growing population and without significantly impairing economic growth. The acceptability of climate policies, which is crucial, hinges on comprehensive analysis and stakeholder engagement. The 2018 "Gilet Jaune" (yellow vest) movement in France demonstrates the resistance that can arise when policies are perceived as unfairly burdening certain groups, particularly lower-income individuals. Similarly, in 2024, German farmers protested against cuts to tax breaks on diesel fuel, arguing that the policy disproportionately burdened the agricultural sector which relies on diesel-powered machinery.[13] The protests again underscored the challenges of implementing equitable climate policies. Some governments have put in place substantial climate policies, but many others have done relatively little. In one respect this is

[9] Rich (2019) deftly explains the relationship between the battles in the USA against ozone and climate change during the 1980s.

[10] Notably in *The Limits to Growth* (Meadows *et al*. 1972).

[11] See de Palma *et al*. (2023).

[12] https://www.energyinst.org/statistical-review

[13] https://www.cleanenergywire.org/news/german-farmers-kick-protest-week-against-diesel-subsidy-cuts-amid-worries-far-right-hijacking-cause

surprising since governments have sometimes been strongly averse to novel risks (e.g., genetically modified foods) and imposed strict regulations to avoid them as per the Precautionary Principle. Yet, in the case of climate change, which embodies many poorly understood and even existential risks, governments have been prone to under regulation.

In summary, while green technologies and policies hold much promise, a realistic approach must acknowledge the physical limits of natural resources, the significant costs of transition, and the need to ensure equitable outcomes. Moreover, the timeframes required to implement technological and regulatory solutions are sometimes long, or even very long. For example, consider the lengthy processes involved in the development of fusion energy, the implementation of fast breeder reactors, the regulation of double-hull designs for ships, and the prohibition of single-use plastics. In the context of climate change, these examples highlight how technological advancements and regulatory measures often require significant time to design, approve, and implement effectively. The road ahead will be difficult, requiring global cooperation and difficult trade-offs. Yet, the alternative—inaction or poorly planned policies—will likely lead to worse outcomes for humanity and the planet.

In this article we address the complexities of combating climate change, emphasizing that while many policies exist, their effectiveness and acceptability remain uncertain. We identify physical, public acceptability, governmental, and other institutional barriers as central to explaining why seemingly desirable actions have not been taken. As explained in Section 2, combating climate change can be seen as a super-wicked problem. To succeed, it is necessary to draw on interdisciplinary knowledge and address the physical, economic, environmental, social, and political aspects of climate change as well as its temporal, spatial, and equity aspects.

Section 2 offers a systems view of the interdependent physical, environmental, economic, and demographic dimensions of climate change. Section 3 reviews international and national policy making on climate change with a focus on explaining difficulties in reaching international climate agreements. Section 4 critically examines some leading climate policies such as carbon taxes and assesses their efficacy and social acceptability. Section 5 uses the automobile sector in the European Union to illustrate some of the difficulties in combating climate change identified in previous sections. Section 6 concludes.

Although relatively broad in scope, the article excludes or mentions only in passing a number of topics directly or indirectly related to climate change. These include agriculture, biodiversity, recycling, energy conservation, differences between developed and developing countries, and the role of climate change in exacerbating conflicts and wars. The article also does not make policy recommendations.

2 A SYSTEMS OVERVIEW OF CLIMATE CHANGE

A comprehensive approach that considers all stakeholders is essential for gaining public acceptance of climate-change policies and ensuring democratic support. This section pursues such an approach by providing a systems overview, depicted in Figure 1, of the forces governing climate change.[14] Climate change is largely a consequence of anthropogenic greenhouse gas (GHG) emissions, mainly due to combustion of fossil fuels for energy. Hence, we begin by

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[14] Elements (1)-(12) in the figure are reviewed now, elements (13)-(22) later in the section.

reviewing the central role of fossil fuels and the difficulties of transitioning to alternative energy sources.

Fossil fuels

Fossil energy (1) is positioned at the center of Figure 1. It is an input to production (2) along with capital (3), non-energy resources (4), land (5), and labor (6). According to the World Energy Outlook (2023), the global energy mix is composed of 31% oil, 27% coal, 23% natural gas, 6% hydropower, 4% nuclear, and 9% renewable energy (including solar, wind, geothermal, and bioenergy). Fossil fuels thus comprise 81% of total energy. Green energy (1a), considered below, accounts for the rest.[15] The cost of extracting fossil energy depends on reserves (7). Costs rise as reserves are depleted, and fall when exploration uncovers new deposits or R&D (8) improves the technology for extraction and processing. Similarly, the cost of extracting non-energy resources depends on non-energy reserves (9) which are depleted by extraction, renewed by exploration, and enhanced by R&D.

Fossil fuels have long dominated energy use due to their advantages: high energy density, ease of storage and transportation, relative safety, reliable supply, and affordability. But fossil fuels have several disadvantages. Combustion of fossil fuels is responsible for about two thirds of global anthropogenic GHG emissions, with CO_2 the main contributor. GHG emissions drive climate change (10) which includes changes in temperature, precipitation, sea levels, frequency and severity of storms, and so on. Despite efforts to curtail carbon emissions, emissions have risen since the COVID-19 pandemic and in 2023 reached a record high of 37.4 gigatons.

In addition to GHG emissions, fossil energy creates local pollution (11) and landscape scarring. Fuel prices are also volatile, which complicates production and energy usage decisions and contributes to macroeconomic fluctuations.

Fossil-fuel consumption can be reduced in several ways: by improving the energy efficiency of fossil-fuel engines, heating and cooling systems, industrial processes, and other uses; reducing leakage and other inefficiencies throughout the supply chain from resource extraction to final consumption; curtailing energy-intensive activities; switching to green energy sources; and preventing GHGs from entering the atmosphere through carbon capture and storage (CCS) (12).

Some natural CCS methods such as reforestation and soil sequestration provide co-benefits such as enhanced biodiversity and employment. By extending the lifetime of carbon resources, CCS can also prolong employment in fossil-fuel industries and reduce financial losses due to stranded assets. But CCS has several limitations and drawbacks. Constructing CCS units for power plants is costly, and the process of carbon removal and storage consumes an appreciable fraction of the energy produced by the plants. CCS does not remove particulate matter and other toxic gasses from the flue gas. The potential to use CO_2 to make products is small compared to the total volume of CO_2 emitted, and the products are likely to cost more than with other methods. Direct air capture is costly and has yet to be demonstrated at scale.

[15] Energy consumption is split among industry (36%), transport (29%), buildings (30%), and other sectors (5%) such as agriculture and non-energy uses like feedstocks in petrochemicals.

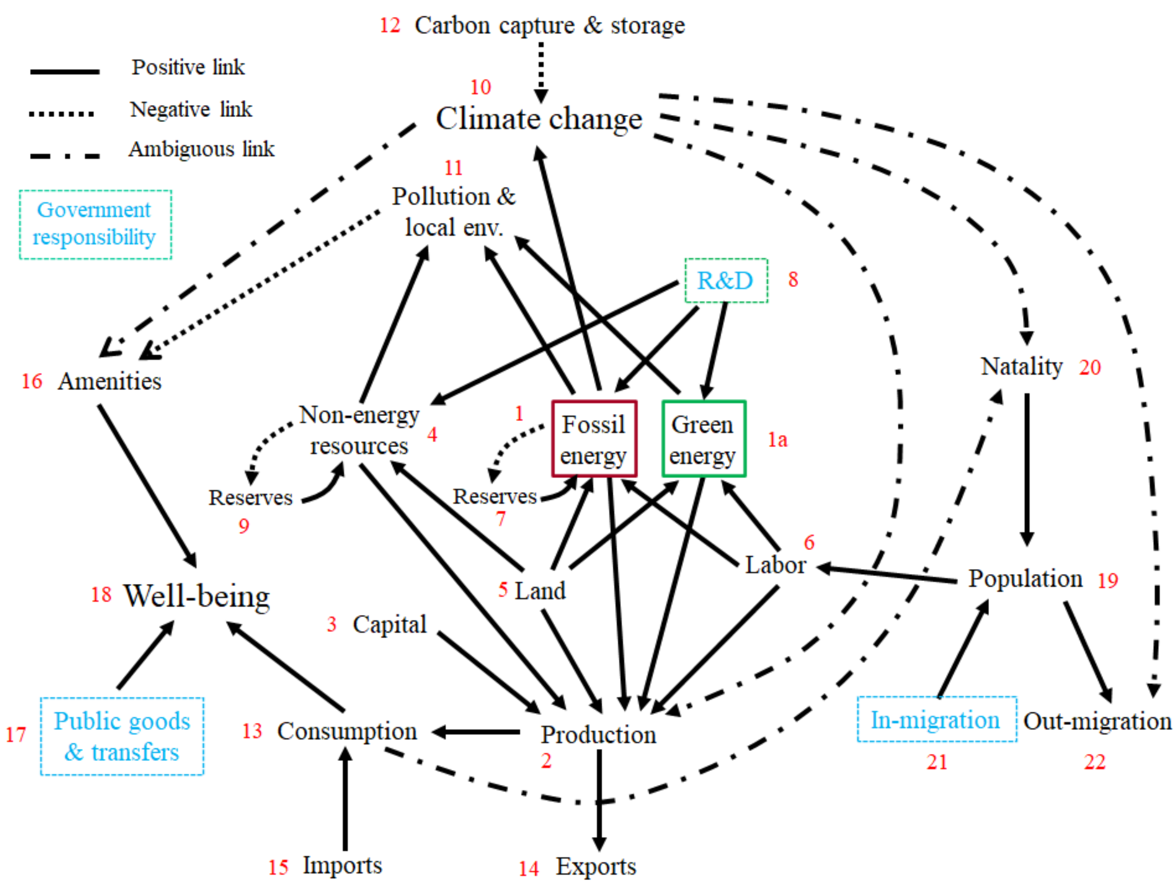

FIGURE 1: Overview of the climate change process

Green energy

Green energy sources (1a) are a linchpin for combating climate change. They come in various forms and vintage. Conventional sources include hydro, geothermal, and nuclear. Largely prospective renewable sources include ocean technologies (tidal, wave, and thermal) and hydrogen. Solar and wind power have been progressing rapidly, and in some countries now account for a substantial fraction of total installed electricity generating capacity. Their costs have fallen rapidly in recent years. According to IPCC (2022a), from 2010 to 2019, unit costs declined by 85% for solar energy, 55% for wind energy, and 85% for lithium-ion batteries. Thanks to learning curves, costs have fallen by about 20% with every doubling of global cumulative capacity, and in many cases are now lower than the cheapest fossil fuels. Yet, despite substantial advances, renewable energy sources are an imperfect substitute for fossil fuels. All have limitations and drawbacks as the (partial) list below indicates.

Availability: Hydro, geothermal, offshore wind, and tidal power are both physically possible and economically viable only at a limited number of locations.

Resource requirements: Batteries and some other renewable energy sources require materials such as lithium and cobalt that are found in only a few countries. Biomass and hydrogen energy are energy-intensive to produce. Power from solar panels and windmills needs to be connected to the electricity grid, often over long distances. A distribution network is also needed to make hydrogen viable as a fuel for transportation. A fraction of the energy in the primary energy source is lost at each stage of production (i.e., extraction, conversion, transportation, storage, and electricity generation) before it reaches the final consumer.

Land use: Solar panels and windmills occupy space that sometimes could be used for agriculture or other purposes. They may contribute to habitat destruction, and when decommissioned may require costly reclamation. As discussed in Section 4, similar to oil and gas extraction, wind energy projects may also invoke local opposition.

Environmental effects: Windmills create noise, kill birds, and are sometimes considered visually intrusive. Biomass energy can generate local urban air pollution. Nuclear power plants create hazardous waste that needs very-long-term storage.

Intermittency and interruptions: Solar power is available only when the sun is shining, and wind power only when the wind is blowing at sufficient speed. Solar and wind energy can be stored in several ways (e.g., pumped storage and batteries) but storage capacity is costly and requires energy that itself may emit CO_2. Renewable energy sources are also susceptible to prolonged disruptions. For example, in 2022 nuclear reactors in France were shut down for planned maintenance as well as emergency maintenance to address safety problems. Hydropower was also reduced following periods of intense heat and droughts, and droughts are causing increasingly frequent power outages around the world.[16] Ironically, climate change is spurring a shift to climate-friendly sources of energy that are more vulnerable to climate change than fossil-fuel energy.

Physical damage: Solar panels are vulnerable to damage (e.g., from hail). Catastrophic events can also happen such as nuclear reactor failures (e.g., Fukushima in 2011) and dam failures.

A final point is that green energy may not displace fossil-fuel energy, but rather supplement it.[17] Less-polluting fossil fuels such as natural gas may also be used as transitional measures. Acemoglu *et al*. (2023) warn against using such fuels this way because it reduces motivation to invest in green energy.

Electricity

Electricity is currently generated by a mix of fossil fuels and green energy. The composition of sources and CO_2 emissions vary widely by country and often by region within a country. The composition does not convey accurately either the marginal resource and environmental costs of electricity generation or the consumer price that reflects full social marginal costs. One reason is that sources such as nuclear and hydro operate continuously to supply base load. Other sources such as natural gas are deployed to meet peak demands. Intermittent sources such as solar and wind are harnessed when available. The incremental cost of electricity depends on which source is on the margin to supply additional demand, and the sources vary in their emissions intensity. This complicates determination of the appropriate prices to charge consumers.

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[16] https://www.nytimes.com/2024/12/30/world/americas/ecuador-hydropower-drought.html

[17] As the Economist (2024a) remarks, "The history of energy shows that new technologies do not sweep old ones away. They tend to be additions, not replacements, and often provide new ways of using old fuels...." Fressoz (2025) analyzes this in a forthcoming book.

A further complication is that some electricity grids are interconnected across regions and countries. In Europe, nuclear dominates in France, hydro in Norway, solar in Spain, and wind in Denmark. Electricity consumed in one country may be generated in another. Connecting the diverse sources has the advantage of smoothing total grid capacity over time and reducing the need for storage and reserve capacity. Nevertheless, as the share of renewables grows, electricity imports and exports, prices, and emissions are likely to become more variable.

Electricity demand is forecast to increase in coming decades due to progressive electrification of transportation, heating & cooling, and industry, and rapid growth in artificial intelligence. This has raised concerns about the stability of electricity networks and whether capacity will be adequate in the long run.

Renewable energy for transportation

Transportation is responsible for a large share of total GHG emissions. Emissions are caused not only by vehicle movements, but also manufacturing vehicles and construction of roads and other transportation infrastructure. Transportation is considered the most challenging economic sector to decarbonize. The potential is good for urban public transportation since buses, trains, and trams run on fixed routes and can be powered directly from the electricity grid without using batteries. Moving heavy freight over long distances is more problematic. Four technologies are under consideration for heavy goods road vehicles: alternative liquid fuels (methane, ammonia, synthetic diesel), battery electric trucks, hydrogen fuel-cell electric trucks, and electric-road systems. All have drawbacks such as added weight, safety, and high infrastructure costs. For aviation, energy sources under consideration include biofuels, synthetic fuels, hydrogen fuel cells, and battery or hybrid-electric aircraft. Enabling long-range flights is a major challenge. For maritime shipping, candidates are low-emission hydrogen, ammonia, biofuels, and other synthetic fuels. All the alternatives face hurdles to adoption at scale. According to IPCC (2022a), the overall transportation sector is unlikely to achieve net-zero CO_2 emissions even by 2100.

Other climate-system dependencies

Figure 1 depicts some other elements of the overall picture.[18] Production (2) is allocated to consumption (13) and exports (14). Consumption is supplemented by imports (15). Trade is a means of adaptation to changing agricultural productivity. It also provides countries with insurance against major crop failures and other disasters. Climate change (10) affects production. As indicated by the dash-dot curve, the effect can be positive or negative although negative effects tend to dominate. Climate change and pollution (11) affect natural amenities (16) such as forests, bodies of water, wildlife, and biodiversity. Together, consumption (13), amenities (16), and public goods & transfers (17) determine well-being (18).

Labor supply (6) is provided by population (19) which is increased by natality (i.e., birth rate minus death rate) (20). Natality depends on consumption[19] (13) and climate change[20] (10).

[18] To avoid clutter, Figure 1 omits some elements such as agriculture, and causal dependencies such as labor input to produce capital. Government is depicted as responsible for public goods & transfers and in-migration, and a supporter of R&D. It also taxes, subsidizes, and regulates other linkages displayed in the figure.

[19] Research has focused on the dependence of natality on income rather than consumption. However, if trade is in balance, and ignoring savings and investment, the two are equivalent. Birth rates tend to

Population is increased by in-migration (21) and reduced by out-migration (22). Migration is another major form of adaptation by allowing people living in areas severely affected by climate change to move to other, generally more productive locations. Migration tends to boost global output, but also increases energy use and GHG emissions. The combined linkages can result in positive or negative feedback loops.

Tackling climate change

Figure 1 reveals many elements that affect climate change, encompassing multiple interdependent physical, technological, socioeconomic, and governmental forces. Climate change has been depicted as a "wicked" problem as it was originally formulated by Rittel and Webber (1973). Lazarus (2009) and Levin *et al*. (2012) go further and call it "super wicked". Sources differ in the list of characteristics they consider as defining wicked and super wicked problems. In terms of combating climate change as a policy problem, the important generic features include the following:

1. The problem is unique.
2. There are many contributing factors, interdependencies, uncertainties, and stakeholders that make it very difficult to formulate the problem, let alone take action.
3. Many possible regulations and policies can be deployed. The best choice is path dependent because it is contingent on what steps have already been taken.
4. Policies are one-shot in the sense that learning by trial and error is costly, and perhaps impossible.
5. There is no quick test of whether policies are successful.
6. There is no well-defined time at which the problem can be considered solved.

Climate change has additional specific features:

7. Delay is costly: damage due to climate change accumulates, and the more time that elapses the worse the problem gets and the harder it becomes to deal with it.
8. The current generation that is seeking to address climate change is simultaneously contributing to it. The current generation also has less to lose than future generations. Worse, individuals and institutions have a tendency to discount heavily the near future; especially if the consequences of inaction are uncertain.
9. Action is required by all entities (i.e., states, firms, individuals) and in all economic sectors. There is no central authority such as a world government to organize and oversee what action is taken.

decline with income and are very low in some developed countries such as South Korea, Japan, and Italy. Death rates also decline with income, but not enough to offset declining birth rates.

[20] Natality depends mainly on temperature, and is highest in temperate climates (Cruz and Rossi-Hansberg 2024).

10. Countries differ greatly in how much they stand to lose from climate change as well as in the costs they will incur in combating it.
11. Most solutions are lengthy and costly to implement. Regardless of how they are designed, they are bound to create losers as well as winners.

We now elaborate on some of these points and make a few additional observations.

First, GHGs emitted at one location quickly disperse around the planet so that the effects are experienced everywhere. Emissions are thus an instance of the Tragedy of the Commons. Individual agents incur a negligible cost when they release emissions into the atmosphere as an open access resource, yet the aggregate costs they impose can be significant. Second, damages accumulate gradually. To many people, combating climate change is not as urgent as either immediate personal concerns such as health care, employment, inflation, and their overall standard of living, or other worries such as loss of biodiversity, war, and societal disruptions caused by technological advancements like artificial intelligence. As discussed in the next section, politicians with limited terms of office also lack sufficient motivation to take a long-term view. Third, damages vary significantly from one country to another, but also within the same country, depending on factors such as coastal or inland areas, flood-prone zones, or rural versus urban settings. Climate models indicate that a 1°C average global warming results in a 2.2°C increase near the North Pole, but only a 0.5°C increase in some southern regions (Rohde and Hausfather 2020). Cold regions such as Alaska, Northern Canada, and Siberia could stand to gain from a warmer climate (Cruz and Rossi-Hansberg 2024) and may resist efforts to prevent it.

Fourth, many aspects of climate change are uncertain including the rate of change in global mean temperature, changes in local climate, the frequency of extreme events, the pace of mitigation and adaptation, and even the accuracy of historical temperature measurements. While better knowledge and improved data are accumulating, significant uncertainties persist, complicating efforts to predict and address climate impacts effectively. The rate of sea level rise at a given location has a wide confidence interval. Local changes to extreme water levels are even more uncertain because of sensitivity to potential changes in the track of storms. Other effects such as changes in rainfall and frequency of storms can be uncertain even in sign. Feedback effects in climate can be positive or negative. The potential for tipping points adds further complexity (Lenton *et al*. 2008), leading to deep uncertainty in which both the probabilities and the scope of potential outcomes, as well as what is possible, are unknown (Haas *et al*. 2023).

The costs of climate change are also highly uncertain. There is uncertainty about its economic effects and about how successful adaptation will be in limiting damages. At the high end, Bilal and Känzig (2024) estimate that even a modest 1°C increase in average global temperature for one year reduces world real GDP per capita with a peak reduction of 12% after about 6 years.[21] Cruz and Rossi-Hansberg (2024) emphasize how estimates are sensitive to assumptions such as the ease of national and international migration, and adaptation of economic activities. They illustrate the extent of uncertainty about welfare losses for the RCP8.5 high-emissions scenario.[22]

[21] The 90% confidence interval on the peak reduction is approximately 4-20%. The reduction persists for more than 10 years.

[22] One of the IPCC's Representative Concentration Pathways in which global warming raises the global mean temperature about 4.3°C by 2100.

As they write (p. 925), “the 95% confidence interval includes catastrophic welfare losses of as much as 20% by 2200 but also no losses ....”.

In summary, combating climate change faces various physical, engineering, informational, and behavioral barriers. Economies are still largely based on fossil fuels which have several substantial advantages. Capturing greenhouse gases before they are released is costly, and methods to remove them from the atmosphere are in their infancy. Green energy sources are advancing, but have limitations in terms of availability, resource requirements, intermittency, and so on. Major uncertainties exist about the rate of climate change and its economic costs. The effects vary widely across the globe, ranging from severe losses to net benefits. Mitigation incentives are weakened by the global nature and slow dynamics of climate change.

Governments clearly have an essential role to play in addressing climate change: national governments in making commitments such as the 1995 Kyoto Protocol and 2016 Paris agreement, regional governments in enabling connections to electricity grids and resolving competing demands of fossil-fuel and green energy suppliers, and local governments in overcoming opposition to green energy projects and facilitating adaptation. Differences between and within countries in government (e.g., democratic vs. autocratic, left vs. right) and consequences of climate change complicate coordination. Moreover, governments at all levels face obstacles and have weaknesses. They have multiple responsibilities and limited budgets to fulfill them. They have to choose between competing priorities such as providing traditional public services, protecting local environments, and even allocating funds between mitigation and adaptation. They may lack sufficient information to make good decisions dependably. And politicians often adopt short time horizons, are risk averse, and susceptible to lobbying and catering to vested interests. Section 3 examines some of these considerations with a focus on decision-making at the national and international government level and how environmental laws can be passed and protected against efforts to undo them.

3 POLITICAL ECONOMY CONSIDERATIONS

Because climate change is a global phenomenon, upper-level governments have a natural role to play in addressing it. This section analyses international and national policy making. It discusses the difficulty of reaching international climate agreements and the translation of international commitments to domestic policies. The focus is on mitigation rather than adaptation which is subject to different political mechanisms. Adaptation is much more a local issue as its effects are generally limited geographically. Reducing emissions has local side effects (e.g., limiting local air pollution) but has mostly global effects on climate.

Decisions on mitigation can best be understood in a two-tier framework. The first tier involves commitments at the international level, and the second tier calls for the implementation of the commitments at the national level. As international agreements are not enforceable, the commitments are expected to be self-enforcing and this causes insufficient efforts. Barrett (1994) illustrates this result using an example featuring ten identical countries. In the self-enforcing equilibrium, four countries sign a self-enforcing agreement and increase their individual abatement effort above the noncooperative equilibrium level. However, the remaining six countries eschew the agreement and reduce their efforts in a partially offsetting way. Relative to the fully cooperative outcome that balances aggregate costs and benefits, total abatement effort increases by only 6.2% and total benefit by only 11.5%.[23]

In practice, commitments or pledges are often larger than can be expected from a self-enforcing agreement. There are several complementary explanations for this. Using an experimental game, Barrett and Dannenberg (2016) analyze a pledge-and-review process similar to the one used for the 2016 Paris Climate Agreement. They show how this process leads to higher targets and efforts than could be expected from a non-cooperative Prisoner's Dilemma viewpoint. In practice, much naming and shaming by green lobby groups occurs before and after the Conferences of the Parties (COP).[24] Without these strong green actions focused on the international negotiation scene, smaller mitigation commitments would likely be made.

Battaglini and Harstad (2020) develop explicitly the two-tier government approach to climate policy. In their two-period model, politicians negotiate international agreements in the presence of re-election concerns and leave the ultimate decision on compliance to politicians who want to win the next elections. In the first period, an international agreement is negotiated by the incumbent political party which may be "green" or "brown". In the second period, an election is held. Voters may also be "green" or "brown". Depending on the outcome of the vote, the elected party decides whether or not to comply with the treaty. The party negotiating the agreement anticipates that if it wins the next election, it will have to comply if the vote is green, and not comply if the vote is brown. In equilibrium, the green party designs an international agreement that can be enforced if it is re-elected. Similarly, the brown party negotiates an international agreement that allows it to escape enforcement if it is re-elected.

Crucial to the results is the rent (i.e., psychic benefit) of staying in office after the elections. The larger this rent, the more parties try to differentiate themselves for the voters by complying when the election chooses a green party and by not complying when the election chooses a brown party. As both the depth of the agreement and the sanction determine the voting outcome, this can lead to strong agreements (both parties comply), weak agreements (only the green party complies), ineffective agreements (nobody complies) and even overambitious agreements. The possibility of multiple outcomes is more likely in a democratic regime where the rent from holding office is high and parties are polarized. The model is consistent with the fact that in countries such as the USA and Australia, green policies are contentious. This contrasts with cases in which there is a broad consensus among voters, and political parties compete on competence.[25]

Commitment to green policies can be influenced by investment in green technologies. Examples include the Inflation Reduction Act (IRA) in the USA and subsidies for electric vehicles in China. Battaglini and Harstad (2020) study this using a variant of their two-period model. In the first period, an incumbent government can invest in technology that reduces the cost of complying with an agreement in the second period. The green party invests more than the brown

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[23] Finus and McGinty (2019) show that with non-identical countries cooperation can be either stronger or weaker.

[24] https://unfccc.int/process/bodies/supreme-bodies/conference-of-the-parties-cop

[25] Green policies are controversial even in Norway; see Farstad and Aasen (2023) for an analysis of the 2021 election.

party, but the green party does not necessarily reduce the cost to zero because then it can no longer differentiate itself from the brown party.

At the international negotiation level, pledges to support the environment often lack a detailed cost-benefit assessment. Indeed, most negotiating parties do not know what it will cost to reach a goal such as net zero emissions by 2050. When costs and benefits are uncertain, long-term promises are easy. In contrast, at the second-tier country level, implementation of a pledge requires concrete actions and policies. Costs of implementation are less obscure, and groups that will be required to take action and bear the costs will be identified; the Gilet Jaune movement in France is a familiar example (Yildiz 2024). At this stage, politicians are prone to postponing difficult decisions. Besides climate commitment, examples where decisions are postponed include delaying the retirement age, privatization of a public service, and macro-economic stabilization by curbing government spending. Alesina and Drazen (1991) show how bargaining between different population groups over the sharing of the costs of macroeconomic stabilization leads to costly delays. It is a war of attrition: the costs of delaying the reform increase over time. Different groups have to share the cost of the reform, and they all prefer a design of the reform that is less costly for them. Stabilization policy decisions will only be taken when the costs of waiting to agree become too high for one group, which gives in and accepts a design that is unfavorable to it. The model fits the case of climate agreements if the costs of delayed action are much stronger for one group than others. If they are not, repeated postponement may be the expected outcome.

Besides economic models, insights into the potential for active climate policy can be gleaned from public opinion surveys. One notable example is a large-scale survey, administered to 40,000 individuals from 20 high and middle-income countries, of a Global Climate Scheme (Fabre *et al.* 2024). The GCS scheme consists of an international equal-per-capita allocation of tradable GHG emission rights, complemented by an annual tax on the richest 1 to 5% in high and middle-income countries. In contrast to the predictions of standard economic models featuring self-regarding agents, the survey respondents expressed widespread support for the GCS. To provide a better guarantee of effectiveness and fairness, they considered it best to implement it at the global (international), rather than local, level.

The associated international transfers of the GCS might seem fairly modest. However, they dwarf the largest benevolent international transfer in economic history. This was the Marshall Plan, which dedicated $13.2 billion (over $130 billion in today's dollars), or 5.2% of US GDP to European countries to rebuild their war-shattered economies. The transfer is comparable to the annual tax proposed for the GCS, but the Marshall Plan was a one-shot gift whereas the GCS tax would have to be paid *every year* for many years.

Survey opinions of the GCS reflect stated preferences whereby respondents are asked to make hypothetical choices in a controlled environment, and sincerity of opinions is checked with complementary survey work. The survey findings do not match with revealed preferences as reflected in actual choices on climate mitigation. The OECD computes for 72 high and middle-income countries an effective climate tax that reflects existing policies including tradable emission rights (OECD 2023). The effective tax rates are generally low, ranging from 124 €/tCO_2 [26] in Switzerland, to 28 €/tCO_2 in the EU, 13 €/tCO_2 in India, 12 €/tCO_2 in the USA, 5

[26] Euros per ton of CO_2.

€/tCO_2 in China, and zero in some countries. Rates vary widely by sector, and 58% of the GHG emissions in the countries covered were unpriced. Fabre *et al.* (2024) propose several reasons for the discrepancy between the stated and revealed preferences. First, policymakers may be ignorant about support for the GCS. Second, people or policymakers may believe that globally redistributive policies are technically impracticable, or politically infeasible in key countries such as the USA. Finally, as policy is disproportionately influenced by economic elites, public debate may be shaped by the wealthiest, who have vested interests in preventing global redistribution.

Thus far we have considered negotiations between and within countries that are liberal democracies. According to the Varieties of Democracy Institute, 91 countries are liberal democracies representing 29% of the world's population and 36% of the world’s carbon emissions. The main bulk of Asian, Middle Eastern, and African countries are largely autocratic. China and Russia alone emit as much carbon as fully democratic countries.

In democratic countries, voices (Malm 2018) are being raised to suggest that democratic regimes will prove incapable of meeting their climate commitments and that only autocratic regimes will make it possible to achieve emissions reduction targets. In view of the pledges to meet the target of net zero carbon emissions by 2050, this enthusiasm for the authoritarian option seems misplaced. So far, the 131 countries that have pledged to achieve net zero produce over 87% of global CO_2 emissions. Among them, many liberal democracies have pledged to do it by 2050.[27] The role of green activists is well established in international agreements, and most, if not all, of them come from democratic countries. Muller (2023) appears to be correct that the best hope of curbing global warming still lies with democratic countries.

The translation of international pledges into law

Several countries have translated national commitments into laws, but the laws are vague as they specify only goals to reach without establishing clear legal duties. For the rule of law to be effective, violations must be discovered with a high enough probability, and punished with sufficient severity. Judges must also decide between conflicting interests without favoring one party (e.g., firms that lobby against environmental protection laws).

Understanding the practical implications of laws and comparing them across countries is difficult for two reasons. First countries differ in their legal traditions (e.g., common law versus Napoleonic law). Second, the citizens of a country can launch a court action based on higher-order principles. For example, in April 2024, the European Court of Human Rights (ECtHR) ruled that the Swiss Government’s climate policies violated human rights.[28]

Whatever legal system a country has, effectively addressing climate change requires a robust legal framework that integrates clear principles, enforceable regulations, proactive judicial oversight, and inclusive public participation to bridge the gap between ambitious goals and

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[27] China and Russia have targeted 2060, and India 2070. A few Arab countries (Tunisia, Lebanon, UAE, Saudi Arabia, and Kuwait) have also made pledges. Africa accounts for only 3-4% of global CO_2 emissions. While some African countries have pledged net zero, their timelines often extend beyond 2050, reflecting developmental priorities and the need for international support (Adeoye 2024).

[28] https://hudoc.echr.coe.int/eng/#%7B%22itemid%22:%5B%22001-233206%22%5D%7D

practical outcomes. Such conditions do not yet exist in France.[29] A similar indeterminacy and hesitation can be found in a 2019-2024 case involving Shell in the Netherlands. Shell won an appeal against a landmark ruling requiring it to accelerate carbon reduction efforts. The appeals court in The Hague determined that Shell had a responsibility to reduce GHG emissions to protect people from global warming. But it dismissed a 2021 ruling that ordered Shell to cut its overall carbon emissions 45% by 2030 compared to 2019 levels, including emissions caused by the use of its products.[30] The court decision dealt a blow to campaigners who have been turning to legal channels to pursue climate action.

In general, laws have adapted only slowly to enforce environmental concerns effectively. For example, the first oil spills on the French Atlantic coast led the Maritime International Organization and the European Union to enact a mandatory law requiring that oil tankers have a double hull. But the rule applied only to new ships, leaving a lengthy transition period during which single-hulled tankers continued to operate. As another example: in 2008, the European Union passed a directive ordering member states to take steps to reduce air pollution. But it was not until 2021 that France's highest administrative court, The Council of State, imposed the first fine for failing to take sufficient measures.[31]

Despite a historic lack of progress, legal proceedings now appear to be gaining momentum. In 2023, a case against BNP Paribas was launched in France on the grounds that the bank's energy loans violated the French Duty of Vigilance Law, enacted in 2017.[32] The Law requires certain companies to adopt plans to prevent environmental and human rights violations. Cases against oil and gas companies have also made progress in the USA. According to a New York state bill signed in December 2024, fossil fuel companies will be fined based on the amount of GHGs they released between 2000 and 2018.[33]

These examples show that climate laws can be implemented. The question arises how they can be introduced more easily and preserved in the face of efforts to undo them while also maintaining flexibility to accommodate changes if new information or circumstances warrant it. According to Lazarus (2009), legislation should be implemented on a large scale at the federal

[29] Civil claims are also hampered by the extreme weakness of the French class action system, especially when compared to common law class actions. For instance, (i) the fact that no publicity of a class action is allowed until the *Cour de cassation* 's decision (French Supreme court) (i.e. 7 or 8 years after beginning the trial and around 12 to 15 years after the facts themselves), (ii) it is an *opt-in* system, which means that only the persons who expressly write that they intend to be claimants are considered as victims and (iii) it is impossible to force firms that have been found guilty to surrender all their illegally acquired profit (although this can be ordered in many other countries).

[30] https://www.reuters.com/business/energy/shell-wins-appeal-against-landmark-dutch-climate-ruling-2024-11-12

[31] https://www.france24.com/en/europe/20210804-french-govt-fined-%E2%82%AC10-million-by-top-administrative-court-over-air-pollution. The fine of €10 million was levied on the French government.

[32] https://www.osler.com/en/insights/updates/first-climate-lawsuit-against-a-commercial-bank-ngos-take-legal-action-against-bnp-paribas-for-fund/.

[33] https://www.reuters.com/sustainability/new-york-fine-fossil-fuel-companies-75-billion-under-new-climate-law-2024-12-26/. Total fines will amount to USD 75 billion over the next 25 years. Revenues are to be spent on mitigation. The bill follows a similar law passed in Vermont earlier in 2024.

level. He argues that delegating authority to lower governments or branches of government makes enactment, coordination, and review more difficult. Businesses also find it easier to comply with one set of rules than with multiple, potentially contradictory standards at the state, provincial, or regional level.

Lazarus (2009) also proposes that climate laws be made "sticky" to enhance their durability. One way is to link domestic legislation with international or multilateral treaty agreements to increase the political costs of non-compliance. Another suggestion, well-studied in the public choice literature, is to create interest groups that support climate legislation. Lazarus (2009) notes that Clean Air legislation in the US was supported by business groups that benefited from pollution control requirements. Likewise, a system of tradable carbon emissions rights endowing recipients with a valuable financial asset would establish a constituency favoring continuation of the system.

Unlike Lazarus (2009) and some other scholars, Levin *et al*. (2012) contend that large-scale policies requiring behavioral changes by many diverse parties are unlikely to be implemented, and if implemented susceptible to being derailed. For example, carbon taxes (discussed in Section 4) tend to create diffuse benefits and concentrated costs, which can produce stronger coalitions of opposition than support. Opposition has come from the fossil-fuel industry and other deep-pocketed entities that can influence the political process. Instead, Levin *et al*. propose gradual implementation in three stages. The first stage, as with Lazarus (2009), entails creating stickiness to prevent early reversals. The second stage involves entrenching support by initial proponents. This could occur automatically as, for example, early adopters of green energy technology become more familiar with it and appreciative of its advantages. The third stage is to expand the population supporting the policy via such avenues as scale economies in production and demonstration effects. [34]

Also, like Lazarus (2009), Levin *et al*. (2012) propose creating vested interests in climate legislation. British Columbia did so with its carbon tax, introduced in 2008, by making it revenue neutral. It also allocated some of the revenues to municipalities and school boards that had committed to carbon neutrality and would lose the revenues if the tax were withdrawn. Another way to generate support is to fund education in green energy jobs such as installing and maintaining solar panels. Municipalities and other lower-level governments may be able to implement green initiatives (albeit on a small scale) more quickly than national governments.

At a still smaller scale, the role of citizens in shaping urban planning and decision-making in response to climate change is becoming an increasingly important topic of discussion (Perlaviciute and Squintani 2020). The United Nations-based Aarhus Convention is the primary legal framework that mandates access to information and the possibility for citizens to participate in decision-making on environmental matters. An example is the democratic experiment "Convention Citoyenne pour le Climat" which involved 150 randomly chosen citizens from the French population to co-design policies to address climate change. The experiment launched a debate on the efficacy of such processes (de Kervasdoué 2020).

Conclusion

In summary, international agreements with naming and shaming remain a keystone of policy making for mitigation. Agreements serve as an anchor point for national action. Moreover,

[34] Levin *et al*. (2012) identify light-water nuclear technology in the US as an example.

climate action organized at the global level using tradable equal-per-capita permit allocations complemented by a redistributive tax seems to be acceptable for a large part of the population. To bridge the gap between ambitious goals and practical outcomes, climate-change policy requires a robust legal framework that integrates clear principles, enforceable regulations, proactive judicial oversight, and inclusive public participation. Arrangements can be upset by events such as changes in national government, increased barriers to trade or migration, wars, and other disruptions. Arrangements can be made durable by making them sticky and strategically creating interest groups that support them. Environmental initiatives at a local or even grassroots level also show potential.

4 CLIMATE POLICY AND SOCIAL ACCEPTABILITY

Section 3 has examined the role of governments in addressing climate change through initiatives such as international agreements and other durable policy initiatives. Here we address the characteristics and limitations of regulations and demand-side instruments such as carbon taxes. We also discuss public attitudes and resistance toward the instruments as one of the major barriers to tackling climate change. In terms of the systems diagram in Figure 1, these instruments can reduce GHG emissions by discouraging fossil-fuel consumption (1), encouraging green energy (1a), altering rules on land use (5), regulating production (2)[35], subsidizing R&D (8), enhancing carbon capture & storage (12), and so on.

Climate policy

Various taxes, subsidies, and other policies have been implemented or proposed to reduce carbon emissions. A tax on the carbon content of fossil fuels is widely supported by economists. From the perspective of simple, static models a carbon tax appears to be an ideal instrument for internalizing the external costs of GHG emissions. However, once spatial and intertemporal considerations are taken into account, instruments such as a carbon tax lose some of their efficacy.

One general limitation of efforts to reduce emissions is the so-called Green Paradox whereby initiatives by some parties are partly, or fully, undone by others.[36] The Green Paradox can occur when countries differ in the stringency of their environmental policies. If one country introduces a measure to reduce its fossil fuel consumption, the global price can decrease and induce other countries to boost their consumption.[37] Firms may also relocate to other countries to protect their profits.

A Green Paradox can also arise due to the finite supply of fossil fuels. Several possibilities exist. If resource owners anticipate stricter regulations or higher taxes in the future, they may accelerate extraction now. The response increases emissions and constitutes a so-called *weak green paradox*. If the full stock of fossil fuels is extracted eventually, cumulative damages to the climate may end up higher than without intervention. A *strong green paradox* then results. The situation is different if a tax or regulation is imposed without warning and remains constant over

[35] For example, by imposing energy-efficiency standards on motor vehicles or new buildings.

[36] The Green Paradox was first discussed by Sinn (2008). Jensen *et al*. (2015) review some of its aspects.

[37] This effect is at work in Barrett's (1994) model, mentioned in Section 3.

time. If so, extraction and the rate of global warming slow. However, extraction continues for a longer period and emissions may peak at a later date. If, instead, the carbon tax is scheduled to rise sufficiently quickly, extraction may be accelerated in much the same way as when introduction of the tax is postponed. Yet another possibility is that an existing tax or regulation is scheduled to be eased or removed in the future.[38] Extraction may then be postponed. These various scenarios illustrate how resource extraction is sensitive to policy timing.

At least in theory, the strong paradox can be avoided in several ways. Activists can buy some of the resource stock and keep it in the ground (Harstad 2012). Oil producers can form a climate cartel and restrict output to keep the price up (Asheim *et al*. 2019). A third approach is to reduce emissions by investing in an abatement technology such as carbon capture and storage or direct air capture. Even if resource exploitation continues for a long time, emissions per unit output then drop, and consequently, total emissions as well. For this reason, Cruz and Rossi-Hansberg (2024) advocate pairing carbon taxes with government incentives to develop abatement technologies.

Social acceptability

The speed at which renewable energy replaces fossil fuels depends not solely on the physical characteristics and costs of energy and energy-using equipment. Social acceptability matters as well. Fournis and Fortin (2016) identify several dimensions of acceptability. One is a distinction between social acceptability concerning process, and social acceptance of results. For example, a proposal to establish a wind farm may be turned down because the process that was followed did not give residents sufficient opportunity to express their concerns. The proposal would then fail the *ex-ante* test of social acceptability. Had the proposal been promoted in an acceptable manner that led to implementation and successful operation, it would have gained social acceptance on the basis of the *ex-post* results.

Fournis and Fortin (2016) also distinguish between three types of acceptance that differ in the set of stakeholders. 'Socio-political acceptance' applies broadly to major social actors such as politicians and the general public. 'Community acceptance' refers more narrowly to specific projects and siting decisions, and to local stakeholders concerned by procedure, distributive justice, and trust. Finally, 'market acceptance' concerns whether innovations or projects succeed in the market place, which depends on consumers and the entrepreneurship of investors and businesses. Individuals often have multiple stakes as residents, workers, and consumers, and may hold different attitudes towards climate change in each role.

Various scholars have studied social acceptance towards renewable energy sources and other climate-related actions such as carbon capture and storage. Three studies will be mentioned here.

Moula *et al*. (2013) investigate Finnish attitudes towards renewable energy technologies. From the results of a multiple-choice questionnaire, they determine that personal attitudes and public acceptance are influenced by several factors: socio-economic characteristics such as age and income, knowledge and direct experience of renewable energy, environmental and political beliefs, and attachment to where people live. A strong sense of place attachment tends to

[38] For example, Australia introduced a carbon tax in 2012, but repealed it in 2014 after a change in government.

intensify both support and opposition to energy initiatives. Procedural aspects of zoning, planning, siting, and licensing decisions also influence attitudes.

Fournis and Fortin (2016) investigate the social acceptability of wind energy projects. From a literature review, they identify several factors contributing toward negative attitudes: if planning follows a mechanical top-down pattern or ignores the local context, if the project is outside the respondent's territory, if information is deficient or suspect, and if opportunities to participate in decisions are lacking.

Stigka *et al*. (2014) review contingent value studies of willingness to pay (WTP) for renewable energy sources. They determine that WTP increases with disposable income and education, is raised by negative experiences with conventional electricity supply problems, and also raised if jobs are created. By contrast, WTP falls with age and household size, is lower for respondents who are responsible for paying electricity bills, is lower in rural areas that have suffered environmental impacts of renewable energy supply projects in the past, and is discouraged by search costs for alternative energy supplies or suppliers.

As noted above, political beliefs can influence attitudes toward green energy. Davis *et al*. (2023) find strong evidence in the USA that ideology matters for adoption of electric and plug-in hybrid vehicles. They determine that sales of new vehicles between 2012 and 2022 were concentrated heavily in counties with the highest proportion of Democratic voters. Surprisingly, the pattern did not appear to decline over the ten-year study period. Davis *et al*. also find suggestive evidence that individual purchases were driven less by intrinsic motives (i.e., personal satisfaction at being a good global citizen) than extrinsic motives (i.e., virtue signaling to other people).

Attitudes towards fossil fuels, renewable energy, CCS, and energy policies are clearly influenced by who gains and who loses. Virtually any technological innovation or climate-change policy will create some losers. Household gains and losses are determined by myriad personal characteristics including household income and size, type of employment, geographical location, exposure to pollution, and health status. Individual firms and whole industrial sectors can have much at stake as well. Inequalities in the incidence of gains and losses, both within and between countries, tend to create perceptions of unfairness and impede or prevent agreement on what climate-related policies should be implemented. Given the complexity of climate change, misperceptions in the gains and losses are common and can be exacerbated by biased and false information propagated by social media.[39]

Some energy-related policies such as consumer subsidies are widely considered unfair. For example, according to a recent US study, "tax credits for buying heat pumps, solar panels, electric vehicles, and other 'clean energy' technologies .... have gone predominantly to higher-income households .... The most extreme is the tax credit for electric vehicles, for which the top quintile has received more than 80% of all credits."[40] In response to these concerns, purchase subsidies for electric vehicles are being phased out in China and Europe.

[39] The extent of misunderstanding is documented by PERITIA (2024), an EU-funded project aimed at helping citizens and policymakers understand trust in science and identify credible expertise.

[40] Borenstein and Davis (2024, abstract).

In the next section we consider electric vehicles and the transition away from fossil fuels in the automobile industry from a European perspective. Automobile manufacturers in the European Union (EU) are facing simultaneous pressure from EU fuel-efficiency regulations and competition from manufacturers based elsewhere. The case study illustrates many of the challenges identified earlier regarding climate-change policy: natural resource constraints, prolonged adjustments, sunk investments, concerns about jobs, economy-wide impacts, behavioral changes that undermine the effectiveness of regulations and other policies, unintended consequences, and differential welfare effects.

5 THE AUTOMOBILE SECTOR IN THE EUROPEAN UNION AS ILLUSTRATION

The automobile sector is a major source of CO_2 emissions and Europe is striving to decarbonize it.[41] The European Commission and member-state governments have introduced a number of regulations and policies that are complementary in some ways, but contradictory in others. In this section, we summarize some key elements of European policies and legislation and then assess the merits of policies favoring electric vehicles.

European policies and legislation

Unlike the USA, European countries have long imposed hefty excise taxes on gasoline and diesel fuel to raise revenue. The taxes are equivalent to a carbon tax of roughly 200 to 300 €/tCO_2 which is roughly comparable to estimates of the social cost of carbon[42]. However, it falls short of the total external costs of driving; especially in cities with severe congestion. The EU has an Emissions Trading System (ETS)[43] that applies to electricity consumption, including consumption while manufacturing and operating electric vehicles. But since the ETS does not yet cover emissions from carbon-based fuels[44] it does not deter usage of fossil-fuel vehicles.

The main tool the European Commission uses to reduce vehicle fuel consumption and emissions are fuel efficiency standards on the sales of new cars and vans. Standards were introduced in 2009, progressively tightened, and from 2035 onwards new cars and vans must emit no CO_2.[45] In effect, this bans the sale of new fossil-fuel vehicles. The current (2025) standards are set as sales-weighted averages for each manufacturer.[46] Compared to other climate policy measures that are

[41] EU policy has been driven by environmental considerations rather than reducing energy dependence although the invasion of Ukraine has enhanced energy security concerns.

[42] Barrage and Nordhaus (2023) estimate a baseline value of the social cost of carbon of 97 €/tCO_2 for 2025 with current policy and a discount rate of 3%. Rennert *et al*. (2022) obtain 222 €/tCO_2 for their preferred estimate with current policy and a discount rate of 2%. Both monetary values are converted from US dollars using an exchange rate of 1.07 US dollars per euro.

[43] https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en

[44] A new, separate emissions trading system is planned for 2025.

[45] https://climate.ec.europa.eu/eu-action/transport/road-transport-reducing-co2-emissions-vehicles/co2-emission-performance-standards-cars-and-vans_en

[46] Manufacturers can form pools to meet their emissions target. https://climate.ec.europa.eu/eu-action/transport/road-transport-reducing-co2-emissions-vehicles/co2-emission-performance-standards-cars-and-vans_en

delegated to the member states, the fuel efficiency standards are strictly enforced. If a manufacturer's average emissions for new cars exceed the current standard, for each car it sells it is fined 95 € for each gram of CO_2 per km emitted above the standard.[47] An important side-effect of the standard is that manufacturers outside the EU have adopted the same standard in order to maintain scale economies in production unless doing so makes cars too expensive for their home and other markets.[48]

Together, national fuel taxes and the EU fuel efficiency standards have been successful in reducing emissions per vehicle kilometre. But the policy measures have not been well coordinated. As now explained, the planned transition to a wholly electric vehicle fleet also has a number of costs and drawbacks.

The case for promoting electric vehicles

Electric vehicles (EVs) are the closest substitute for fossil-fuel vehicles. Thanks to the EU Emissions Trading System, EVs emit no GHGs[49]. They also emit fewer local pollutants[50] and are quieter. This may justify their use in urban areas, and many European cities have created low emission zones and zero emission zones that favor EVs. However, similar to fossil-fuel vehicles, EVs still pose safety hazards, contribute to traffic congestion, and require parking space. Yet, electric vehicles do not pay fuel taxes, and differential registration fees or distance-based charges on EVs are still uncommon.[51] This creates two problems.[52] First, underpricing the variable (i.e., operating) costs of EVs encourages driving and exacerbates their external costs. Second, it is costly for government budgets. Fuel-tax revenues exceed revenues from the sale of ETS permits to generate the electricity used to manufacture and operate EVs. Revenues from VAT on vehicle sales and after-sales service also generally decline. Since most EVs are currently imported, tax revenues from vehicle production are lost, too. Governments have made major investments in battery-manufacturing plants to support domestic industries. But in many cases, manufacturing batteries can be done more cheaply elsewhere and it is unclear whether the investments will pay off. [53]

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[47] Car manufacturers gamed the fuel efficiency standard from 2007 to 2014 (Reynaert and Salee 2021) and the European Commission eventually replaced the New European Driving Cycle (NEDC) by the more rigorous Worldwide Harmonized Light Vehicles Test Procedure (WLTP).

[48] See de Palma and Riou (2025).

[49] EV batteries are an exception if they are imported from China or other countries outside the EU that do not have comparable emissions controls for manufacturing.

[50] EVs do emit particulate matter from abrasion of their brakes and tires, and silt stirred up from the road surface.

[51] ITF (2023) describes recent initiatives in some countries with fees and charges.

[52] Lindsey *et al*. (2024) analyze these costs in detail for the case of France.

[53] A notable example is Northvolt, a Swedish battery developer and manufacturer, which received funding from the EU as well as governments in Europe and Canada and investors in the USA. However, due to mismanagement, in November 2024 Northvolt filed for protection under Chapter 11 of the US Bankruptcy Code.

A further potential drawback of the pending sales ban is that fossil-fuel vehicles may continue to be manufactured in the EU and sold abroad where environmental standards are less stringent. Old fossil-fuel vehicles in Europe may also be sold elsewhere rather than scrapped. In either case, the global environmental benefits of the ban will be reduced. As now discussed, accelerating the replacement of fossil-fuel vehicles by EVs also imposes costs on automobile manufacturers, industry employees, and customers.

Challenges for automobile manufacturers

As noted, EU fuel efficiency standards are set as sales-weighted averages. To meet the standards, manufacturers have an incentive to reduce the prices of their EVs and/or reduce production of their fossil-fuel cars (Littlejohn and Proost 2022). Both adjustments tend to reduce profits which are constrained by the highly competitive nature of the market for road vehicles. In France alone, for example, 51 manufacturers sell 161 models of car. Media comparisons of technologies, equipment, technical reviews, and pricing are widespread. Manufacturers quickly lose sales if their products are more expensive than competitors' without offsetting technological advantages. Their operating margins depend on production costs and warranty costs which are directly linked to product quality. Manufacturers aim for high production volumes to reduce costs. Competition reduces their market shares and may weaken their ability to make the transition to clean-energy vehicles. Competition from Chinese firms is especially intense. Governments have sought to protect their domestic firms by imposing tariffs on imported Chinese cars, but this increases the consumer price of EVs and incentivizes Chinese firms to build plants in Europe.

Another challenge for the car industry and its satellite services is the amortization of investments which can amount to 10% of the retail price of a car. These investments involve the purchase of machinery and tooling, some of it highly specialized, which may become obsolete before it wears out. Patents related to production of fossil-fuel engines will lose their value. In addition, after factories close, the buildings are rarely re-used and gradually fall into disrepair, leaving a visible and depressing scar. Moreover, it may be too costly to retrofit them to build EVs due to the heavy weight of batteries which require thicker concrete foundations.

Impacts on regional economies and employment

Whatever their political model, most industrialized countries have integrated the road transport industry into their development plans. Manufacturers have profited from selling popular cars by producing high volumes with large factories. Reducing production at these plants will affect jobs. Changing powertrain technology (i.e., engine and gearbox assembly) from fossil fuel to pure electrification (rather than hybrid) reduces the number of parts to be manufactured and related jobs. Due to lesser maintenance and service requirements for EVs, downstream employment in servicing sectors declines as well. If the losses occur in areas where car production is concentrated, further losses occur among parts suppliers, garages, road infrastructure maintenance, and ancillary industries. This may happen in France in the Sochaux-Montbéliard or Cleon regions, in Germany around Wolfsburg, in Romania around Pitesti, or even in Sweden near Göteborg. Regions heavily dependent on producing fossil-fuel vehicles may have no good alternative to producing EVs. But EV production may end up elsewhere since it is difficult for governments to influence where multinational car manufacturers site their plants.

The extent to which these risks extend to an entire country depends on the overall contribution of the car industry to its economy. In the EU in 2022, the automotive industry provided 13.4 million jobs including 2.4 million in manufacturing alone (ACEA 2024). The jobs vary widely from country to country, accounting for 6.8% of manufacturing jobs in France, 10.9% in Germany, and as much as 15.5% in Slovakia. The social and industrial situation could end up similar to that experienced by mining and steel regions between 1960 and 1990. Examples abound in Europe of old industrialized regions with inefficient firms that received subsidies which delayed development of new economic activities. Polèse (2019) uses the expression "negative cluster" to describe situations where the (regional) government is essentially captured by a declining cluster dominated by a few big employers and trade unions.[54]

A further consequence of the transition towards net-zero is the change in materials required to make and use EVs. Fossil-fuel vehicles require large amounts of steel and cast iron to make camshafts, crankshafts, gearbox pinions and shafts, and part of engine blocks. Less of these materials is needed for purely electric vehicles. But EVs require more of other materials, such as copper, cobalt, nickel, and neodymium. Demand for them will increase and may exceed current extraction and production capacities for some time. Countries that use these materials will need to develop a culture of recycling as close as possible to 100% for protection against supply disruptions or sharp price hikes. Countries producing raw materials that are in decline will have to deal with the economic and social consequences, particularly if they cannot shift to other activities in the short run.

Costs for consumers

Transformation of the automotive sector will impose costs on consumers as well as firms and industry employees. In most countries, EVs cost more to buy than fossil-fuel vehicles.[55] They also still suffer from range anxiety and extended charging times, and fewer models are available than for fossil-fuel vehicles. Reducing reliance on cars is feasible in the heart of major cities. But in the suburbs, it would be very expensive to build a comprehensive public transport network with connections to other modes of transport such as bicycling. In response to changes in mobility, changes would also be required in the locations of commercial and service centers.

The situation is even more complex in rural areas. The car has made long journeys to commercial and service areas viable, and sometimes enabled these areas to sustain a large enough population to maintain a network of schools. Distributing activities back to villages and small towns in these areas will reduce their economic productivity and impoverish residents. In addition, public transport services will continue to be hampered by low passenger volumes which could lead to an increase in transport costs per trip and/or low service frequency. Travel times are also likely to increase because of the number of stops to be served and the likely changes to bus or train service. All of these changes will very probably adversely affect the well-being of

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[54] There is evidence that the transition needed after abandoning coal mining activities depends strongly on the local institutions (Bang *et al*. 2022) and that a region with diversified economic activities is much more robust to shocks. Countries outside the EU now also face problems with job losses in the coal industry (The Economist 2024c).

[55] This is despite purchase subsidies, which some countries are now reducing or eliminating.

these areas which are already suffering a loss of population to cities and their suburbs, and lack widespread political support (Chamorel 2019; Bordenet 2024).

The automobile industry has faced systemic crises before, such as the 1970s oil crisis which forced manufacturers to pivot toward smaller, more fuel-efficient vehicles. Addressing the climate crisis will require a similarly thoughtful, determined, and collective approach, focusing on education, problem analysis, customer respect, and persistent improvement. The potential depends on availability of energy and raw materials, the time available for a transition, the competitiveness of the firms, technological advances, whether government subsidies are provided, whether competing firms in other countries are also subsidized, and the willingness of consumers to adopt electric and possibly other alternative-fuel vehicles.

Summary

Efforts in Europe to decarbonize the automobile industry have involved national governments and the European Commission as a supranational entity. The battle features several characteristics of a super wicked problem listed in Section 2. In particular, many regulations and policies have been deployed, but legislation has proceeded slowly and there has been a lack of consistency in addressing climate change and other external costs of road transportation. Regulations aimed at the automobile sector are having economy-wide ramifications that affect all major groups of stakeholders: firms, workers, motorists, and governments. Learning by trial and error is costly or impossible, and delay is also costly as climate-change-related damages continue to accumulate. Countries differ greatly in how much they stand to lose from climate change as well as how much they stand to gain as suppliers of critical raw materials or producers of electric vehicles. The review leads to important policy questions. Should the sales ban on fossil-fuel vehicles be imposed as planned, or postponed until after 2035? Should fossil-fuel vehicles be allowed to play a limited, but continuing role — perhaps subject to high fuel taxes? Should hybrid vehicles be treated separately? Should Europe strive to be a major player in the production of batteries? Or should it instead try to become a leader in other green-energy technologies such as hydrogen vehicles?

6 CONCLUSION

A transition is underway to decarbonize the global economy that affects all segments of the population, all regions of the world, and all countries regardless of their political system. Renewable energy sources, methods of energy conservation, and other green initiatives have either been deployed or are under study. Progress varies across economic sectors, countries, and regions within countries. Due to the inherent advantages of fossil fuels and huge investments in equipment and production processes designed to operate with them, the transition will be protracted. At least in democracies, securing social acceptance for alternative energy sources and demand management policies is also essential. The distribution of benefits and costs matters, but acceptability also depends on procedural fairness (transparency, consistency, and inclusivity), distributive justice, and trust.

Decision makers tasked with formulating and implementing climate policies face various uncertainties. These include the speed of climate change both globally and locally, the frequency of extreme events, the supply of rare metals and other raw materials, the pace of technological advances, the degree of success at mitigation and adaptation, the evolution of public attitudes toward climate change and the environment, and geopolitics. Crucially, decision-makers must balance the trade-offs between addressing climate change and ensuring economic growth.

Technological change cuts both ways. Improvements continue to be made in solar and battery technology, and there is some progress with carbon capture and storage. On the other hand, new technologies such as artificial intelligence are increasing electricity consumption and concomitant demands on the capacity and reliability of the electric grid.[56] So could autonomous vehicles, especially if they lead to increased travel. [57]

Economists have long argued that a carbon tax or tradable carbon permit system can serve as the primary tool to internalize climate-change-related externalities and provide consumers and firms with adequate incentives to make socially efficient decisions. However, in many countries carbon taxes and heavy-handed environmental regulations have met strong opposition and some measures have been repealed. Moreover, carbon taxes (or equivalent) are designed to internalize negative externalities from carbon emissions, rather than other externalities such as traffic congestion, local pollution, and noise. Furthermore, Acemoglu *et al*. (2023) argue that this is not enough to support an efficient transition toward a carbon-neutral world because investments in green technology create another, positive knowledge externality. Individual firms and local (or even national) governments do not capture all the benefits from new technologies. R&D thus calls for a global subsidy, but funding has been inadequate.

The systemic barriers to climate action are numerous and deeply entrenched. The interdisciplinary nature of the problem, the distributional consequences of solutions, and the financial challenges associated with implementation collectively contribute to inaction. Given all the complexities, dealing with climate change is sometimes considered a super wicked problem that defies treatment. Consequently, a key message of this article is that climate-change-related policies need to be carefully thought out with recognition for the broad spectrum of outcomes that may result — whether of an economic, social, environmental, or geopolitical nature. The Green Paradox is one example. Policies should not only be well-understood by decision makers, but also explained to the public and other stakeholders in an effort to promote social acceptability. Such an approach is facilitated by interdisciplinary collaboration, both within and outside academia (Lamb and Steinberger 2017).[58] Effective solutions require integrating insights from fields as diverse as environmental science, economics, sociology, and political science. Yet, unlike centralized efforts such as the Manhattan Project or CERN, potential collaborators lack a common training or language, which hinders progress.

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[56] See Ligozat (2024) on skyrocketing energy consumption of Generative AI. According to Juliette Nouel "The electricity consumption of AI data centers and cryptocurrency mining could exceed 1,000 TWh by 2026, equivalent to Japan's total energy consumption": https://lnkd.in/epEb23wr

[57] Autonomous vehicles may also encourage urban sprawl and add to traffic congestion — at least until conventional vehicles have largely disappeared from the road. Additionally, the digital infrastructure required for autonomous vehicles, such as data processing, storage, and transmission, will add a significant carbon footprint to their adoption (Zewe 2023).

[58] See AICC YouTube chain - Action versus Inaction facing climate change: https://www.youtube.com/@AICC-Academia

This article has adopted a relatively pessimistic tone by concentrating on the many uncertainties and challenges related to climate change. Yet, there are some reasons for hope. First, the article has focused mainly on mitigation. The situation is different for adaptation which requires four types of actions: public infrastructure to protect against calamities (e.g., fire, floods), regulation of private infrastructure decisions, help in restructuring economic activities (mainly agriculture), and migration policies. While barriers to migration persist, progress is being made in the other directions. Moreover, there is growing evidence (IPCC 2022b) that climate catastrophes force politicians to make costly public investment decisions even if their benefits are mainly realized far into the future. While such efforts are best made before disasters strike, they do constitute action.

Second, greening the world economy may not be as costly as widely believed. The *Economist* magazine[59] argues that most existing cost projections are biased upwards by assumptions of continuing high rates of population and economic growth, and a need to cut emissions rapidly. The *Economist* remarks how progress in green energy has been consistently underestimated. It notes that maintaining the existing fossil-fuel economy will also be costly, and that the relevant cost of greening is the difference between these costs and those of a green economy. It also observes that the economies of developing countries are also less rooted in fossil fuels, giving them an opportunity to leapfrog to green technology. Developed countries could reduce global emissions more cheaply and quickly by enabling technology transfers to developing nations and providing financial assistance. This would lower the cost of decarbonizing the planet.

Time will eventually tell whether this optimistic view is borne out.

[59] The Economist (2024b).

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