CHAPTER ONE
CLIMATE CHANGE

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EXECUTIVE SUMMARY

An urgent need for aggressive policies

Climate change poses an immense challenge and threat, already leading to the loss of life and ecosystems, increased conflict, and economical losses. We have finally reached a moment of quite unanimous recognition of the great threat that climate change represents. Several high-emitting countries, such as the United States, have recently stated their willingness to also be part of the solution. Steady actions with clear and credible milestones are therefore highly valuable at this point. Europe is the right level to shape most climate policies for EU member states. There is an urgent need for aggressive policies to lead the change and engage other countries, which can be achieved by a combination of policy tools: improved carbon pricing, subsidies to R&D, standards, bans, better management of forests and land, etc. They are all part of a big suite of decarbonization policies.

Carbon pricing is an essential signal

Carbon pricing is an essential signal to convey our collective climate ambition to all citizens, consumers and producers. There is a strong consensus among economists that a uniform carbon price is necessary to induce an efficient and fair ecological transition. The EU Emissions Trading Scheme (ETS) should be strengthened to make carbon pricing more effective and transparent, replacing national pricing schemes (such as the carbon tax in France). The ETS should include all fossil-fuels by regulating emissions embedded in refined products, thereby including the transportation and housing sectors without any exemption. It should cover imported emissions by imposing the same effective carbon price to imported goods and services, with the aim of imposing a level playing field and incentivizing trade partners, barring any protectionist temptation. The credibility of the universal ETS carbon price should be reinforced for the long run by imposing price floors and ceilings growing at 4-5% per year. The carbon dividend, which could rapidly amount to €200 billion per year, should be fully redistributed to the EU citizens, in a transparent way, potentially to favor the lower deciles and the workers most affected by the transition. Carbon pricing should be fiscally neutral.

A battery of other policies are needed

A battery of other policies are needed to ensure adequate progress towards mitigation goals, and to ensure international action. These policies should include subsidies to renewable technologies or building retrofits, phase-out targets for fossil-fuel based technologies such as combustion engines and heating systems, a ban on coal use, environmental conditionality of the Common Agricultural Policy, and R&D subsidies for negative emissions technologies and for electricity storage. Nuclear electricity is a valuable asset to maintain low emissions in France. Consumers, investors, corporations and banks should be empowered by establishing a transparent carbon accounting system, but climate finance is a poor substitute for state-controlled climate policies. Prioritization over alternative climate actions should be based on a sound cost-benefit analysis accounting for costs and co-benefits, with climate benefits being measured using a carbon value compatible with our collective climate ambition. This guarantees that the transition will be obtained by minimizing the disruptions to households and by maximizing the opportunities, e.g., in the form of job creation and co-benefits. Although bans have implicit costs and subsidies for some are necessarily taxes for others, many, but not all, recommendations of the Convention citoyenne pour le climat are likely to pass this test. To attain our new climate ambition, more will be necessary in terms of public infrastructures, R&D, and carbon pricing.

Priority to international policy tools

Internationally, France and the European Union account for a relatively small share of emissions. Policy efforts should prioritize actions that can have positive spillovers to other parts of the world. The EU and France should seize the current momentum of climate action, both in the private and in the public sector, and ensure that commitments to decarbonize the economy are taken seriously. Among policy tools, efforts should be devoted to innovation towards substitute technologies that do not require the use of fossil fuels, in addition to negative emissions technologies, such as direct air capture, rock weatherization, or agricultural engineering. The EU should also seek explicit agreements surrounding carbon pricing and explore international policy tools to encourage other countries to participate in such mechanisms.

In summary, European governments need to come together and increase the ambition of both carbon pricing and other climate change policies to coordinate a rapid transformation of our economies and societies. A portfolio of ambitious policies has the potential to kickstart the required change and encourage other countries in the global scene to also ramp up efforts. It is both a moral duty and the efficient path of action. The time is now.

INTRODUCTION

Over the last four decades the accumulation of scientific knowledge on climate change has left no doubt about the unbearable social and environmental costs associated with our emissions of greenhouse gases (GHG). There is a growing consensus that our economies must be greened, the sooner the better. Europeans have democratically decided to build an economic system entailing a 55% reduction of emissions by 2030 (compared to 1990) and zero net emissions by 2050. The complex question is how to reorganize our society to do this without being paralyzed by the difficult compromises that need to be made. In this report, we offer a coherent answer to this question. It is supported by a large consensus among academic economists around the world.

Over the last two decades, Europeans have been able to fulfill their international climate promises, with an emission reduction of almost 25% between 1990 and 2019. In fact, the energy transition has already begun. In recent years, progress on low-carbon solutions and markets has been faster than ever. Solar electricity costs have fallen 80% in 10 years. Wind costs are down around 60%, and batteries are 85% cheaper. Today, a stealth green revolution is propelling us. The environmental awareness of a growing share of the people has also radically transformed the social landscape of climate politics, from consumer and citizen activism to climate finance, responsible investment and carbon accounting. We are all part of the solution.

For the next three decades, we believe that it is possible to combine economic growth with the EU climate ambition. Net cost estimates of the 2050 net zero emissions target represent a reduction in GDP (Gross Domestic Product) of less than 1% over the period, far below the climate damage estimates of inaction. Thus, we must fully decarbonize our economy within a short period of time on a scale and intensity unprecedented in peace time. The recent policy against Covid-19 shows us that it is possible as soon as the political will is there. Consumption behavior should change dramatically to reduce carbon-intensive products and services and to favor short circuits. Coal, and then natural gas, must be replaced by solar and wind sources in our electricity mix, and electricity storage technologies must be developed. The transport sector should exclude gasoline and diesel engines within the next decade or so. Cities and their suburbs should be reshaped to ease collective and individual mobilities. Several industrial sectors are doomed to disappear together with their jobs, whereas new economic activities will emerge. Labour and social interactions should be adapted, in particular to favor telecommuting. Houses and buildings should be retrofitted at a much faster speed and in a more efficient way than currently observed. Large scale carbon capture and sequestration will likely be necessary within the middle of this century. Efforts in R&D will be key to bypass the current technological locks for the development of carbon-free solutions.

Over the last few months, huge national and European plans have been decided in which hundreds of billions of euros will be spent to green our economies. This will not be enough, as too many consumers and corporations continue to invest in carbon-intensive assets and projects. In line with the vast consensus of the economics profession, we support an ambitious carbon pricing policy to force all polluters to internalize the consequences of their actions. A universal carbon price high enough to attain our global climate goals should be imposed to all consumers and producers in Europe, with no exemption. Carbon pricing is aimed at making it privately profitable to implement many of the necessary green actions described above by realigning the myriad of private interests in our society with the common good, thereby contributing to attaining the global climate goal at minimum cost. By raising the price of carbon products and services, this system allows us to green our growth at the lowest cost for the citizens. History shows that the evolution of relative prices plays a major role in our lives, and that it is a central element of any societal transition. The carbon pricing policy should also fight social inequalities. This should be done by redistributing a fraction of the carbon dividend to the lower deciles of the population and to the specific losers of the transition (coal miners, specific rural areas) in a transparent way. Since the emergence of the *Gilets jaunes* (Yellow Vests) movement, cost-efficiency and redistribution issues have become key for the social and political acceptability of any climate policy.

Europe is the right level to define and implement a carbon pricing mechanism. Our proposal relies on the existing EU-ETS system of emissions allowances. This system should urgently be reformed to enlarge its scope and intensity. The objective should be for EU-ETS to cover all measurable emissions under EU jurisdiction, which implies a border carbon adjustment. Beyond the scope enlargement, a menu of other reforms should also be examined. One possible reform would be to obtain a European treaty establishing a multi-decade carbon price floor, growing at 4-5% per year from a scaled-up 2021 level around €60-€80/tCO_2. The long-term visibility of the carbon price over the next three decades is key to trigger the energy transition based on private, irreversible investment projects whose emission reductions are dispersed over a long period of time. To solve the credibility issue of increasing carbon prices in the future, one could consider a strategy that has already been successfully implemented for the European monetary policy: creating an independent Carbon Central Bank (CCB). The CCB would receive a mandate from the EU political institutions to govern the carbon price in a manner compatible with the democratically-determined climate goal of the Union.

Whatever the policy used to reshuffle carbon pricing in Europe, special attention should be given to the use of its revenue. The EU should redistribute this revenue to each country in proportion to its emissions. A fraction of it could also be allocated to the Just Transition Fund created at the occasion of the EU recovery plan of July 2020 ("Next Generation EU") to facilitate acceptability by countries with lower marginal abatement costs (MACs). In the absence of a European solution, France should rely on a reshuffled carbon taxing mechanism, enlarging its scope, and redistributing its revenues.

Carbon border adjustment mechanisms (CBAMs) are useful not only to control for environmental dumping and for leveling the playing field, but also to incentivize EU consumers and producers outside this continent. It is a WTO-compatible tool to align all market players for the common good. Economists of both sides of the Atlantic agree that CBAMs should be used to incentivize the creation of "climate clubs". Under the Biden administration, the European Union and the United States, potentially with China, could form the core of such a club, yielding a critical mass to attract many other countries within this club. This suggests launching a climate diplomacy round that clearly departs from the "lowest common denominator" principle in force in the COP negotiations carried by the UNFCCC.

Carbon pricing is a necessary policy, but it is far from sufficient. Climate change is indeed far from the only market failure that justifies public intervention. Together with the urgent need for action, this justifies a wide spectrum of interventions, from subsidies for firms, consumers and investors to industrial/agricultural norms and consumption bans. There are several reasons to attack the climate challenge with a variety of tools. First, from a management of uncertainty point of view, it can be useful to ensure improvements in strategic sectors at a faster pace than possibly signaled by carbon pricing. Second, these policies often tend to be more popular than carbon pricing, potentially enabling a more ambitious policy portfolio. These public interventions are also justified by other market failures due to non-climate externalities, asymmetric information, limited rationality, or biased beliefs. Third, these policies can be targeted to areas in which other co-benefits exist and are currently unpriced, such as the transportation sector, which is responsible for significant local pollution; investments targeted at re-stimulating depressed areas; or increasing the efficiency of building envelopes, which could also be beneficial in terms of resilience in the face of growing extreme events.

Innovation is an area of public intervention that deserves further attention. The intense informational externalities of research activities imply that carbon pricing is not enough to solve the market failures of green research. Europe should finance a large and sustained scientific and R&D program to remove critical technological locks, such as electricity storage, batteries, green agriculture and the like. Priority should be given to R&D projects that are more likely to succeed, yielding large impacts over a wide set of sectors. Such policies have the additional benefit to reduce the cost of the transition outside Europe, thereby making it very effective to incentivize other countries and regions to reduce their dependence on fossil fuels. We should not put all our efforts on the basket of breakthrough innovation, which might not materialize, but we should be aware of its spillover benefits when addressing the global tragedy of the commons.

The cost efficiency, effectiveness, feasibility, and credibility of each of these policy options should be evaluated to prioritize their implementation. In particular, their cost-benefit evaluation should be based on the true social cost of carbon and should also take in account their non-climate impacts. Not everything that is green is necessarily desirable. Even some actions that have no impact on the public budget, such as banning certain goods and anti-pollution standards, have hidden costs for citizens that must be understood. The existence of unpriced co-benefits is often critical, for example, when life-threatening pollutants in cities can be reduced. The redistributive impacts of climate change policies should also be measured and given a proper social value. Jobs creation could be another key policy consideration. Using this cost-benefit approach justifies, for example, phasing out coal as soon as possible from the EU electricity mix.

In sum, an ambitious policy portfolio should be rolled out in France and the EU to face the raising threats of climate change. An ambitious policy portfolio would send a strong signal to consumers, investors, and other countries, and contribute to the necessary change ahead.

SECTION 1

THE CLIMATE PROBLEM

The last half century has accumulated an overwhelming stock of empirical facts and scientific knowledge that basically eliminate any doubt that the emission of CO_2 and of other GHG gases changes the climate of our planet for the worse. Humanity is now confronted by the risk of a dramatic deterioration of its environment, and of the collapse of its economic welfare. France and the European Union have committed to take responsibility and confront the challenge, at least on paper. On November 8, 2019, the French Parliament promulgated the law "*Énergie et Climat*" that commits France to reduce the consumption of fossil fuels by 40% in 2030 (compared to 2012) and to attain zero net emissions by the year 2050. In December 2020, the EU decided to reduce its emissions by 55% in 2030 (compared to 1990), on top of the net zero emissions goal by the year 2050. For the classical political accountability problem of long-term promises, it is good to commit to a clear target for 2030. Zero net emissions by 2050 is a very ambitious target, which will require a radical transformation of the global economy and the way we live. The nature and the costs of this necessary transition are still imperfectly known. The waiting game that has been played by most countries over the last three decades puts us in the uncomfortable position of urgently adopting irreversible climate actions, while simultaneously exhibiting enough flexibility to adapt to many uncertainties, both climatic and technological.

In its 2018 report entitled *Global Warming of 1.5°C*, the Intergovernmental Panel on Climate Change (IPCC) stated that if all countries around the world do the same proportional reduction of emissions pathway in the next 30 years as promised by EU, the increased average temperature of the atmosphere could be limited to 1.5°C compared to the pre-industrial age. In the absence of radical scientific and technological breakthroughs, this outcome is not plausible, but this should not inhibit the EU's willingness to perform its fair contribution to the global efforts.

We take the democratically-determined EU commitments as a common goal, and explore the strategies to attain this ambitious climate objective in an efficient way.

Economists have long debated about which climate ambition should be socially desirable, weighing the short-term cost with the long-term benefits of the ecological transition. Current estimates of these costs are around 1% of GDP in 2030, whereas its benefits in terms of reduced climate damages are at least one order of magnitude larger. Deep uncertainties surround the costs associated with the last 20% of emission suppression, for example, in the aviation industry. The optimality of this suppression remains an open question.[1] This issue is related to the level of carbon value, which is discussed in Section 3 (point 1).

A key question is whether Europe should stick to its climate ambition if it remains isolated from the world on this issue. It is clear that Europe has a historical responsibility, particularly due to its accumulated emissions over the last two centuries, to lead the world outside the problem that we collectively created. A strong ethical and economic case can be made for Europe being ahead of the pack. At the current social cost of carbon, many green technologies are unilaterally cost effective even if no other countries participate, which is an important development that has contributed to the easing of international discussions. That said, if no other sets of countries participate, the temperature targets will become unreachable and there will be a growing need for adaptation, R&D, negative emissions technologies, and geoengineering. Our position is that such a failed outcome, which reflects in part the history of climate negotiations to date, should be avoided at all costs. This report is based on the assumption that the EU is not isolated on the climate issue, and that at least the United States, China and India are strongly on board by the year 2030. We make proposals to increase the probability that this will happen.

1. An Existential Threat

The Integrated Assessment Models used for the fifth report of the IPCC vividly document the unbearable damages incurred in the future if we collectively fail to reduce our carbon footprint. Our responsibility towards future generations is at stake. If we do nothing, the average temperature could increase by more than 3°C by the end of this century, and much more thereafter. Extreme climate events such as droughts and hurricanes will be more frequent, leading vulnerable populations to starvation, reducing agricultural and labor productivity, raising ocean levels, forcing migration, and stressing food security and water supply. Natural assets and their flow of ecosystem services will be deteriorated or

[1] This question is associated to the issue of implementing a ceiling price in the EU-ETS system (Section 3, 1.1). It is also related to the size of the carbon sinks.

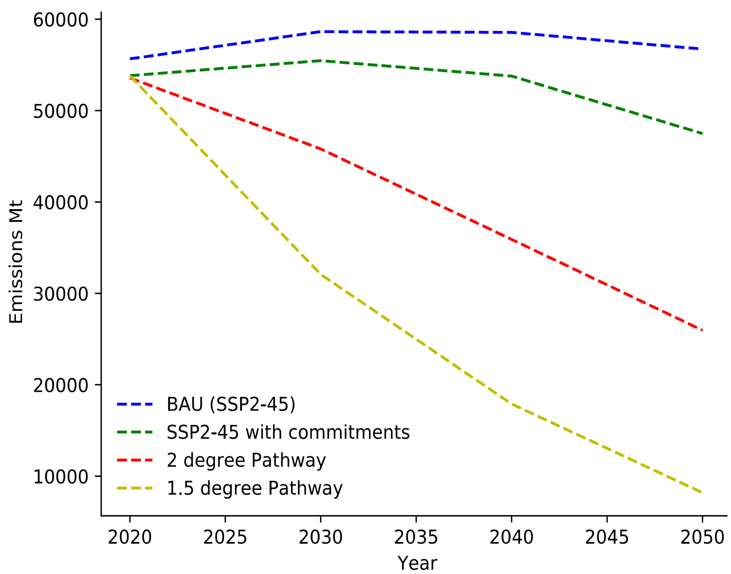
destroyed, through forest fires, the acidification of the oceans, and changes in the ecological habitats. Biodiversity will incur irreversible transformations.

Deep uncertainties surround the climate dynamics of our biosphere under these human-induced shocks never seen before. A simple measure of these impacts is given by a key climate parameter called the climate sensitivity. It measures the increased average temperature of the atmosphere when doubling the concentration of CO_2. In its 2013 fifth report, the IPCC believed that it was likely to be somewhere between 1.5°C and 4.5°C. This wide range illustrates the uncertainties affecting various aspects of the climate dynamics far away from its pre-industrial equilibrium. For example, climatologists have identified feedback loops, such as the release of methane from the permafrost in Siberia generated by the increased temperature there, but the quantification of this phenomenon remains a challenge. Other feedback loops are uncertain, such as the ones involving the change in the albedo (reflecting power of the planet) due to changing clouds and ice surfaces, or the effect of global climate change on the absorption of CO_2 by plants. These uncertainties will take too much time to resolve, and immediate, decisive actions are urgent; waiting to get the information is not an option anymore. In the absence of action, Alestra et al. (2020) estimated a permanent loss of world GDP of around 13% by the year 2100 due to climate change. Stern (2007) estimated that the inaction would have an impact on intergenerational welfare equivalent to a permanent loss of consumption somewhere between 5% and 20%, i.e., something like a permanent Covid-19 crisis.

The degree of confidence about these estimates is limited. The climate system and the damage function linking the temperature change to its environmental, health and social impacts are highly non-linear. For example, the human body works optimally at a body temperature around 37°C. Increasing it by 0.2°C reduces our ability to perform multiple tasks. At 38°C, our ability to think deteriorates rapidly. At 42°C, we die. Human labour productivity deteriorates when local temperature goes beyond 22°C (Heal and Park, 2016). Because poor households can less easily protect themselves from external weather conditions, they are more vulnerable, with important consequences to their health and wealth. The optimal temperature for maize productivity is 18°C. Its agricultural productivity goes to zero below 10°C, or above 30°C. Biodiversity is highly sensitive to changes in humidity and temperature. Different environmental assets on which human beings rely for their subsistence will be destroyed. Entire regions will become inhabitable by most species, in particular human beings. Thousands of reports have been published over the last three decades on the expected catastrophic climate damages from our inaction, and it is not our objective here to write a new one. Rather, our responsibility as social scientists is to describe possible strategies to help humanity confront the climate challenge.

Some basic carbon arithmetic is useful to understand the intensity of the climate challenge. The atmospheric concentration of CO_2 was around 280 parts per million (ppm) in the pre-industrial age. It crossed the 400 ppm bar in 2016, growing at a rate of 2.2 ppm per year (except in 2020 due to the Covid-19 pandemic). The ambition of limiting warming to 1.5°C leads to a global carbon budget for Humanity. The IPCC report (2018) states that we should not emit more than 2,800 $GtCO_2e$ since the preindustrial period for a 50% probability of limiting warming to 1.5°C. We already emitted approximately 2,200 $GtCO_2e$. The associated remaining budget is being depleted by current emissions of approximately 42 $GtCO_2e$ per year (a historically high level – in the 1970's, global emissions were around 15 $GtCO_2e$/year). This means that, at the end of 2020, our remaining global carbon budget is down to 480 $GtCO_2e$. At this speed, our global carbon budget would be zero at the end of 2031.

Figure 1 – Emission pathways compatible with 2°C goals



Source: Own elaboration

Climatologists have alerted governments and public opinions for at least three decades now, but global GHG emissions have continued to grow at a rate of 1.5% over the last decade, stabilizing only briefly between 2014 and 2016 but this fall will certainly be followed by a post-pandemic rebound. In the worst days of the Covid-19 lockdown, daily emissions only receded to their 2006 level. Nations made promises (called Nationally Determined Contributions, or "NDCs") in the framework of the Paris Agreement of December 2015, but they are largely insufficient. The UN Environmental Program (2018) claimed that,

> "if NDC ambitions are not increased before 2030, exceeding the 1.5°C goal can no longer be avoided. Climate damages already prevail, with an increase of average temperature already observed of 1.1°C since 1880, with important regional variations. In Antarctica, the average temperature has already increased by 4°C since 1980. Pathways reflecting

current NDCs imply global warming about 3°C by 2100, with warming continuing afterwards."

Despite renewed and elevated NCDs made throughout 2020, the world's projected emissions are well above not just the 1.5°C warming pathway, but the 2°C warming pathway. This is illustrated in Figure 1. Any additional delay in implementing radical reforms to fight climate change dramatically increases the global cost of the transition.

To decisively fight the threats of climate change, radical and immediate coordinated policy action is needed.

We have seen that the cost of inaction will be prohibitive. What do we know about the cost of action?

Given the existing capital stock that relies on fossil fuels and their ample availability at relatively low prices, switching to alternative sources of energy will be costly in the short run, due to the need for new investments and their higher costs (e.g., hydrogen, fuel cells, etc.). However, the necessary effort to decarbonize the economy does not mean that one should give up economic growth, in particular if we succeed in performing a least-cost mitigation strategy. After all, between 1990 and 2019, EU emissions of CO_2 were reduced by 23%, but the EU GDP increased by 50%. Most costs take the form of capital investments (power plants, electric vehicles, house retrofits, etc.). Although that could have a negative impact on consumption, these necessary investments can act as a positive stimulus in the next few years in a post-Covid-19 world with underemployment.

Many studies have examined the necessary additional investments that are necessary to green our capital. For example, in the transportation sector, the additional investment cost measures the cost differential of using an electric vehicle rather than a fossil fuel vehicle. Quinet (2019) and France Stratégie provided a recent synthesis. The OECD estimates at $6,900 billion per year the necessary green investments in the world for the next 15 years, which corresponds to a 10% increase in the current flow of investments in infrastructure. In IPCC (2018), this flow is estimated at 2.5% of world GDP every year.

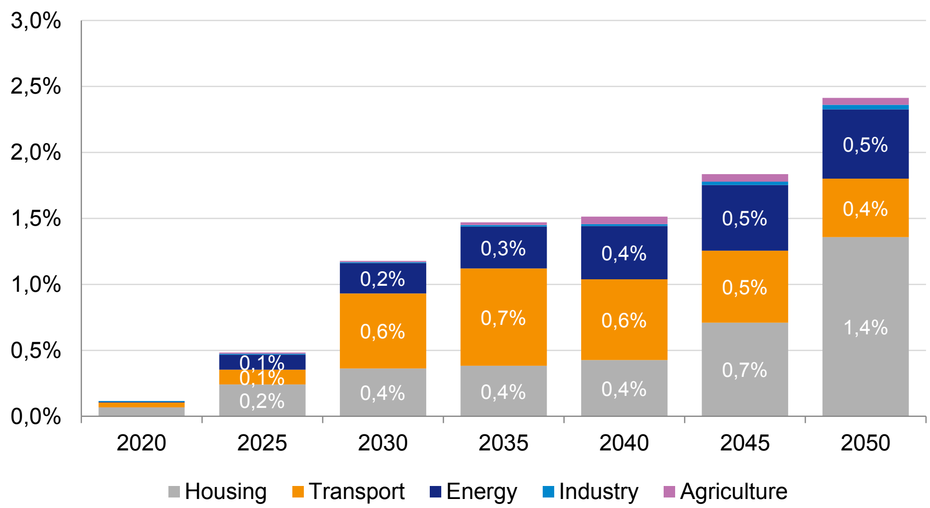
The European Commission (EC, 2018) estimated the flow of necessary additional investments in Europe from 2030-2050 to be between €175 and €290 billion per year to achieve net-zero emissions in 2050. In France, the recent report of the *Stratégie nationale bas-carbone* (SNBC, 2020) from the Ministry of Ecological Transition has estimated the flow of sectoral investments that supports its strategy toward carbon neutrality in 2050 (see Table 1). A simple number to keep in mind is the 2.5% share of GDP necessary to fund the transition in the next few years, but this share will increase over time. Only half of it should be counted as extra costs (SNBC, 2018). Quinet (2019) also estimated the investment overcosts per sector. These estimates are described in Figure 2. This transition is thus feasible in terms of capital allocation. Most of this additional effort will have to be borne by the private sector, and it will be necessary to make these investments attractive for the stakeholders.

Table 1 – Flow of gross investments to attain net-zero emission in the *Stratégie nationale bas-carbone* (in € billion per year)

	2019-2023	2024-2028	2029-2033	2034-2050
Housing	14	18	22	28
Transport	21	36	52	85
Energy and networks	11	10	11	13
TOTAL	**46**	**64**	**85**	**126**

Source: SNBC (2020)

Figure 2 – Estimation of investment overcosts per sector in France, expressed in percents of GDP



Source: Quinet (2019)

Investment costs are only one element in the various costs associated to the ecological transition. Some of these costs will be compensated by a flow of economic benefits, as in the case of the thermal insulation of dwellings, which will reduce household energy bills. Other costs are not capitalistic. The net cost for France to achieve its climate ambition could be estimated as follows. France should reduce its emissions (currently at 0.31 $GtCO_2$/year) by around 35% in the next 10 years. Assuming an abatement cost around €250/tCO_2, as estimated by the Quinet Commission for 2030 (Quinet, 2019), this yields a total cost of €27 billion that year, or approximately 1.1% of GDP_{2030}, assuming a 1% growth rate. It is an upper bound since this estimation assumes a flat marginal abatement cost curve.

2. Perceptions and Willingness to Act

With such overwhelming scientific evidence, what is the willingness to act and the perceptions of the public? How can they impact, accelerate, or delay the needed transformation of our economies? The good news: there is consensus in the need for action. Among the public, there is ample consensus on the nature and magnitude (to an extent) of the problem. French people are particularly aware of the human origin of climate change. According to a recent survey by Douenne and Fabre (2020a) to 3,002 French residents, over 90% of respondents agree that climate change is present whereas only 3% believe it is not occurring. Furthermore, 80% of respondents agree that climate change is at least of serious gravity. Among such households, 35% of them chose the gravity to be disastrous and over 40% to have cataclysmic consequences.

Even with such a strong acknowledgment of the perceived gravity of climate change, there is a gap between acknowledging the need for action and actively supporting ambitious climate change policies. Households understand this is a serious matter, but are unaware of the degree of deep transformation necessary to address the problem (Douenne and Fabre, 2020a). Furthermore, there are additional challenges associated with finding agreement on how to allocate the burden, both inter-temporally and across households, along with a mismatch between the needed investment in, and costs of, varying policy tools, and the expectations on how much the transition will cost. There is also a general issue of building trust around the particular climate change policies that are eventually chosen. We highlight several challenges below.

Challenge 1 – Social acceptability and beliefs around the cost of the transition

There is substantial disagreement on how the burden of the transition should be allocated among the public, as well as often a misperception on the costs of climate change policies, either over- or under-estimating its monetary costs. Such perceptions affect the policies that can be approved, as some of them end up being more popular than others due to these misperceived costs.

In a recent survey sponsored by the Haut Conseil pour le climat (HCC, 2020), 91% of the respondents consider that it is urgent/very urgent to act against climate change. But only 72% of the respondents support the idea to apply the polluter-pay principle to tax carbon emissions, which would affect their purchasing power. Earlier in 2020, the Convention citoyenne pour le climat (CCC, 2020) flatly rejected any debate on the carbon tax defended by Katheline Schubert, Professor at Paris School of Economics, at the occasion of one of their early plenary sessions. Moreover, the report of the CCC, which provides many important recommendations, ignores this policy option. The HCC examined the reasons for the relative distaste of the carbon tax in France. Almost nine out of ten respondents believe that the climate policy should not affect the financial situation of the middle class, thereby suggesting that they believe that the ecological transition could be performed at no cost. An alternative interpretation would be that a majority of the French citizens believe that the rich should pay. The policies of the last three decades bear a responsibility for this biased perception among the French population of a happy energy transition, creating millions of jobs and reducing the electricity bill. It has created the conditions for the emergence of the *Gilets jaunes* movement (Yellow Vests).

While support for other policies is larger, their costs are often hidden. It is also unclear that this support will be enough to facilitate the needed investment without substantial efforts in communicating the urgency of action, or to give power to political parties that are more ambitious in the fight against climate change.

Challenge 2 – Social acceptability around equity and fairness concerns

Replacing cheap fossil fuels by renewable sources of energy will be costly for society, at least in the short term given the existing technologies. Some people will bear larger costs than others. This raises a critical concern about the redistributive impacts of the climate policies, in particular because the income-elasticity of energy demand is smaller than unity in Europe. In other words, poorer households spend more of their income on heating and transportation. To find a good compromise that can have enough support, it is important to be quantitative about these impacts and create compensation mechanisms within the proposed policies. It is thus essential to convey the difference between incidence (who bears the impact of the costs of the policy) and overall cost effectiveness (e.g., overall costs per reduction of ton of carbon) to ease such debate. To induce the acceptability of a measure that creates positive net social value, we support any measure that transfers part of the gain of its winners to compensate its losers.

Even though carbon taxes clearly enumerate the costs and incidences, there is still strong opposition to this policy. Much of the resistance stems from tax aversion, which influences beliefs about tax properties such as effectiveness or fairness (Douenne and Fabre, 2020b). Adding explicit, redistributive goals as a foundational aspect of climate change policies has been suggested as a possible means to address this problem. However, opposition may persist even in the presence of explicitly redistributive taxes, thus the need to carefully address this challenge. Indeed, in a recent survey performed during the *Gilets jaunes* movement in France, Douenne and Fabre (2020b) found that the respondents tend to overestimate their loss, to wrongly think that the combined policy (carbon tax cum lump sum redistribution) is regressive, and to not perceive the effectiveness of the carbon tax at reducing emissions.[1]

Challenge 3 – Social acceptability around the tragedy of the horizons

The belief of relatively costless transition may limit the political support to any policy that would impose sacrifices to the citizens. As it induces procrastination, it raises the issue of the intergenerational sharing of the cost of the transition. Even if many of the climate damages are no longer perceived as distant in the future, the costs of action are immediate. Inertia is inherent to the carbon cycle. Current anthropogenic GHG emissions will persist in the atmosphere and in the oceans for centuries and millennia. They will impose damages for many generations to come. The US Interagency Working Group on the Social Cost of Greenhouse Gases (IAWG, 2013) gives us a simple way to estimate the duration of the flow of damages, which is around one century. Reducing emissions today contributes to reducing damages in the short term, but most of the benefits will be felt in the distant future, on average in 100 years.

This so-called "tragedy of horizons" is an additional source of complexity to fight climate change. The Covid-19 experience can be a useful contrast to understand this challenge. In the case of the Covid-19 crisis, citizens perceived almost immediate collective benefits to their individual efforts, which made the strict lockdown more socially acceptable. In the case of the climate crisis, the collective benefit of our individual efforts will be much stronger than those of the Covid-19, but they will materialize in a more distant future, which limits the desire for short-term sacrifice.

Challenge 4 – Social acceptability around the tragedy of the commons and international competition

Additionally, the international dimension of the problem can create conflicting views on who should bear the costs of this transition at a global level, what is known as the "tragedy of the commons." The European Union needs to set the expectation that the efforts to combat climate change will be maintained even if other countries fail to comply, at least for a while. It is not obvious that public opinion will follow.

That said, it is important to pay attention to the potential losers from asymmetric regulation. The lack of international harmonization can particularly impact workers in emissions-intensive sectors, leading to some regions or household groups being most affected by these competition issues. These sectors have often already suffered from loss of

[1] The lack of transparency about the objectives of the carbon tax since its introduction in 2015, the limited political attention to the redistributive issue, and the dramatic softness to tax exemptions for powerful pressure groups (truckers, farmers, taxis…) have also contributed to this fiasco.

employment opportunities due to the process of globalization of the supply chain and the energy-bias in trade (Shapiro, 2020).

As we will highlight in the next sections, finding a balanced policy approach that confronts and addresses these challenges is essential. Wide acceptability of climate policies is needed to ensure their success and continuity. Even if there is substantial agreement on the scientific evidence regarding the existential threat that climate change poses, successful climate change policies need to be feasible and implementable as rapidly as possible.

Despite the difficulties (tragedy of horizons and commons, belief bias), finding wide and decisive consensus in practical policy implementation is of utmost importance to effectively fight climate change.

3. The International Challenge

In addition to the challenges in perceptions and willingness to act at the national level, solving the climate crisis requires considering the global nature of the problem. French CO_2 emissions represent less than 1% of the global emissions of this GHG. Even if France were to fully decarbonize its economy, that would only marginally affect the climate dynamics. Even at the European Union level, EU-28 is currently responsible for approximately 9% of global CO_2 emissions. There is thus no point to think about our climate policy in a vacuum. But it creates an internal coordination problem that is easier to solve under the EU constitution than under the much weaker rules of international law.

There is a risk that such immense challenge, and the limited impacts of greenhouse gas reductions by the European Union to the global problem, can lead to nihilistic positions that prevent progress. While this has been true for many decades, the impacts of climate change today are sufficiently acute that governments are starting to take more serious action. In some ways, the increased perceived costs of the problem reduce the coordination challenge. In this scenario, there is high value in leading an effort to tackle the problem. Being united reduces the international free-rider problem in the global negotiation and makes compliance by other trade partners, now more willing to act on their own, more attractive.

Recent encouraging developments can make the value of these commitment and policies even larger. Several high-emitting countries have recently announced their intention to commit to net-zero carbon emissions by 2050 or 2060, including China, Japan, South Korea, and the likely addition of the United States under a Biden administration. Whereas announcements set a useful guiding post, the European Union can lead by example by sticking to intermediate goals, such as the recently announced plans of 55% reductions by 2030 that ensure progress at an adequate pace. Europe can play a major dragging and exemplary role at the international level.

Europe is the right level to shape an efficient climate policy. The EU should set an example with ambitious goals and materialized action to contribute to solving the international challenge.

To make more clear the need for the EU to markedly pave the road for ambitious international climate policy, it is useful to understand the magnitude of the challenge. Even if Europe enhances its climate change mitigation efforts in line with its carbon targets, this will be insufficient if other countries do not match the effort.[1] In fact, the Paris Agreement nationally determined contributions (NDCs) are insufficient to achieve the IPCC Fifth Assessment Report mitigation scenarios to limit warming given current pledges.

The IPCC Sixth Assessment Report predicts several country-level shared socio-economic pathways (SSP) for CO_2 emissions extended as far as 2100. SSP1-1.9 represents a pathway for global emissions in which average global temperature rises are limited to 1.5°C, and SSP2-2.6 represents a pathway for global emissions in which average global temperature rises are limited to 2°C.[2] These two pathways in particular should be seen as targets relative to pathways such as SSP2-4.5, which is regarded as the high-emissions baseline, or business-as-usual scenario.

In the following analysis, this report attempts to calculate the gap between the world's current climate pledges and the target emissions scenarios. The two sources of climate pledges are Paris Agreement NCDs, collected from the Climate Action Tracker website,[3] and the recent net-neutrality commitments made by several nations. These pledges are combined with historical OECD emissions from the Greenhouse Gas Emissions database[4] to create reasonable country-level emissions pathways through 2050. For any nations without NCDs or net-neutrality commitments, the SSP2-4.5 mitigation scenario[5] was inserted to create a global forecast for emissions based on our current pledges.

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[1] See Deutch (2020) for a piece discussing similar limitations to any US efforts that focus narrowly on net zero emissions by 2050.

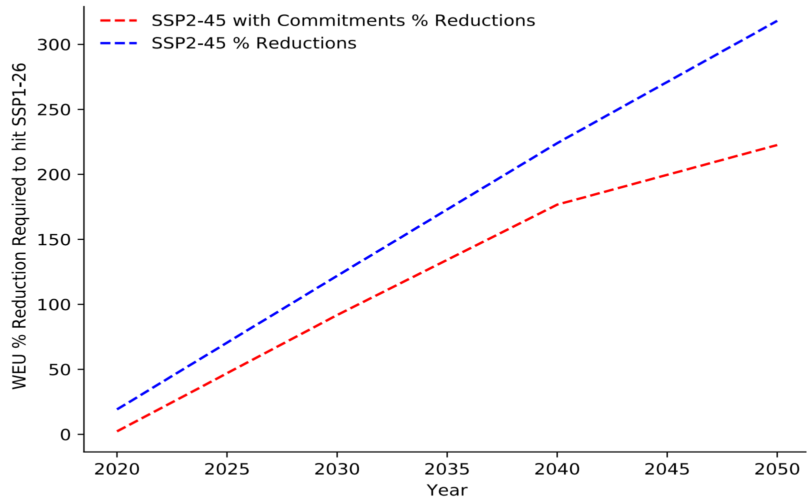
[2] Meinshausen, M. (2019), "The implications of the developed scenarios for climate change," In: Teske, S. (ed.), *Achieving the Paris Climate Agreement Goals*, Springer.

[3] https://climateactiontracker.org/.

[4] OECD Stats, Greenhouse Gas Emissions.

[5] As a test of robustness, and to demonstrate the differences between SSP2-4.5 relative to the Paris Agreement NDC forecasts, the business-as-usual mitigation scenario alone is used as a secondary reference to compare to the SSP1-2.6 mitigation scenario.

Figure 3 – Required percentage reductions to 2015 emissions (%)



Source: Own elaboration

Figure 1 compares the global emissions trajectories, in $GtCO_2e$, for the SSP1-1.9 mitigation scenario, the SSP1-2.6 mitigation scenario, the SSP2-4.5 mitigation scenario alone, and the SSP2-4.5 forecast combined with country-level pledges. While the SSP1-2.6 2°C warming track requires global emissions to be halved by 2050 relative to present day, the business-as-usual model indicates relatively stagnant emissions trends. The SSP2-4.5 track combined with mitigation pledges by key actors helps reduce emissions some but falls substantially short at delivering sufficient reductions by 2050. With clear evidence that the current stated commitments are not sufficient to meet the 2°C warming target, we then compute by what percentage, relative to 2015, the Western European Union must reduce their CO_2 emissions to reconcile the gap. Figure 3 shows the annual percent reductions.

Perhaps the most noteworthy aspect of Figure 3 is the stark nature of the results. The percent reductions are daunting at 50% in 2025 and net-zero by 2030, and become unrealistic under both scenarios shortly thereafter. There are four main lessons to take away from this analysis. First, the Paris Agreement NDCs and net zero commitments will not be sufficient to limit the rising global average temperature. Stronger mitigation policies are required for any hope of attaining the 2°C warming goal. Second, the burdens of these mitigation policies cannot be undertaken by only a handful of countries and regions. The efforts must span the globe if they are to have meaningful impacts. Third, it makes very clear the need to invest in negative emissions technologies that can help compensate for emissions in other regions. Finally, this analysis highlights that the scenario in which Europe takes “too much action” in mitigating climate change is highly unlikely under the stated goal of staying within target regarding the global carbon budget and warming.

Decisive action needs to be taken to fight climate change given the limitations in international enforcement. The need for negative emissions technologies and other policy solutions that engage a larger share of countries is self-evident.

Policies that reduce the compliance costs of non-complying countries (e.g., technological change either through explicit R&D policies or subsidies that trigger innovation) could be prioritized based on this principle as well. One option is to emphasize technologies that make alternatives to fossil fuels cheaper, such as scalable battery technologies for the electricity sector. This could help displace the burning fossil fuels even in countries that cannot afford, or do not desire, to participate in the effort to fight climate change. We discuss these aspects in detail in our recommendations regarding innovation policy (Section 3, point 4).

Carbon pricing implemented at the regional level is subject to substantial limitations when solving the international challenge, as it typically only prices domestic production. To ameliorate these issues, one should prefer policies that do not generate leakage, i.e., consumption taxes as opposed to production taxes or carbon border adjustment mechanisms. The desirable properties of these mechanisms need to be traded-off against the other aspects of the policies (e.g., feasibility). We discuss these issues more directly in the section about how to strengthen the EU-ETS (Section 3, point 1).

On moral grounds, there is an argument to envision a broader global cap-and-trade system with emission allowances based on an equal per capita basis. The mean emission of greenhouse gas in the world (as in France) is around 6 tCO_2e per capita and per year. But each of the 331 million people living in the U.S. emit 16 tCO_2e per year on average, whereas the 90 million people leaving in D.R. of Congo emit basically none. If one considers a carbon value of €60per tCO_2e, this means that U.S. excess emissions have an annual value of €200 billion, whereas the carbon credit of D.R.C. should be valued at €32 billion per year. The North should seriously recognize its responsibility in future climate damages and should consider the possibility of paying the South for implementing the necessary investments to green its economy. This could be performed by requesting the South to enter in a ETS mechanism and by offering them free permits proportional to their population, which would at the same time increase the incentives for mitigation in developing countries.

Climate change policies that alleviate the tragedy of the commons should be prioritized over otherwise similar alternatives. Policy innovations that incentivize developing countries to join carbon pricing schemes should be considered, even if they lead to substantial transfers between countries.

Summary – Facts, Perceptions and Challenges

- Scientific evidence indicates a tight window to mitigate the already irreversible impacts of climate change.
- France's public opinion understands the need for action but might not be aware of the scale and costs of the necessary action.
- Perceptions disfavor taxes and policies that do not directly address the impacts of regulations on the middle class.
- France can and should play a relevant leading role within the EU and the world to continue leading with ambitious decarbonization targets.
- Climate policies should be designed to actively help reduce the international coordination problem.

SECTION 2

MAKING CLIMATE POLICY PROGRESS

For many years now, France and Europe have been attempting to achieve their ambitious objectives of emissions reduction with a wide set of policy instruments and micro-actions. There is a myriad of opportunities, small or large, transitory or permanent, individual or collective, cheap or expensive, to decarbonize our economy. Two key questions need to be addressed in this context:

1. Which actions should be prioritized to attain our climate objectives?
2. How should we reorganize our economic system to make sure that these necessary actions will be implemented?

The first question is about which climate actions to implement, such as retrofitting houses or buying an electric car. The second question is deeper as it addresses the role of capitalism, market regulations, individual freedom, democratic values and economic growth to fight climate change. These two questions are intertwined, because the structural transformations of the economy should be aimed at making sure that the prioritized climate actions will be implemented everywhere and by everyone at the right intensity, today and in the future.

Determining the optimal climate policy would require knowing the marginal abatement cost of every possible climate action by every economic agents in every sector of the economy. Such a goal is herculean, as experienced by the IPCC, or by the Commission Criqui currently working under the auspice of France Stratégie to estimate the cost per tCO_2 saved by different climate actions. In this section, we explore various methodological questions. What is the right framework to evaluate different policy options? What are the relevant trade-offs? How to quantitatively and qualitatively assess the merits of each policy? In Section 3, we make some specific policy recommendations based on the principles described here.

1. Guiding Principles and Policy Tools

The EU has democratically determined its climate goals through an emission reduction pathway that goes through a 55% reduction (with respect to 1990) by the year 2030, and zero net emission by 2050.[1] This emission reduction target should be attained at minimal cost for the citizens. This means searching for the set of climate actions that have the least cost per ton of CO_2-equivalent saved. This requires the implementation of all actions that have a cost per ton of CO_2 avoided below a certain limit value. This threshold is named the "carbon value", or the shadow value of the climate goal (Quinet 2019). The higher the cost per ton, the larger the emissions reductions. This shadow value provides information on the marginal costs of complying with the emission target. The more stringent the climate goal, the larger the carbon value. The carbon value also depends upon the cost of the available green technologies. This concept exists independent of whether one wants to decentralize the climate action through a carbon price, i.e., a carbon tax or a market for emission permits. It exists as soon as one recognizes the need to minimize the social cost of the transition.

The scientific evidence informs the policy design and in particular this carbon value. First, it provides a measurable objective on the necessary reductions of emissions (high certainty). Second, it provides a measurable cost to reducing such emissions. This effort to estimate the schedule of carbon values that is compatible with the French climate ambition has been performed three times under the auspice of France Stratégie, with three commissions chaired successively by Marcel Boiteux in 2001, Alain Quinet in 2009, and again Alain Quinet in 2019 ("Quinet 2"). The recommendations contained in their report are summarized in Table 2. The estimation of the shadow price of carbon for long time horizons should be taken with caution. For a net-zero emission in 2050, the estimations of this shadow price of carbon of the six models used in Quinet 2 are between €511 and €3,513/tCO_2. In IPCC (2018), the range of this shadow value for 2050 is between \$45 and \$1,050/tCO_2 for the 2°C target, and between \$245 and \$14,300/tCO_2 for the 1.5°C target. This reminds us the deep uncertainty surrounding in particular the marginal abatement cost for full decarbonization of our economies.

[1] The 2050 horizon is too distant to make current politicians accountable for such a distant commitment. Intermediate commitments can thus add important value.

Table 2 – Shadow carbon price (in 2018 euros per metric ton of CO_2) in France implied by three different commissions

	Boiteux (2001)	Quinet 1 (2009)	Quinet 2 (2019)
2010	32	32	
2020	43	56	69
2030	58	100	250
2050	104	250	775

Source: France Stratégie

The prices presented in Table 2 are useful to highlight the dramatic changes that need to be accomplished over the next few years and decades. The carbon values estimated for 2030 and 2050 correspond to the shadow price of the corresponding emission targets committed at the time of the publication of the report. For the Quinet 2 report, this is a 40% reduction in 2030 and net zero emissions in 2050. The shadow price of the carbon budget in 2030, almost four times as large as in 2020, highlights the need to steeply increase our efforts to fight climate change. The 8% annual growth rate of the carbon value seems too high compared to what would be socially desirable, suggesting that we are currently in too slow a transition pace (Gollier, 2020).

Carbon budgets should be a guiding tool in understanding the costs of the necessary effort to stay within the targets and also as a way to track progress.

In this report, we take the 2°C target as given. Economists disagree on whether this objective is too ambitious or too weak. Answering this question requires making normative judgments about how to weigh the sacrifices to be made by the current generation against the reduction of climate damages incurred by future generations if these sacrifices are made. An alternative to valuing carbon as the shadow price of the 2°C target would be to use the Pigovian approach based on the social cost of carbon (SCC). The SCC is the present value of the flow of marginal damages generated by emitting one tCO_2 today. This is a legitimate measure of the benefit of a climate effort to be used when examining its social value creation. Integrated assessment models such as the DICE[1] of William Nordhaus have estimated this flow of climate damages, but the uncertainty surrounding them remains very large, in particular for temperature increases exceeding 2°C. Moreover, economists disagree on which discount rate should be used to compute their present value, since a large fraction of these damages materialize in the distant future. Even if one treats all generations equally, there are two main arguments to discount them at a positive

[1] Dynamic Integrated model of Climate and the Economy.

rate. First, future generations are expected to be wealthier. Under inequality aversion and in a growing economy, the discount rate should be interpreted as the minimum internal rate of return of an investment that compensates for the fact that investing for the future requires sacrifices from the poor (the current generation) for the benefit of the wealthy (future generations). The low current interest rates and the possibility of secular stagnation reduces the power of this argument. Second, the discount rate should be adjusted for the risk profile of the benefits of the project. Dietz and al. (2018) have shown that in the DICE model, most of the benefits of reducing emission materialize if future generations are prosperous. This means that fighting climate change does not hedge the macroeconomic risk. This justifies adjusting the discount rate upward.

All in all, a discount rate in the range of 2-3% seems to be justified to estimate the SCC. Nordhaus (2018), who used a larger discount rate of 4.5%, recommends a carbon price around €35/tCO_2 in 2020 and €100/tCO_2 in 2050. On the contrary, Stern (2007), who uses a much smaller discount rate around 1.4%, obtained much larger estimations of the SCC. For the medium range of discount rates between 2% and 3% that we recommend, the SCC and the shadow value of carbon for 2020 are in the same range of €50-€100/tCO_2. Carleton and Greenstone (2021) suggest a discount rate of 2% and a social cost of carbon at €100/tCO_2.[1]

So far, we have only described carbon pricing as an operational tool for determining whether climate action is socially desirable. This is only the case if the net cost per ton of CO_2 avoided of this action is smaller than the carbon value. In theory, one could imagine a world where the state would evaluate in this way the myriad possible climate actions that are under the control of a myriad of economic actors, consumers, companies, state and local governments. In theory still, the state could impose on each of these actors to carry out these socially desirable, but generally individually undesirable, actions. But the state is not omniscient and omnipotent, and this planning can only work for large-scale actions that are relatively easy to verify, such as anti-pollution standards in the automobile and residential sectors, or the banning of coal and national flight connections.

Hence the second question asked at the beginning of this section: how to organize society so that the actions that should ideally be carried out by this myriad of actors are actually carried out? How can we adapt our society based on individual freedom within the framework of a democratic society to achieve our collective goal of reducing greenhouse gas emissions? As will be explained in more detail in the following section, economists are almost unanimous in recommending that a carbon price, equal to the carbon value defined above, be imposed on all emitters without exemption. Faced with the question of whether

[1] Carleton, T. and M. Greenstone (2021), "Updating the United States government's social cost of carbon," University of Chicago, Becker Friedman Institute for Economics, *Working Paper*, No. 2021-04, January.

to emit by paying this carbon price or not to emit, this universal carbon price would naturally lead each emitter to efficiently integrate in the evaluation of its actions their impact in terms of emissions reduction and climate damage.

This carbon pricing can be done through a tax proportional to emissions, or through an emissions permit market. These two pricing systems are in place in France, but the price of carbon they induce remains too low. A necessary step to make progress in climate policy is to implement more aggressive carbon pricing. As we explain below, a carbon price has the very appealing features of being technically simple to implement, covering many sectors without picking ex ante the winners and the losers from the transition (leading to cost efficiency gains), and allowing a quick ramp up in the ambition of climate policies without the need of large sums of public spending, rather increased revenues.

In theory, carbon pricing could be implemented through subsidies rather than through taxes. Indeed, the right price signal of the climate constraint could be sent to all emitters by offering a universal subsidy per tCO_2 saved. But funding that scheme would require raising additional tax revenues elsewhere in the economy anyway. And determining the benchmark emission from which emission savings would be measured is not feasible. We are not aware of any economist defending this solution.

Unfortunately, carbon prices as high as those reported in Table 2 are unrealistic at the national and European level, and even more at a global scale. However, it is important to still advance carbon pricing strategies, even if imperfectly implemented. Indeed, a recent MIT study highlights that even modest carbon prices, in combination with other policies, can substantially improve the efficiency of the combined policy portfolio.[1] The new EU ambition to reduce emissions by 55% by the year 2030 makes carbon pricing more necessary than ever.

Strengthened carbon pricing, locally and globally, should be an important step to cost-efficiently fight climate change.

A successful policy portfolio to deal with climate change will need to incorporate several other policies. A successful portfolio of climate change policy should include actions along a wide range of policy tools (e.g., see Acemoglu et al., 2012), such as subsidies, standards, etc. There are several reasons why a full battery of approaches is needed, ranging from the existence of market failures that limit the effectiveness of carbon pricing to political economy considerations that make the policy tool set acceptable.

[1] Dimanchev, E. G. and C.R. Knittel (2020), "Trade-offs in climate policy: Combining low-carbon standards with modest carbon pricing", *MIT CEEPR Working Paper*, No. 2020-020, November.

Before examining the possible instruments of these non-price policies in detail, let us list the reasons why such instruments should be considered. They are listed in the so-called Stern-Stiglitz report (Stiglitz et al., 2017):

> "Achieving the Paris objectives will require all countries to implement climate policy packages. These packages can include policies that complement carbon pricing and tackle market failures other than the GHG externality. These failures are related to knowledge spillovers, learning and R&D, information, capital markets, networks, and unpriced co-benefits of climate action (including reducing pollution and protecting ecosystems). Some countries may conclude that the carbon-pricing trajectories required, if carbon pricing were the sole or dominant instrument, could entail excessive distributional or adjustment costs. Others may conclude that, given the uncertainties, requirements for learning, and scale and urgency of the transformation, rapid and more equitable change could be achieved more efficiently and effectively in other ways."

The coordination of the large transformation ahead has been highlighted as a benefit of more directive policies. Some researchers (e.g., see Rosenbloom et al., 2020) frame the climate challenge as a complex system problem whose decarbonization requires a coherent sequence of strategic decisions by different actors. The transformation of cities illustrates the complexity of the ecological transition from the point of view of a systems problem, in which prescriptive coordinated policies can be useful and preferred to a carbon price.

While these policies are generally more popular and well received, a challenge when implementing a wide range of policies is that it can be overwhelming to select which actions one should take. For this reason, a systematic and comprehensive cost-benefit analysis should guide action in this area, as we explain below. It is also important to ensure that the set of measures taken are consistent across sectors and consistent with an ambitious carbon budget overall goal.

Finally, due to the greater popularity of climate change policies that are more directed towards particular sectors (e.g., bans, subsidies, sector-specific taxes), it is tempting to lay out recovery plans that only rely on such measures, ignoring the need to increase the price of carbon. There are two points worth mentioning in this regard. First, this would be a missed opportunity. Failing to integrate the necessary pricing signal in the economy can lead to more inefficient, costly outcomes, potentially missing novel approaches to mitigation, and it is an implicit subsidy to the consumption of emissions-intensive products. Second, policymakers should be aware that the state cannot do everything, and that the bulk of climate efforts will be carried by the private sector. The extent, depth, and aggressiveness of directed climate change policies should be increased very substantially to match the targeted carbon budget. The war against the climate can only be won by mobilizing all economic actors. In the absence of a stronger carbon price, and particularly for policies involving subsidies, incentives or public investment, it is important to consider how revenues will be raised to match the challenge.

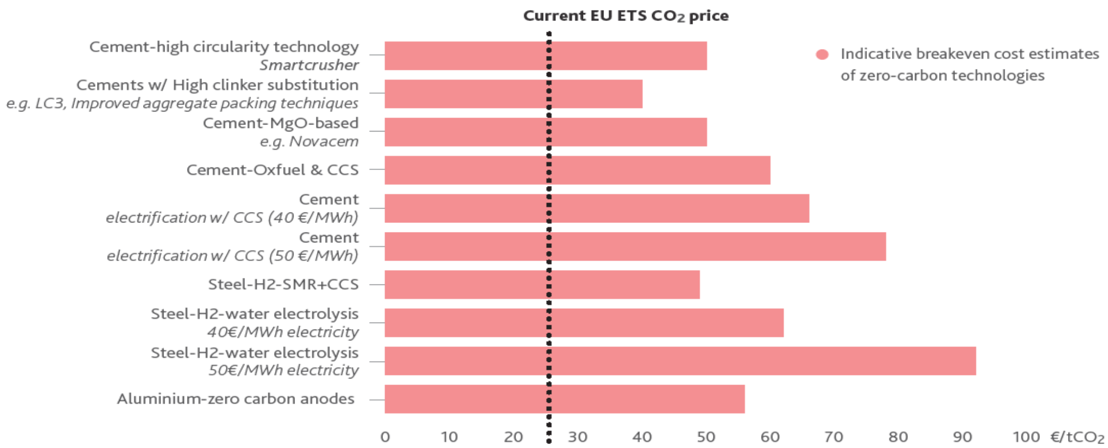
A wide range of targeted policies are needed to adequately fight climate change. Given limited resources, these policies need to be evaluated to inform the design of an effective policy portfolio. The ambition of such policy portfolio needs to match the desired target.

2. Carbon Pricing

In a free-market economy of free people, consumers and corporations have no natural tendency to integrate the global carbon budget constraint in their own actions plans. Thus, "climate change is a result of the greatest market failure the world has seen" (Stern, 2007). Since Pigou (1920), economists have been discussing a simple operational solution to solve this market failure. Over the years, this solution took a simple name, the polluter-pay principle, a principle that is overwhelmingly supported by French citizens. If a carbon price is uniformly imposed to all economic agents and is established at a level compatible with the global emission target, it aligns the myriad of private interests on this collective goal. If it is combined with other policies to tackle other sources of inefficiencies, it does this at the lowest possible collective cost. It therefore provides the best compromise between "the end of the month" and "the end of the world", a key condition of social acceptability in particular if the distributive effects are neutralized by a transparent redistribution of the carbon dividend. The urgency and the intensity of the climate challenge should be translated into a large carbon price. Carbon pricing has the advantage of being the policy tool that puts emphasis on the cost efficiency in terms of cost per tCO_2 built-in without the need of identifying the policies that will work in advance.

This point is very clear when considering the impact of a carbon price in a particular sector. Figure 4 presents estimates for different decarbonizing strategies in the cement and steel industries, which account for 18% of GHG emissions in Europe. These estimates suggest that costs are between €40 and €90/tCO_2 depending on the exact technology chosen. Instead of choosing a technology, the carbon price signals the costs of emissions and leads to the most cost-effective choices. It might also spur the development of alternative technologies not represented in Figure 4. As opposed to more prescriptive policies, a carbon price leaves room for innovative responses to the increased cost of carbon.

Figure 4 – Cost per tCO_2 saved in the cement and steel industries



Source: Sartor and Bataille (2019)

A value to carbon emissions also helps inform the needed actions across sectors. To illustrate the choice dilemma, let us consider three specific climate actions:

- Coal-to-gas: In Europe, the levelized cost of electricity (LCOE, which ignores the carbon price) is larger for natural gas than for coal, but one kWh of coal electricity generates more CO_2 than one kWh of gas electricity. It is estimated that a carbon price around €30/tCO_2 will make natural gas more competitive than coal to produce electricity in Europe. In other words, switching from coal to natural gas would have a cost per tCO_2 saved of €30/tCO_2. Such a reallocation of the EU electricity would have a large impact on EU emissions.[1]

- Residential photovoltaic panels: In France in July 2020, the feed-in-tariff program offered to all households willing to install photovoltaic panels on their roof a 20-year contract with a guaranteed price of 18.44 cents per kWh. Let us consider the best-case scenario in which such green kWh production eliminates coal kWh production for two decades. The policy increases the cost of the kWh for consumers by 10.94 cents and eliminates 340 g of CO_2. This raises the social cost of emission reduction to €304/tCO_2 saved.[2]

[1] A simple estimation of the cost per tCO_2 saved comes from the observation that in Europe in 2030, the levelized costs of electricity of new coal and gas power plants are expected to be equal to respectively €80/MWh and €97/MWh. One MWh emits 0.99 tCO_2 on average when produced with coal, but only 0.43 tCO_2 on average when produced with natural gas. In other words, one can save one tCO_2 at a cost of 17/0.56 = 30.36 euros by switching from coal to gas. This estimation does not take account of the other costs (lost jobs in the mining sector) and co-benefits (coal is dirtier) of this climate action.

[2] In 2010, the guaranteed price was 60 c/kWh, leading to a cost per tCO_2 around €1,544. We ignore here various other costs and benefits of the PV investment, such as the elimination of particulate matters around

- Speed limitation: In 2018, the Commissariat général au développement durable estimated the impacts of reducing the speed on French highways from 130 km/h to 110 km/h. The reduced death toll, the increased time lost in transportation, the fuel saved, the reduced noise, the cost of changing traffic signs, the increased congestion and the reduced emission of CO_2 were all taken into account. This cost-benefit analysis resulted in a measure of the social cost per ton of CO_2 saved around €500.

Implementing measures ranked by the marginal abatement cost (MAC) per tCO_2 saved minimizes the monetary costs for a given emissions reduction goal. Even if policies are not approved only based on this measure, the calculation of a unified MAC makes clear potential inconsistencies in climate change policy. For example, it would be inefficient to limit the speed on highways for the climate argument while continuing to use coal to produce electricity in Europe. Taking the first action and not the second leads to reach the goal of reducing emissions at a higher social cost. It also highlights that one of the best climate actions is to switch off all coal power plants on the continent and stop its extraction at a much faster and ambitious pace than currently planned.

People often underestimate the impact that prices have on our life. There exists no societal transition in History that has not been accompanied by a radical change in relative prices. Gutenberg printing invention dramatically reduced the cost and the price of books, thereby triggering the Renaissance and the Reformation movements. From pricey whale oil in the 16th century to the LED today, the cost and price of light has been reduced by a factor 1000, thereby transforming the "Dark Age" into a planet of light. After WWII, France controlled housing rental prices, with dramatic consequences on the supply of housing in the 1970's, with "bidonvilles" surrounding the cities, and with the actions of Abbé Pierre.[1] The price of gasoline at the pump has been twice larger in the EU compared to the United States over the last few decades, and this has a huge impact on the structure of the fleets of automobiles on the two sides of the Atlantic. Similarly, a growing price of carbon is necessary to accompany the energy transition.

A carbon price induces firms and consumers to choose the least-cost abatement options at that given carbon price. In the long run, price signals have a transformative impact on our lives.

There exist two possible carbon pricing mechanisms. Under the carbon tax mechanism, the state controls the carbon price by fixing the level of the carbon tax, and economic agents facing the tax adapt their emissions to this price signal. In that system, the price is

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the coal power plants, the environmental cost of producing and recycling PV cells, or the other PV subsidies such as tax shields on capital expenditures and zero-interest-rate loans. A more comprehensive cost-benefit approach is discussed in more details below.

[1] We don't want to mean here that an unregulated competition on the housing rental market is the solution.

determined by the state, and the quantity is determined by the market. Alternatively, the state could sell emission permits to emitters and allow them to exchange these permits on a market where an equilibrium price of carbon will emerge. In that "cap-and-trade" system, the quantity is determined by the state, and the price is determined by the market.

A carbon price, implemented in either form, can be very effective and efficient at signaling necessary changes in production, as it signals the external costs of emitting CO_2 without the need to ex ante know what the best options are. The EU has had a carbon price in place since 2005 with its European Union Emissions Trading Scheme (EU-ETS), a cap-and-trade market. In 2019 in the EU, CO_2 emissions from the power sector fell by 12%, led by a steep decline in coal power generation, which was replaced half by natural gas and half by renewables. A plausible interpretation is that this comes mainly from a large increase in the price of CO_2 on the EU-ETS, from around €5/tCO_2 earlier in the decade to around €25 in 2019. It has reached €38 at the beginning of 2021. A tax on carbon dioxide emissions in Great Britain, the "Carbon Price Support" (CPS) of around £18/tCO_2 introduced unilaterally in 2013 on top of the EU-ETS mechanism, has led to the proportion of electricity generated from coal falling from 41% in 2013 to 7% in 2018 in that country (Gissey et al., 2020). Leroutier (2019) estimates that the CPS has reduced the total power sector emissions in the UK by almost 50% by 2017.

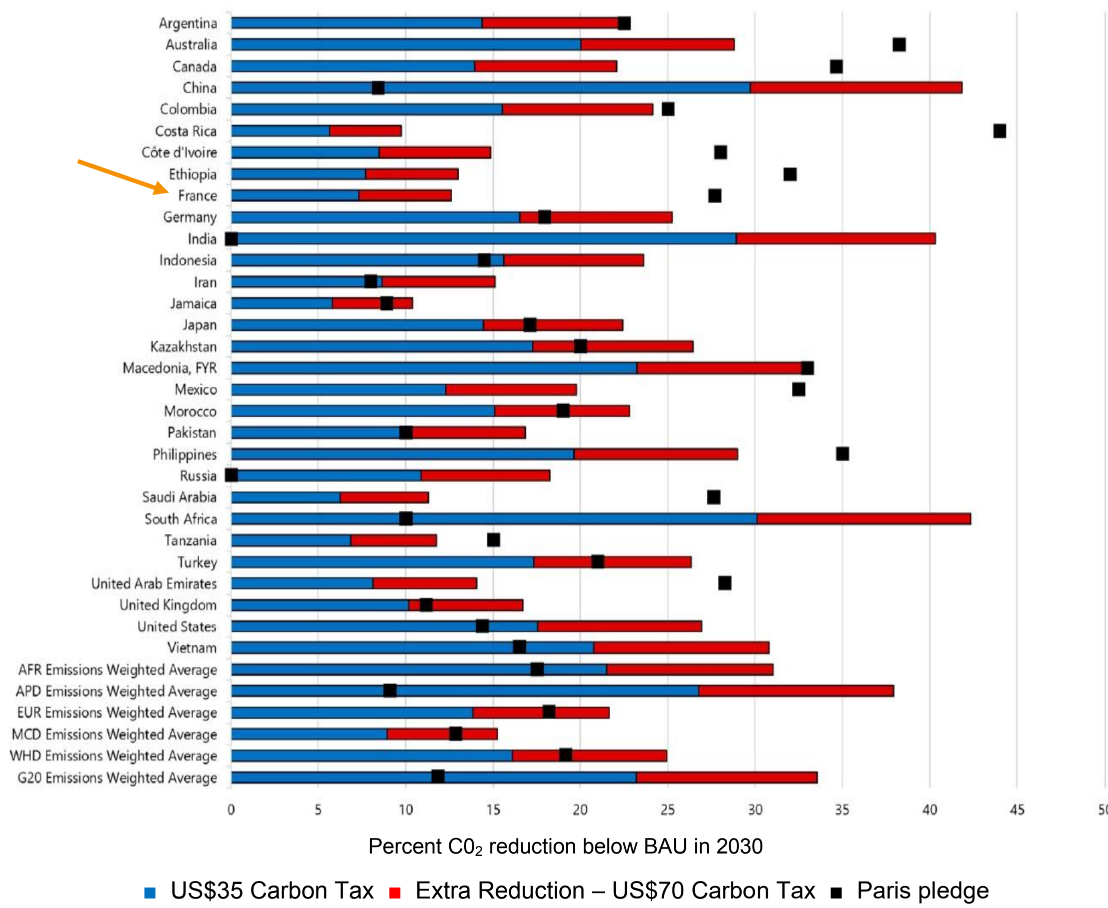
A carbon price does not only modify the production processes of goods and services in a more sustainable way. It also reduces the consumption of these goods and services whose production cannot be decarbonized. For example, it increases the price of gasoline at the pump, thereby reducing its consumption. For example, the £18/tCO_2 CPS in the UK raised the price of electricity by 20% (Gissey et al., 2020), because coal electricity is often the marginal technology that balances supply and demand in the UK. And a €50/tCO_2 tax on gasoline raises its price by 12 cents per liter. The long-term price-elasticity of gasoline demand has been estimated somewhere between -0.5 and -1.2.[1] This means that price-signals work, as illustrated by the difference in car characteristics between Europe and the United States linked to the vastly smaller gasoline taxes on the other side of the Atlantic. A carbon tax is thus compatible with the concept of degrowth, but a degrowth targeted on carbon-intensive goods.

A recent econometric analysis of the impact of carbon taxes on CO_2 emissions in Europe has been performed by Metcalf and Stock (2020). They use the important heterogeneity of carbon tax levels and timing across European countries over the last 20 years. They show that a \$40/tCO_2 carbon price limited to 30% of emissions sources would reduce global EU emissions by 4 to 6%. They argue that reductions would likely be greater for a broad-based carbon price mechanism since the study does not include in the tax base those sectors with the lowest marginal costs of carbon pollution abatement. (IMF, May 2019) is more optimistic,

[1] See for example the recent meta-analysis by Labandeira, Labeaga, and López-Otero (2017).

since this analysis shows that a uniform carbon price of \$35/tCO_2 could easily generate enough reductions of CO_2 to attain many national NDCs of the current Paris Agreement. However, this will be much easier for countries such as Germany, India or China, which use coal in their electricity mix than for France. More information is available in Figure 5. The French case is specific, because of its already vastly decarbonized electricity mix. Because the United States do still heavily depend on coal and did not incentivize people to save energy in the past, it would be much easier for that country to reduce emissions. The Stern and Stiglitz's report of the High-Level Commission on Carbon Prices (Stiglitz et al., 2017) claimed that "the explicit carbon-price level consistent with achieving the Paris temperature target is at least \$40-80/tCO_2 by 2020 and \$50-\$100/tCO_2 by 2030."

Figure 5 – Impact of a \$35 or \$70/tCO_2 carbon tax on CO_2 emissions, and comparison with Paris pledges

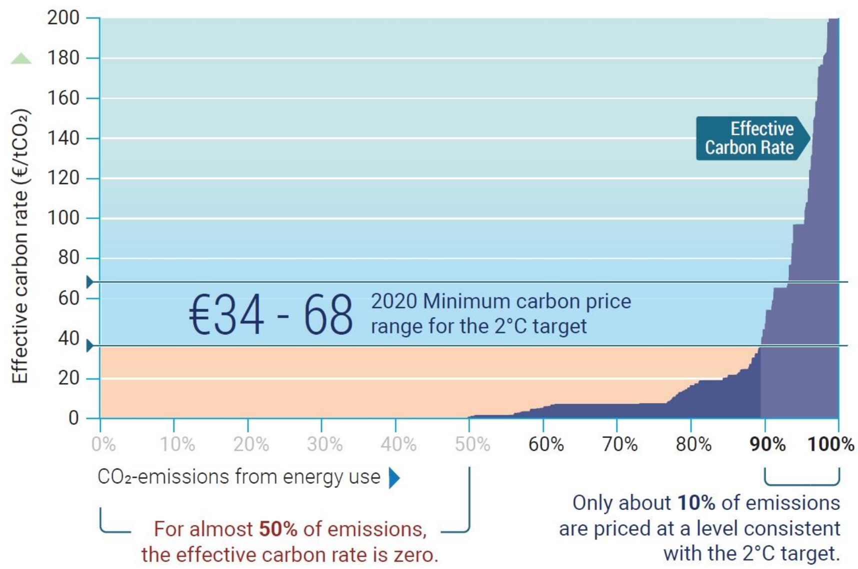


Source: Stiglitz et al. 2017

Carbon pricing not only incentivizes cleaner production processes, it also signals the benefits of reducing consumption of emissions-intensive goods leading to the necessary transformation of our society.

Carbon prices should be applied uniformly. However, we are very far from such a uniform carbon pricing in the OECD and G20 countries, as illustrated in Figure 6. Measuring effective carbon prices is made complex because of the other taxes covering energy products. In Europe for example, non-carbon taxes are imposed on gasoline to finance road infrastructures and to cover other externalities (local pollutants, congestion, noise). For France, it has been estimated at the occasion of the *Grenelle de l'Environnement* that these other taxes cover the value of these non-climate costs (Rocard, 2007).[1]

Figure 6 – Distribution of effective carbon prices over energy-related CO_2 emissions for 42 OECD and G20 countries, representing 80% of global CO_2 emissions



Note: Carbon prices include carbon taxes, permit prices related to existing ETS and excise taxes on energy (also including those not motivated by a climate policy objective).

Source: OECD and UNEP (2018)

The absence of exemptions to the carbon price is critical for the lobby-proof argument, but more importantly for least-cost efficiency. The government must resist the influence of the lobbies in this area. Any difference in carbon prices faced by different consumers, producers,

[1] Indeed, Figure 6 can be very misleading for gasoline products. A recent IMF report (Coady et al., 2019) shows that gasoline is still subsidized relative to its true cost to society in France and the EU, and, therefore, its effective carbon rate is below the desired level. The effective carbon rate of gasoline products is mostly zero in the European Union.

sectors, countries or regions is cost inefficient, as transferring some efforts from agents confronted by a high carbon price to agents confronted by a lower carbon price would reduce total cost for the same total emissions reduction. Similarly, imposing specific emissions targets to specific sectors or regions would raise the global cost with no global benefit associated. Splitting the global carbon budget into sectoral or regional carbon budgets will require imposing different sectoral or regional carbon prices, which is not least-cost efficient.

The fairness of the allocation of emission reductions should be measured by the allocation of net costs, not by the allocation of emissions in the economy. The French *Stratégie nationale bas-carbone* (SNBC) by the ministère de la Transition écologique et solidaire (2020) provides a reference scenario of sectoral reductions until 2033.[1] The executive order ("décret") 2020-457 of April 21, 2020 translates this scenario into sectoral carbon budgets.[2] But visibility and predictability should be on future carbon prices, not on sectoral reduction efforts. Ideally, the SNBC should be optimized by ensuring that the sectoral targets it sets lead to an equalization of marginal abatement costs, i.e. implicit sectoral carbon prices.

The important exemptions to the carbon tax offered to taxis, farmers, fishers, truckers or airline and maritime companies do not only demonstrate the inefficiency of the system. They have also nurtured a sense of inequity that has been at the origin of the *Gilets jaunes* movement (Yellow Vests). The dual mechanisms of a carbon tax at €44/tCO_2 for consumers, and the EU-ETS price at around €25/tCO_2 for the industry, reinforced this sentiment.[3]

There is a strong consensus among academic economists around the world on this issue. In January 2018, the Climate Leadership Coalition (CLC) published a statement to support a uniform carbon tax in the United States.[4] In its first article, it stated that "a carbon tax offers the most cost-effective lever to reduce carbon emissions at the scale and speed that is necessary." It was signed by more than 3,500 academic economists, 27 Nobel Laureates in economics, all former Chairs of the Fed, and 15 former chairs of the Council of Economic Advisers. In Europe, a similar statement[5] was coordinated in 2019 by the European Association of Environmental and Resource Economists. In the early summer of 2020, a coalition of three

[1] It is fair to say that the SNBC is not a compulsory allocation of the mitigation efforts in France. Its periodic revision should be based on the equalization of the marginal abatement cost across sectors.

[2] See *Journal Officiel*, décret n° 2020-457 du 21 avril 2020. For example, the transportation sector should reduce emissions from 0.137 Gt$C0_2$ in 2015 to 0.94 GtCO_2 in 2029, whereas the agricultural sector should go from 0.089 to 0.072 GtCO_2.

[3] The use of the carbon tax to increase budgetary revenues, as opposed to benefit households, also reinforced such perception (Douenne and Fabre, 2020b).

[4] "Economists' statement on carbon dividends", first published in the *Wall Street Journal* on January 17, 2019: https://clcouncil.org/economists-statement/.

[5] https://www.eaere.org/statement/

German Academies of Sciences[1] published a statement "to create a uniform price for all greenhouse gases, covering all sectors, regions, stakeholders and technologies."

In France, several public institutions have publicly recommended to relaunch a redistributive carbon tax after the carbon tax freeze by the government in December 2018 at the occasion of the *Gilets jaunes* movement. The Haut Conseil pour le climat, the Conseil des prélévements obligatoires,[2] the Conseil d'analyse économique,[3] the Commissariat général au développement durable,[4] the Conseil économique du développement durable[5] and the French-German council of economic experts have all recently expressed their support for using such a solution, as an inescapable instrument to attain our climate objectives. Several French think-tanks, like Institut Montaigne[6] and Terra Nova[7], and NGOs share this view. Over the last three decades, France Stratégie has published a series of reports to revise the values of carbon that are compatible with the French climate ambition.

Ideally, governments should use their fiscal power to price all emissions, using a unique carbon price per tCO_2, without any exemption.[8] Any emitter would examine its own options to reduce its emissions, and it would rationally decide to implement all those which would cost it less than the carbon price, and only these ones. This universal carbon pricing system is a crucial signal to decentralize the mitigation decisions of the myriad of emitters on this planet. It is easy to implement when the sources of GHG emissions are observable and it does not require raising revenues. It is also a transparent decentralization procedure whose lobbies will find hard to manipulate.

Recognizing a growing consensus among academic economists and elsewhere, we recommend to decentralize our collective climate ambition through uniform carbon pricing.

For a given capital stock in the energy, industry, transportation, housing and agricultural sectors, the margins to reduce emissions exist but are relatively limited. The current carbon

[1] *Energy Transition 2030: Europe's Path to Carbon Neutrality*, German National Academy of Sciences Leopoldina, ACATECH - National Academy of Science and Engineering, Union of the German Academies of Sciences and Humanities, June 2020.

[2] CPO (2019), *La fiscalité environnementale au défi de l'urgence climatique*, September.

[3] CAE (2019), "A proposal for the climate: Taxing carbon not people," by Bureau, D., Henriet, F. and K. Schubert, note No. 50, March.

[4] See Commissariat général au développement durable (2020), *La tarification des émissions de CO_2 en France*, July.

[5] CEDD (2019), "Impact du prix du carbone sur les émissions de CO_2. Des indices aux preuves", November.

[6] Chaney E. (2019), "Dividende carbone : une carte à jouer pour l'Europe," Note.

[7] https://tnova.fr/revues/taxe-carbone-comment-la-fiscalite-verte-s-est-mise-en-place-dans-certains-pays.

[8] We discuss in Section 3 (1.2) which sectors and emissions are likely to be included in practice.

price affects the incentives to reduce emissions using intensive margins: drivers can reduce their speed and distance; people can consume less beef; frequent flyers can switch to trains; households can use air-conditioning less intensively. However, there are limits to what can be attained in this way. The ecological transition requires more radical large-scale transformations that will affect the capital structure of the economy.

Most investment projects necessary to green our capital structure have long maturities: 15 years for electric cars, 20 years for PV panels and windmills, 50 years for nuclear power plants and the housing sector, and a century or more for high voltage electricity networks and transportation infrastructures. The decision to invest in these assets is determined by the expectations about what the carbon price will be during the entire lifetime of the investment rather than by the current carbon price. The carbon prices that will prevail until at least 2050 are the key determinants of the profitability of most green projects today. The low expectations about them is a key element of resistance to the triggering of the green revolution. Many green investments are socially desirable given our collective climate objectives and their associated carbon price, but they are not perceived as privately profitable because of these low expectations. The hesitations of the French government on the level of the carbon tax, and the EU's procrastination on the indispensable reforms of the EU-ETS system do not reassure the private actors involved in the transition. Too many producers and consumers continue to invest today in long-lived, carbon-intensive projects.

In spite of their large size, the announced recovery plans of 2020 do not provide a transparent way to green our economies. In particular, public money has been used to bail-out carbon-intensive industries, whereas consumers and corporations continue to invest in projects that are not compatible with the EU climate ambition. Governments can save our jobs and companies and, at the same time, reallocate productive capital in line with this ambition by credibly committing on large future carbon prices. It is also recommended that France and other EU countries abandon their current support for the fossil fuel industry, which takes the form of public loans and guarantees at below-market price for exploration, insurance, investments by state-owned companies, or direct fossil fuel tax exemptions. IISD (November 2020) recently estimated that G20 governments provided "$584 billion annually (2017–2019 average) via direct budgetary transfers and tax expenditure, price support, public finance, and [state-owned entreprise] investment for the production and consumption of fossil fuels at home and abroad." It also observed that "G20 countries allocated some $170 billion in public money commitments to fossil fuel-intensive sectors in response to the Covid-19 crisis between January 1st and August 12th, 2020." States should not interfere in the industrial organization of fossil fuels markets in any other way than carbon pricing.

To trigger now an extensive ecological transition compatible with our collective climate ambition, it is necessary to commit on a trend of growth for carbon prices until 2050. All subsidies to fossil fuels should be immediately banned.

There is much uncertainty today about which mitigation technologies will be available in even a few years from now, and about the associated cost per tCO_2 saved. This implies that we don't know today what carbon price will be necessary in the future to attain the planned emission target. Among the 356 IAM models used in the 5th report of the IPCC that are targeted to a 450 ppm CO_2 concentration, the mean carbon price in 2030 is $118/$tCO_2$, with the standard deviation of $273/$tCO_2$ and a range between 0 and $500/$tCO_2$. This large heterogeneity reflects the technological uncertainty we face to decarbonize our economies (Gollier, 2020). This scientific uncertainty is reflected in the public debate, with some experts promising degrowth as the only possible abatement strategy (such as Jean-Marc Jancovici, from the Shift Project), while others believe that we will be able to completely decarbonize the European electricity mix by 2050 without increasing the price per kWh (such as Philippe Quirion, from Cired). Targeting quantities – i.e., fixing an objective in terms of limits to temperature increases, an intertemporal carbon budget, or emission pathways – leads to a large uncertainty on future carbon prices that will be borne by green entrepreneurs. At the same time, it may be socially desirable to allow for more emissions in the future than initially planned if marginal abatement costs remain prohibitively large. Under uncertainty, flexibility is key. Incomplete markets, i.e., the inability to find insurance against the carbon price risk, justify completing markets by imposing floors and ceilings to future carbon prices (see Section 3, 1.1).

The macro-finance literature over the last three decades has demonstrated that uncertainty is a key element in the timing of the decision to invest. In the absence of long-term risk-sharing mechanisms, more uncertainty induces entrepreneurs to postpone their decision to invest. The OECD (2021) has recently built climate policy uncertainty indices for a set of countries and it has correlated these indicators with the firm-level intensity of green investments. It shows that "the overall increase in environmental policy uncertainty observed in the countries covered by [its] indicator in recent years may have significantly slowed down efforts to decarbonize the economy." Thus, targeting emission reductions may have been a bad choice in the policy debate since the Kyoto Protocol when these initial quantity targets were negotiated. Then, why not commit to price targets? Price targets have the advantage to reduce the risk borne by green entrepreneurs. They are thus likely to trigger a strong movement towards the ecological revolution necessary to fight climate change. A carbon pricing pathway should be planned today for the next 30 years aimed at maintaining the temperature increase below 1.5 °C with some predetermined probability (90%, 95%?). Some variations below or above this price targets would be allowed by using some predetermined rules (Metcalf, 2019).

A key challenge of the current EU-ETS mechanism is that it is quantity-based, and therefore its prices can fluctuate substantially. This is particularly true with a carbon emission pathway approach where fixed emission reductions must be achieved at different dates. A given temperature target is associated to an intertemporal carbon budget, which allows more flexibility to react to the resolution of uncertainty surrounding green technological progress. The lack of a clear future price signal can limit investment. A clearcut illustration of this is given by the feed-in tariffs for PV panels in many EU countries. The existence of a guaranteed price for the electricity generated by these panels over 20 years triggered a huge demand that forced many countries to reduce the incentive. If this is possible with a subsidy to PV, why wouldn't it be possible with a carbon price?

Economists have discussed passionately about quantity targeting versus price targeting since the publication of the seminal paper by Weitzman (1974) on this topic. Given risk-bearing argument against the quantity targeting, there is now a consensus among economists that price targeting should be favored, as exemplified by the Economists' statement on carbon dividends of the Climate Leadership Coalition signed by 27 Nobel laureates in economics. As explained later on, the high price uncertainty generated by a quantity target limits the strength of the price signal. This must be fixed by switching to a hybrid mechanism in which the quantity target is framed by a price collar (see Section 3, 1.1). Yet, in practice quantity targets are much more common place.

France and the EU should commit on a carbon budget that is compatible with their climate goals with high confidence. Carbon price predictability should be promoted over emission targets to trigger the large-scale all-encompassing ecological revolution today in spite of the low current carbon prices.

3. Evaluating Complementary Climate Change Policies

We support a holistic approach to fighting climate change. The intensive work performed by the 150 randomly-selected citizens of the Convention citoyenne pour le climat produced a report (CCC, 2020) which illustrates the wide variety of possible actions [1] (see Box 1, next page).

[1] Other measures not directly related to climate change are not discussed here.

Box 1 – The "climatic" measures proposed by the Convention citoyenne pour le climat

- Banning terrace heaters.
- Banning advertisements for carbon intensive goods, such as S.U.V.
- Banning airline connections between French cities that can be traveled within 4 hours by train (see Section 3, point 7).
- Taxing the aviation industry proportionally to its carbon emissions (ibid.).
- Improving the attractiveness of trains, bicycles and shared transportation systems, through specific subsidies and a stronger public support for train/bike/car-sharing infrastructures.
- Banning soon the most polluting cars from densely populated cities (ibid.).
- Planning the phase out of the fossil fuel cars in Europe (ibid.).
- Banning fuel and coal heat systems, together with housing units ranked F and G, by 2030 (see Section 3, point 3).
- Reinforcing subsidies for global thermal retrofitting of the poorly insulated housing units, improving regulation (certification and labelling systems) of the energy efficiency market (ibid.).
- Developing the carbon accounting for all goods and services, and enlarging the scope of firms with a climate reporting obligation (see Section 3, point 5).
- Compensating and re-training workers most affected by the transition (see Section 3, 1.4).
- Imposing a carbon border adjustment mechanism (see Section 3, 1.3).
- Reducing the tax deductibility of carbon-intensive transport expenses.
- Rebalancing truck freight to (more efficient) railways.
- Reducing the speed limit on highways.
- Reforming the international pollution standards prevailing in the shipping industry.
- Promoting low-carbon organizations of labour.
- Investing in the energy efficiency of public buildings.
- Reforming the EU Common Agricultural Policy to green the agricultural sector (see Section 3, point 6).
- Penalizing environmental crimes ("*écocide*").

A large set of specific climate policies should be implemented at an intensity compatible with the strong EU ambition and the global transformation of our society necessary to achieve them. This climate policy package should be optimized to attain the emission target at a minimal social cost in order to reinforce its social acceptability. On a more positive tone, the portfolio of climate policies should be aimed at maximizing its positive impact on the welfare of French citizens, under the constraint of satisfying our emission target. It is a prerequisite for its acceptability. This requires being disciplined when comparing alternative policies given the wide range of options that are available and its varying implications in terms of co-benefits and potential spillovers. The intuition suggests that many recommendations of the CCC are expected to pass this test, but others not. For most of them, as we write this report, this cost-benefit analysis remains to be done.[1] A counterexample is the recommendation to reduce the speed limit to 110 km/h, which is known not to pass the test of generating more social benefits than social costs, as demonstrated by the Commissariat général au développement durable (Fragnol, 2018). Or, it is clear that short flights are dominated by fast train connections from a social point of view, but the threshold of train travel time of 4 hours to ban flights, as proposed by the CCC, should be optimized considering all costs and benefits. Even if some recommendations do not pass a strict cost-benefit analysis, it is necessary to provide a justification behind their adoption. This will increase transparency and avoid backlash as more and more ambitious policies are put in place. Even if suggested by the CCC, these more ambitious policies will also leave winners and losers behind, and thus generate some tensions. Finally, the recommendations of the CCC, whose global impact on French emissions have not been estimated, will certainly be insufficient to attain the 55% reduction target for 2030, in particular because they failed to address the key issues of the electricity mix and carbon pricing. In this report, we recommend to combine a portfolio of specific efficient policies with the imposition of a universal carbon price. Both legs are necessary to achieve our climate ambition.

Many, but not all, recommendations made by the Convention citoyenne pour le climat are likely to have a positive net social benefit for our citizens under the climate constraint. They will not be sufficient to reach the climate ambition of the country.

The multiplicity of targeted policies is a potential source of complexity and inefficiency. For example, subsidizing the development of solar and wind electricity in Europe is costly for the public purse, but it will have no effect on EU emissions, at least in the short run, since the electricity sector is covered by the EU-ETS system. These subsidies simultaneously reduce the demand for allowances by the electricity sector and their equilibrium price. This mechanically generates an equivalent increase in emissions by the

[1] The CCC's recommendations that will be translated into law will have to be evaluated ("*étude d'impact*") in the spring of 2021.

other sectors covered by the ETS (waterbed effect). In short, the solar and wind subsidies are pocketed by the cement and steel industries. These subsidies should at least be neutralized by an equivalent reduction of allowances on the market. It is also inconsistent to impose an eco-contribution from the airline industry, and at the same time asking it to fully compensate emissions by planting trees, to integrate the EU-ETS system, and to ban local flight connections. Social acceptability and least-cost efficiency require transparency, coherence and simplicity. In particular, if citizens accept the idea that a price signal is useful, a single instrument across sectors should be used. It should be a reformed and enlarged ETS system.

A first benchmark for evaluating the efficiency of policies at reducing GHG emissions is to create standardized measures of the monetary costs of reducing a ton of CO_2 for alternative policy tools, what is often called the Marginal Cost of Abatement (MAC). Cost measures in euros per tCO_2 can be very useful to elucidate which policies are urgent, which policies are more in a middle area in which other trade-offs should be considered, and which policies are unlikely to generate enough benefits even if feasible. This analysis can be performed by a public institution to evaluate any specific climate policy, by a socially responsible investor to evaluate the alignment of her portfolio to the common good, or by a corporation interested in measuring the extra-financial merits of its investments. This shadow price would then play the role of an “internal price of carbon” (see Section 3, point 5).

To make this classification, simply compare this MAC to the carbon value. The shadow price, or internal price of carbon, is likely to be larger than the carbon price that is put in place, given its limited social acceptability, thereby illustrating the second-best nature of the global climate policy package under this motivation. Valuing additional policies at the shadow cost of carbon makes it precise that current carbon pricing efforts are not on par to the challenge. Importantly, this shadow price of carbon should be unique for all policies being evaluated and included as an integral part of policy-making more generally.

The CCC recommended that climate impacts be included in the list of criteria for the evaluation and for the selection in public procurement procedures. The evaluation of the competing projects should be based on a sound cost-benefit analysis, in which their non-financial performances are integrated into the global measure of performance through transparent tutelary values. For example, decision-makers should use the public carbon value (from Quinet 2) to measure and compare the effective societal value creation of the projects under scrutiny. The greenness of a project cannot be in itself a sufficient condition for its selection against other competitive proposals. Public decision-makers should not get discretion about how to value extra-financial performances of offers submitted in public procurement, and clear evaluation guidelines should be published at the central level.

Transparent measures of the cost of reductions of alternative policies should be calculated. The shadow price of carbon should serve as a signal to all aspects of public policy making.

For most interventions, the cost per tCO_2 will be only one dimension of a much broader cost-benefit analysis (CBA). These policies will have other impacts, or co-benefits, beyond reducing CO_2 emissions. They will generate positive externalities (learning by doing, dynamic benefits from investing, knowledge and network spillovers, reduced local air pollution, etc.), more jobs, and they could have an impact on inequalities. The evaluation of public interventions, in particular from the EU Green Deal, should incorporate the social value of (good) jobs in more labor-intensive projects, probably tilting actions toward locally produced biofuels or reforestation in comparison to capital-intensive windmills for example. But contrary to the current practice of a multiple criteria approach, we recommend using CBA with a transparent way to value co-benefits, in particular, labour and inequality benefits. Many climate actions will transform society in a non-marginal way, so that the CBA must include general equilibrium effects that are difficult to predict in this context. Additionally, green policies tend to be seen more favorably by the constituents.

In addition to the cost of reducing one tCO_2 and its benefits, the degree of effectiveness in reducing emissions and the certainty around the estimated reductions is another important aspect to consider. Following the example from above, stopping coal extraction and consumption is likely to have immediate impacts on emissions, given that all likely substitutes, including natural gas, have smaller emissions intensities. Carbon capture and sequestration at power plants, on the other hand, can be more speculative over long horizons and its effectiveness harder to measure. The monitoring and verifiability of the reductions is also of crucial importance.

For policies to effectively reduce greenhouse gas emissions, they must be additional. Given scarce resources to fight climate change, it is inefficient to incentivize measures that would have occurred even in the absence of such incentives. This can be true at a micro level,[1] or at the macro level.[2] Given limited resources to expand these policies, it is important to consider these potential inframarginal effects when evaluating policies.

From a practical perspective, incorporating climate change at all stages of policy making requires: (i) transparently publicizing the official shadow price of carbon used in the evaluation of policies, (ii) setting guidelines for how to compute the climate change benefits and co-benefits of proposed policies, and (iii) creating a body of public servants that can provide guidance on the climate risks associated with given policies.

[1] See Boomhower and Davis (2014) for an application to energy efficiency on ways to measure additionality.

[2] For example, compensate the exit of a declining industry under the premise of climate change regulation.

Independent evaluation offices should be enhanced to systematically consider the climate change impacts of a wide range of policies. The CBA analysis should quantify the costs per tCO_2 abated and account for additional co-benefits in a transparent way.

There are many justifications for sectoral policies complementary to carbon pricing. In the remainder of this section, we discuss three of them: the learning effect, redistributive impacts, and employment co-benefits.

The learning effect is an argument often put forward in favour of using sectoral measures for the rapid deployment of green technologies. The use of a technology in real-world conditions generally leads to the acquisition of new knowledge that contributes to its improvement. Photovoltaic electricity is a good example of this. In the mid-2000s, many European countries willing to support the emergence of national champions in this sector offered generous feed-in tariffs, which created a green bubble. This bubble burst when the installed capacity exceeded that needed to acquire the new knowledge. Production was then relocated to China, limiting the co-benefits of local jobs to the installation of the photovoltaic panels alone. Calibrating the required size of a feed-in tariff program can be complicated, as the potential learning and spillover effects are unknown ex ante and difficult to assess ex post. However, as does the degree of uncertainty imply a trade-off between quantity and price in carbon pricing, this example reveals the importance of incorporating explicit quantity and performance targets in subsidy programs, which is now much more common.

Our income tax system is imperfect. As is well-known, in a second-best world, it may be undesirable to impose first-best solution, such as a universal carbon price. Stiglitz (2019) illustrates this idea with a simple example that supports the Stern-Stiglitz recommendation for a menu of policies. Consider for example the airline industry, whose services are consumed more intensely by wealthier people. Imposing a larger shadow price of carbon for that sector is optimal because it has the additional advantage of being paid by less vulnerable households, and because it allows the policymaker to reduce the carbon tax in other goods and services consumed by the poor. Cremer, Gahvari, and Ladoux (2003) calibrated an optimal carbon tax model in the context of France, where energy has an income-elasticity smaller than unity. They found that “the redistributive role of environmental taxes requires the polluting goods to be taxed at a rate much below their marginal social damage.” In Section 3 (1.4) we will come back to the redistributive issues related to carbon pricing.

A clear difficulty comes from using one instrument – the carbon price – to address two objectives at the same time: climate change and inequality. It is not appropriate in any cost-benefit analysis to adapt the value of one impact to take account of another impact that is not valued. Rather, the right method is to put a value on each of the impacts of the policy. This suggests to value inequality reductions independently of valuing emission reductions. CBA toolboxes should include distributional weights (Adler, 2019) that have the effect of valuing more benefits accruing to poorer households.

The French bonus-malus system is a good example, where people must pay a tax of €20 000 when purchasing a new car that emits more than 185 gCO_2/km. If one assumes 200,000 km lifetime distance for the car, and if we consider a substitute at 120 gCO_2/km, this sends an implicit carbon price signal of more than €1,500/tCO_2. However, these high-emission cars are mostly purchased by wealthy households, which may contribute to the justification of this policy, supported by the Convention citoyenne pour le climat. A similar observation should also be made for canceling some local airline connections in France, as proposed by the CCC, since they are mostly used by businessmen. Notice that these recommendations are based on a degree of collective inequality aversion that is larger than what is implicit in the French income tax system. These climate policies are more redistributive than the income tax system. This could be justified by the low price-elasticity of the demand for these goods.

Because the standard CBA toolbox in France and in Europe does not contain any notion of distributional weights, this evaluation remains to be performed. Distributional weights are already used for intertemporal comparisons. Recall that the concept of the discount rate is based on the idea that investment increases intergenerational inequality, and that it is therefore desirable only if its rate of return is high enough to compensate for this undesirable inequality effect. While discounting plays a key role in the evaluation of public policies carried out, for example, by the General Secretariat for Investment (SGPI), its equivalent concept in the context of intragenerational inequality (the weighting of benefits by the marginal utility of beneficiaries) is practically absent from analyses. We recommend that interpersonal distributional weights receive the same attention in CBA as intertemporal discount weights. In other words, we recommend that the French government strengthen its socio-economic evaluation toolbox by explicitly integrating a value of inequality reduction, rather than making it a separate argument in the evaluation of the impact of public policies.

A high carbon price will generate losers among the poor even when redistributing the carbon dividend. Clear examples are found among coal miners in Poland, or some rural households in France with limited green options. Specific tools should be used to address this problem, such as the EU Just Transition Fund or the development of public transport infrastructures. In the context of involuntary unemployment that is particularly intense during the Covid-19 crisis, public policies should value the social benefit of creating good jobs, as discussed in the previous Blanchard-Tirole report (Blanchard et al., 2003). Special attention should be given to regions that have been hit hard by the phasing out of carbon-intensive industries. Other climate policies, including direct subsidies to industries, should be evaluated by using job values that are specific to the local labor market characteristics.

The evaluation of climate change policies should include an explicit valuation of the benefits of reducing inequalities (distributional weights), and of creating jobs in regions facing involuntary unemployment. The quantifications of the relevant trade-offs should be made clear in an integrated cost-benefit analysis.

Summary – A Policy Portfolio to Fight Climate Change

- Enhanced carbon pricing should be an important step to increase the ambition in climate change mitigation.
- A wide range of other policy tools should be engaged to fight climate change to ensure adequate pace and to optimize against large uncertainties.
- These policies can target areas where co-benefits are substantial.
- Because these policies do not tend to raise revenue, and given restricted budgets, careful selection of projects is desirable.
- Performing transparent cost-benefit analysis is crucial to limit the cost of the transition:
    - valuing carbon reductions at the true cost of carbon, as informed by the shadow price of the budget constraint;
    - valuing the other benefits of these policies with clear assumptions and weights;
    - evaluating a wide range of public policies, even if they are not strictly targeted to fight climate change, to flag inconsistencies or unveil possible synergies.

Each sectoral measure must be consistent with all other climate policies, and with the carbon pricing mechanism.

SECTION 3

A CLOSER LOOK AT SPECIFIC POLICIES

In this section, we explore a number of global and sectoral climate policies, starting with the keystone thorough reform of the European carbon pricing system.

1. Strengthening the EU-ETS

Strengthening the EU-ETS seems to be the most feasible path of action within the EU. However, current efforts in Europe are modest, leading individual countries to enhance the extent of carbon pricing with country-level initiatives.

In France, carbon pricing in its dual form (EU-ETS market and carbon tax for non-ETS sectors) failed to obtain the popular consent, as illustrated by the *Gilets jaunes* movement (Yellow Vests). It is too complex to be transparent and it continues to be perceived as an additional tax without any ecological benefit. This is confirmed by the absence of redistribution of the fiscal revenue, both from the tax and from the auction of allowances (EUA). The large discrepancy between the EUA price and the forthcoming carbon tax levels in France, together with the existence of very visible exemptions to the tax, demonstrated the inequity of the system to the public. These observations, along with the lack of a clear vision of how to attain the announced climate objective, make it necessary to propose a more transparent, more efficient, more effective, and fairer approach.[1]

Given the nature of the climate challenge (carbon leakages, free-rider problem, difficulty for coordination and progress on international agreements, etc.), the European Union and its partners appear to be at the right level for decision-making on, and implementation of, carbon pricing. Only the EU is in a position to put in place a coherent and ambitious climate

[1] The complexity induced by the duality between the carbon tax and the permit market also led, in 2009, to the rejection of the first carbon tax project in France, resulting from the Grenelle Environment Round Table.

policy on the continent, with the following advantages: (i) avoid natural tendencies to environmental dumping among members, (ii) enhance the benefits of cooperation in the face of the common enemy, climate change, (iii) speak with one voice in international negotiations, and (iv) serve as an example of climate cooperation among nations. One possibility would be to create a uniform carbon tax. However, a formal carbon tax at a level compatible with the EU climate ambition will never materialize in the Union given the unanimity rule necessary to implement any fiscal reform in Europe. Therefore, we believe the best way forward is to work on the strengthening of the EU-ETS along several key dimensions. If the reforms are successful, it would eliminate the need for the French carbon tax. Separate pricing systems for different sectors or for different countries can only be interim solutions.

In order to evaluate any reform of the EU carbon pricing system, it is useful to think about its aspects that need strengthening along three dimensions: ambition, scope, and incidence. We list them in Table 3.

To ensure economic efficiency, the EU-ETS should be reformed to widen its scope, increase price predictability, and increase price ambition to a level closer to the shadow price of carbon. The fiscal revenue should be used in a transparent way, possibly to make the tax progressive.

Table 3 – Summary of the goals of a reform of the EU-ETS

Ambition	• **Price level**: Prices should be raised in line with EU climate goals • **LT Credibility**: Multi-decade price commitment
Scope	• **Raise ETS sectoral scope**: All local emissions should be covered • **Raise ETS geographic scope**: All imported emissions should be covered • **Raise ETS temporal scope**: All future emissions should be covered
Incidence	• **Transparency**: Carbon dividend should be transparently allocated • **Progressivity**: Compensate the lower deciles

Source: Own elaboration

1.1. Strengthening price ambition and predictability

The EU-ETS, created in 2005, has a long history of half successes and half failures. It has the merit to exist, but it still covers only 45% of the global EU emissions. Because of the structural EUA supply-demand imbalance since 2012, the equilibrium price of the CO_2 permits has been much smaller than the social cost of carbon, i.e., the present value of marginal climate damages generated by the corresponding emission. Thus, it has not induced market participants to internalize the social cost of their pollution. Moreover, equilibrium prices have been very unstable. Finally, economists and experts have divergent beliefs about which shadow price of carbon will be necessary in the future to support the EU climate goals (Gollier et al., 2020).

The bottom line is that, under a quantity target mechanism such as the EU-ETS, households, corporations, innovators, and investors face deep uncertainties about the future cost of not shifting to greener technologies soon. This raises the important issue of who bears the risk of the energy transition. Because economic agents can hardly share the carbon-pricing risk through an insurance scheme, markets are incomplete, and the transition risk is inefficiently shared in the economy. This inefficiency inhibits the necessary green investments and justifies a departure from the pure quantity target mechanism of ETS. Let us recall here that many states have succeeded in setting up a system of guaranteed prices for photovoltaic kWh over several decades, which has had unexpected effects on the creation of considerable solar capacity. Why couldn't what has been done in this sector be achieved by setting a carbon price target over the same period of time?

Another argument in favor of switching from a pure quantity target to a hybrid system is based on the necessary coexistence of the specific climate policies that complement this carbon pricing mechanism. Any specific policy that reduces emissions in a sector will have the undesirable effect to depress the price of EUAs, thereby raising emissions in other sectors. This justifies moving toward a price target.

Several events of political interventions to reform the EU-ETS system have not improved its long-term credibility issue, but have already transformed it into a hybrid mechanism that combines price and quantity targets. The adoption of the Market Stability Reserve (MSR) in 2014 had no significant impact.[1] In 2017, the announcement of a complex mechanism to cancel excess allowances from the MSR had a strong impact on the EUA price. It increased the Linear Reduction Factor that specifies the annual reduction rate of the supply of allowances. The rate at which the MSR cancels allowances from auctions when the stock of unused allowances exceeds a certain level was doubled for the period from 2019 and 2023. We believe that this hybrid system remains too complex to restore credibility and long-term visibility. And there is still a long way to go to bring the long-term predictability required to trigger the extensive green transition.

[1] As allowances can be banked by market participants, putting excess allowances in a reserve (rather than invalidating them) should have no effect on their equilibrium price.

In this report, we propose two possible strategies to strengthen the current EU carbon pricing system. They are summarized in Table 4. Option 1 is in line with the current discussions to impose a minimum carbon price (see for example Fischer et al., 2019). In option 2, we recommend the creation of an independent Carbon Central Bank to solve the long-term credibility problem. In the spring of 2020, the Conseil économique pour le développement durable (CEDD, 2020) provided similar recommendations.

Table 4 – Summary of the options for a reform of the EU-ETS

Option 1 **Price collar on EU-ETS**	• **EUA price floor and ceiling growing at 5% per year** • **CBA indexed on EUA price**
Option 2 **Carbon Central Bank**	• **Independent CCB with EU mandate** • **Announce price targets, annual revision**

Source: Own elaboration

Option 1 – Predictable price collar for an all-encompassing EU-ETS

The EU Green Deal of the von der Leyen Commission contains several critically important initiatives. A key element of the EU-GD is to implement a carbon price floor when new allowances are auctioned. Unsold allowances due to the price floor should definitely be removed from the market (in exchange for imposing a price ceiling, see below). This is a highly relevant policy reform that goes in the right direction to reduce the uncertainty faced by green entrepreneurs. It mixes a quantity target with a (minimum) price target.

Notice that if the floor price is large enough, this reform could be reinterpreted as an EU carbon tax without the name. There is therefore a legal issue about whether introducing such a price floor should require unanimity of the members of the Union. (Fischer et al., 2019) argue that it should not. Otherwise, a grand bargain negotiation should be made where an ambitious carbon floor should be negotiated with countries with low MACs (such as Poland) against compensations (Just Transition Fund).

One critical ingredient is still missing here. The lower price predictability should not be limited to short time horizons. The grand bargain should be made on the basis of a carbon floor pathway covering the time horizon of the CO_2 reduction pathway. A Climate Treaty should make that explicit, together with a scientifically-founded revision mechanism. In the absence of a clear rule-based mechanism to control the evolution of the floor price, the long-term credibility of the system will remain limited.

Many western countries such as France (Quinet, 2019) and the United States ("Interagency Working Group on the Social Cost of Greenhouse Gases: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866", 2016) have established commissions in charge of periodically revising the carbon price pathway compatible with the national climate ambition. One of President Biden's first decisions on the first day of his arrival at the White House was to sign an executive order recreating a scientific commission in charge of setting a carbon value for the United States. In spite of its key role in this domain, and up to our knowledge, the European Union has never attempted to translate its greenhouse gas reduction targets into a sequence of carbon prices compatible with its highly publicized climate ambition. For example, it would be interesting to estimate the impact of the recent upward revision of the EU emission target (-55% in 2030 with respect to 1990) on the carbon value necessary to attain this new ambition. Given the critical importance of providing such a long-term price signal to the myriad of public and private operators of the energy transition, delivering this information would be very useful. This work could serve as an input to establish the carbon price floor and its projection over a long time horizon. Mobilizing Integrated-Assessment modelers (IAM), every year the European Commission should publish an estimation of the path of future shadow values of carbon necessary to achieve its climate ambition.

There are various challenges associated with this political long-term commitment. In particular, the constitutionality of binding future governments to a climate policy may be questioned. Notice, however, that France is already engaged through its ratification of the Paris Agreement and the binding EU climate ambition. This long-term climate ambition has also been translated in our legal system in the "*loi du 8 novembre 2019 relative à l'énergie et au climat*," which acknowledges the net zero emissions target for 2050. The associated carbon price should be considered as a corollary of this commitment.

Policymakers should be concerned by the complementarities that prevail between the various climate policy instruments. An important issue is the so-called "waterbed effect": direct subsidies for renewable electricity reduces the demand for EU-ETS emission permits and the corresponding equilibrium carbon price. The effect of the subsidy on total emissions is zero in that case. The intensification of non-price instruments should therefore be combined with an equivalent reduction of emission permits on the ETS market (Van den Bergh, Delarue, and D'haeseleer, 2013). This is yet another reason to advocate for an increasing price-floor or a price-based (as opposed to quantity-based) scheme.

Policymakers should also be concerned by the potential scenario in which the anticipated technological progress necessary for the energy transition does not materialize. The marginal abatement costs could skyrocket under that scenario, triggering economic and social catastrophes. This would mean that the marginal cost of our sacrifices would be much larger than their marginal benefit. The carbon pricing mechanism should eliminate ex ante this possible efficiency by introducing a “safety” valve in the form of a carbon price cap growing over time at a predetermined rate. California has implemented such a mechanism. It should be noted, however, that setting a price cap creates the risk that emission reduction targets will not be met.

The EU-ETS system should be reformed to credibly commit to a carbon price floor and ceiling growing at a predetermined rate over the next three decades.

Option 2 – An EU Carbon Central Bank

The prevarication of States on the implementation of a carbon pricing policy necessary to achieve their stated emission reduction objectives makes their future promises not very credible, which reduces the speed of the transition. The political sphere already encountered a similar long-term credibility issue. Fighting climate change requires implementing effort in the pursuit of a long-term goal that can be eroded by more urgent objectives. The temptation is always present to postpone the necessary climate effort, thereby raising a credibility issue. Fighting inflation in the 1980’s had a similar flavor, and the credibility issue has been successfully resolved by creating an independent institution, the European Central Bank, with a democratically-determined, long-term mandate to let consumption prices grow at 2%. This inspiring example suggests the creation of an independent Carbon Central Bank (CCB), with the mandate to keep the EU carbon price path compatible with the climate goals created by the democratic institutions of the Union. The EU-CCB would replace the current EU-ETS.

The governance of the EU-CCB would be independent.[1] Its board would be composed by legitimate scientists nominated by the National Academies of Sciences. Its prescribed goal would be to attain the emission targets prescribed by the Union. Its instrument would be the price of the emission permits that any importers or local extractor of carbon must pay to the CCB. The CCB would set the annual carbon price and make multi-decade projections for future carbon prices.

An alternative strategy for an EU carbon pricing mechanism would be to create an independent Carbon Central Bank with the mandate to set the carbon price based on the EU climate ambition.

[1] For more details, see Delpla and Gollier (2020).

1.2. Strengthening the sectoral scope

As stated above, the EU-ETS as of today covers only part of CO_2 emissions. A key proposed improvement under the European Green Deal is that the EU-ETS should cover a larger set of emissions sources. The extent of the sectoral expansion is still to be determined.

We propose to go one step further by making the EU-ETS an all-encompassing reliable system of EU carbon pricing. This would have the benefit of cost-efficiency and effectiveness. It would also make the system much more transparent, fair, and understandable.

To cover the transportation and housing sources of emissions, sellers of fossil fuels should have to purchase the corresponding allowances on the market. This all-encompassing carbon pricing mechanism would be an extraordinary achievement and would make Europe the most environmentally efficient region of the world. Moreover, it would be easy to implement due to the limited number of fossil fuel producers.[1] Given the relatively high price of allowances on the EU-ETS, the inclusion of currently uncovered sectors may generate a large shock to the economy. Rather than solving this issue by creating sector-specific ETS markets (as currently discussed in Brussels), we believe that a transition could be organized by converting CO_2 from different sectors at different rates converging to the same value within a few years.

In the polluter-pay principle, it is the polluter who pays the tax. The tax collection may be complex when the number of polluters is very large, as is the case for CO_2. If the Carbon Border Adjustment Mechanism is made politically and diplomatically possible, an alternative solution would be to tax the fossil fuels at the source. This would mean taxing fossil fuel producers rather than CO_2 emitters. The price signal would therefore be made upstream rather than downstream on the economic chain of carbon products. Following Stavins (2020), focusing on the carbon content of the three fossil fuels upstream "could enable a policy to capture 98% of the US CO_2 emissions with a relatively small number of compliance entities – on the order of a few thousand – as opposed to the hundreds of millions of smokestacks, tailpipes and other sources that emit CO_2 after fossil fuel combustion." Because the same quantity of fossil fuel can emit different quantities of CO_2 (and other pollutants) in the environment, this upstream carbon pricing mechanism should be combined with complementary policies to regulate the functioning of the combustion (boilers, cars, etc.).

[1] For example, refineries in California are already subject to carbon prices with limited additional administrative burden.

In the case of EU, that would mean imposing the carbon price on the importers of gas and oil when these raw products enter the EU soil, and on the exporters of the coal and limestone mines. The carbon price would be easier to collect as the number of importers and local extractors of fossil fuels is much smaller than the number of emitters. This upstream mechanism is likely to reduce the risk of manipulations, and to make the overall system more socially acceptable. It would also facilitate the expansion of the sectoral scope of the EU-ETS.

Fossil fuel emissions should be priced upstream, as opposed to at the point of combustion, to facilitate their total inclusion in the EU-ETS market and put an end to a longstanding missing gap in the coverage of transportation and heating emissions.

Greenhouse gases are not only limited to CO_2, and therefore a relevant question pertaining the strengthening of the EU-ETS is whether its sectoral scope should also be expanded to include other greenhouse gases. The EU-ETS has already been expanded with the inclusion of nitrous oxides and perfluorocarbons (PFCs) from aluminum production, but one could potentially enhance its umbrella.

Our position is that including all other greenhouse gases under the same scheme would probably be difficult from an administrative point of view, especially when thinking about agricultural and land emissions. Given that CO_2 emissions are over 70% of greenhouse gases and they are easier to monitor, we consider a first-order issue to properly include these emissions together with those already regulated.

That said, methane emissions should be better integrated in the calculations of CO_2-equivalent emissions, at the very least for oil and natural gas. Recent studies suggest that methane emissions from the extraction and combustion of natural gas are much larger than previously believed (Howarth, 2019). These additional emissions should be incorporated into the calculation of the relevant rates for the combustion of fossil fuels as a way to further enhance the scope and cost effectiveness of the carbon pricing scheme. These policies could be complemented with reinforced incentives to reduce methane leaks, e.g., for local distribution utilities where leaks are believed to be substantial according to recent measurements in the United States (e.g., see Von Fischer et al., 2017).[1]

Additionally, there has been a sustained growth in recent years of highly potent greenhouse gases (HFCs). Even if their share is relatively small, these are extremely concentrated gases that are human produced, and therefore their regulation seems

[1] Several studies lead by EDF in collaboration with several universities and companies document extensively methane leakages along the supply chain of natural gas, see https://www.edf.org/climate/methane-research-series-16-studies.

important. Because of their presence in major appliances due to their cooling properties, the bank of HFC gases that are expected to be released to the atmosphere, if not properly captured and destroyed, will increase the burden on mitigation efforts (Velders, Solomon, and Daniel, 2014). We believe that international agreements to search for alternatives and ban their utilization are probably the best approaches to address this growing threat.

Active policies to reduce or mitigate greenhouse gas emissions not covered under the EU-ETS should be put in place, including efforts to reduce methane emissions and bans to highly potent greenhouse gases.

1.3. Strengthening the geographic scope

In an open economy, imposing a carbon price generates carbon leakages, i.e., a partial offset of emissions in the ambitious country by the transfer of carbon-intensive production to other countries. However, the EU-ETS system has not had such an effect, at least not in the first decade of its implementation. Existing studies suggest that these carbon leakages remained limited over the last decade in Europe, but this may be due to the low observed carbon prices during the period (Fowlie and Reguant, 2018; Branger and Quirion, 2014). Attaining the EU climate ambition will require a much larger carbon price than its current level. The carbon leakage problem will therefore become first order. If firms delocalize the production of their carbon-intensive production to low-ambition countries that do not price carbon emissions, the net effect of the carbon price will be zero for humanity, and vastly negative for the ambitious country, in terms of incomes and employment. This carbon leakage problem reinforces the free-rider problem. In Europe, this environmental dumping has induced the EU Commission to repeatedly offer free allowances to its industrial corporations facing international competition.[1] If the future allocation of free permits depends upon current emissions, this distorts the incentive to decarbonize. And the distribution of free allowances on the basis of historical emissions raises the question of fair competition in the sector concerned and access to the market for new entrants. Moreover, the loss of revenue generated by the non-auctioning of these allowances reduces the carbon dividend to be redistributed to European citizens. This system of free quotas is therefore not good.

Fortunately, the EU Green Deal will replace the free allowance instrument to level the international playing field by imposing the Carbon Border Adjustments Mechanism (CBAM). The European Union is a net importer of CO_2. It is estimated that the emissions generated by the production of imported products in the EU is equivalent to 30% of the

[1] At the beginning of the current trading period 2013-2020, the manufacturing industry received 80% of its allowances for free. This proportion decreased gradually to 30% in 2020. Airline companies continue to receive their allowances mostly for free.

domestic emissions of CO_2 (Lamy, Pons and Leturcq, 2020). The absence of any carbon price signal faced by many importers – and thus by their European customers – is a source of legitimate concern for the Europeans. To level the playing field, importers of carbon-intensive goods should pay the same carbon tax as local producers, when combining the carbon price they pay at home with its adjustment at the border of the EU. Beyond its primary goal to eliminate carbon leakages, the CBAM is a transparent way to project the European ambition to price the global carbon externality to the rest of the world. As suggested by (Nordhaus, 2015), this is also an efficient strategy to incentive low-ambition countries to do more. This is because the CBAM is collected by the EU and not by the exporting country. The CBAM should be based on the carbon tax differential between the EU and the exporting country. This may seem easier on paper than in reality. For example, an exporting country could impose an explicit carbon tax to its manufacturers that could be less explicitly compensated by a reduction of other taxes. Sweden has a large carbon tax on gasoline, but the price paid by customers at the pump does not differ much compared to other countries.[1] This complexity suggests starting the CBAM on a restricted list of items for which the tax issue is limited.

The CBAM is also a better instrument than conditioning trade deals (CETA, Mercosur, etc.) to the compatibility of the parties to the Paris Agreement, i.e., to Nationally-Determined Contributions (NDC). This solution could be counterproductive. Because the NDCs are nationally determined without any norm and a limited pressure from naming-and-shaming (a necessary condition for the success of the Paris COP 21, and probably for future COPs too), imposing such conditions in future trade deals will incentivize countries to be less ambitious when renegotiating their future NDC. This raises the complex question of the fair distribution of the effort to reduce emissions at the global level. This issue cannot be solved in bilateral trade negotiations. On the contrary, the establishment of a universal carbon price, potentially with compensation, is based on a well-established efficiency argument. The CBAM is also more transparent and more efficient. It should be fully automatic and symmetric across all trade deals with the European Union, without the partners having to negotiate the types of economic development followed by each of them.

Various articles – II:2(a), III:2, III:4, XX – of the GATT may be invoked to defend the CBAM at the WTO. But a CBAM is only possible if Europe is itself completely clean on its own uniform carbon pricing system, removing free output-based allowances for energy-intensive and trade-exposed sectors. The current text from the EU Parliament that supports simultaneously the CBAM and the preservation of free allowances contradicts the objective of leveling the playing field, and will fail to convince WTO. This is a pre-requisite to a successful WTO negotiation, as the non-discriminatory nature of the global pricing

[1] For example, in February 2021, the price of super E5 was €1.44/liter in Sweden and in France.

proposal will be key. We recommend that the EU-ETS be reformed in scope, in price stabilization, and in intensity before implementing a CBAM. In order to justify fairness with external competitors to the WTO, it is essential to first organize the fairness and transparency of a uniform carbon price internally.

Given the many technical difficulties of a CBAM, it should be implemented gradually, starting with the energy-intensive, trade-exposed sectors, such as cement, steel, aluminum, paper and electricity, for which the CO_2-content is relatively easier to measure (as proposed for example by Mehling et al., 2019). This narrow coverage is likely to imply competitiveness and leakage problems for downstream producers not covered by the CBAM mechanism. A long-term goal would be to impose CBAM to all goods and services imported in Europe, based on actual CO_2 emissions along the entire upstream value chain ("scopes 1 and 2"). One could impose ISO rules for all importers to report the CO_2-content of their product, as they already emerge in Europe. A more immediate but approximate strategy would be to estimate the CBAM adjustment on the basis of a benchmark production process from which the emission associated to transportation would be added. The difficult issue is to characterize this benchmark. Economists have discussed three possible benchmarks for imports: (1) the carbon content of equivalent goods produced in the EU; (2) the carbon content generated by the best available technology; and (3) the carbon content generated by the worst available technology, unless the concerned importer can demonstrate that it uses a better technology. This third benchmark would avoid discriminating a priori between import sources. As far as electricity to produce the imported good is concerned, the average emissions of CO_2 per kWh of the exporting country should be used as a basis to estimate the CBAM. The CBAM should not be an instrument to reinstall protectionism in Europe.

Finally, the question of trade retaliation is central. The lump-sum refund to each country of the total amount of taxes paid by its firms is not a tool providing appropriate incentives. The transfer of pollution-reducing technologies is preferable, but raises the question of compensating firms harmed by such a weakening of intellectual property rights (Gollier, Schmidt and Schubert, 2020). EU politicians and trade partners should realize that the CBAM is an environmental policy, not a competition or trade policy. It just requires that all things consumed in Europe are covered by the same carbon price. The creation of the CBAM should follow an intense diplomatic campaign to convince trade partners to join an ambitious climate coalition. The CBAM, as an environmental policy, should be an act of last resort. Finally, let's keep in mind that even if exporters to Europe formally pay the adjustment, market forces imply that most of this additional cost will be paid by European consumers. The idea that we will make the Chinese producers pay is mostly a fantasy.

Carbon border adjustments mechanisms indexed on the EU-ETS carbon price should gradually be implemented to level the playing field, to eliminate carbon leakages, to suppress free quotas, to project the European carbon pricing ambition abroad, and to incentivize other countries to improve their ambition.

The ETS should also be examined as a building block of a more global carbon pricing mechanism. Suppose that the European Union and the United States, potentially with China, would be able to form a climate coalition with a friction-free interconnection of their ETS markets. Other regions of the world could be interested in joining this ETS coalition. In its international negotiations at the annual COPs, the North should offer a deal to other countries that would take the following form. The joining parties would accept to cover their emissions under the ETS and, therefore, require their constituents to obtain allowances that match their emissions. In exchange, the North would offer them free allowances. In the extreme version of the mechanism, adopting the moral principle of distributing free permits in proportion to their population, most developing countries would have a net benefit to join the ETS. Here, the opaqueness of this cross-country redistribution of wealth is an advantage, given the reluctance of the western world to support the South financially, as illustrated by the failure of the Green Fund established by the COP 16 in Copenhagen. Cap-and-trade systems, together with the CBAM, are a powerful mechanism to redistribute wealth across regions and countries, and is a useful instrument to build a larger climate coalition. Of course, it requires a strong infrastructure to measure actual emissions and to impose penalties to non-compliant parties.

The European Union should aim at forming a coalition of climate-ambitious countries (including the United States) with a unified ETS market. This climate coalition should encourage other countries to join its ETS in exchange for the distribution of free permits.

1.4. Strengthening transparency and redistribution

In the framework of this reform, the income from the carbon pricing implemented at EU level is fully redistributed to the member states. In this section, we examine the possible allocation strategies of this resource by France.

Eurostat estimates the EU-27’s carbon footprint at 7.0 tons per person in 2018. Pricing it at €60 per ton would generate a carbon dividend of €200 billion per year. In contrast to the strong consensus among economists to price carbon, there is no consensus about how to spend this fiscal revenue. Many EU experts propose to use it as a new source of funding for the European Union, for example to repay the Covid-19 recovery plan gradually.[1]

[1] See for example Fuest and Pisani-Ferry (2020).

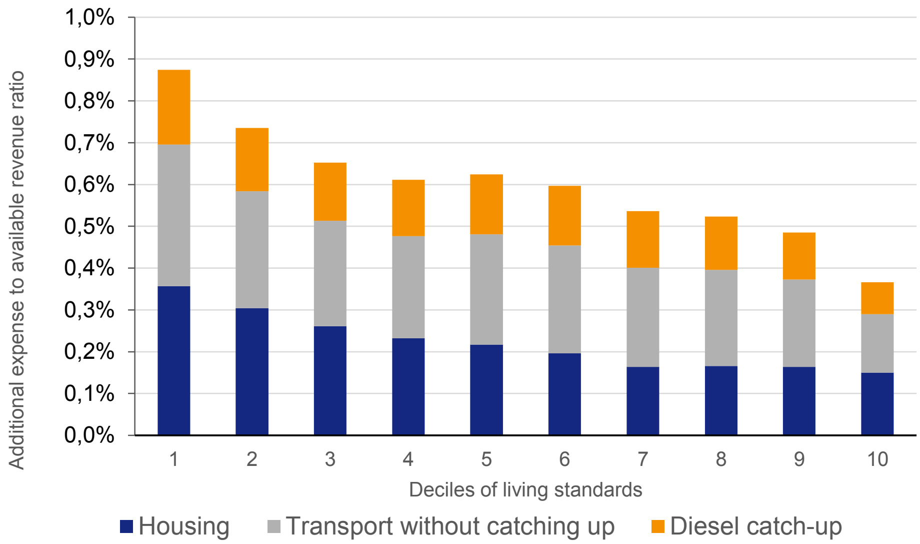
We oppose this view. As explained earlier in this report, redistributing the carbon dividend to the states proportionally to their historical national emissions can contribute to social acceptability, to compensate the lower deciles of the income distribution among their citizens. It should also be used to compensate the most visible losers of the energy transition such as the coal miners through the Just Transition Fund. At the end of the day, the use of the carbon dividend should be left to the European negotiators to build a stable coalition supporting an ambitious ecological transition. Given the social acceptability problem, we recommend that the carbon pricing mechanism would never be used as a new fiscal resource, neither for the EU nor for France. The entire revenue generated by the CBAM and the auction of allowances should be redistributed to the member states, and France should redistribute this revenue to its people.

In no way should carbon pricing be associated with the idea of raising a fiscal revenue. The carbon dividend should be entirely redistributed to the people.

How should France redistribute its carbon dividend? Four in every five respondents in a recent HCC's survey (Haut Conseil pour le climat, 2020) believe that the climate policy should reduce social inequalities. In the western world, poorer people devote a larger fraction of their income to purchase energy. This has the immediate consequence that any uncompensated policy that implies an increase in the cost of energy is regressive by nature. For example, replacing the cheap coal with the more expensive natural gas or biofuels would raise inequalities. Levinson (2019) shows that pollution standards in the automobile sector are regressive. Of course, the same problem arises with a carbon tax. But carbon taxation has the advantage of generating tax revenues that can be used to reverse its impact on the net income distribution, i.e., to make the carbon tax-and-dividend policy progressive. This "carbon dividend" is a key element of economists' recommendations for a just fight against climate change.

Bureau, Henriet and Schubert (2019) have estimated the impact of an increase in the French carbon tax from the current €44.6/tCO_2 to €86.2/tCO_2 accompanied by the catching-up of the diesel tax by 7.8 cents per liter, as was planned for 2022 before the *Gilets jaunes* movement. Figure 7 shows the impact of this proposed change in the carbon tax on the household disposable income, as a function of the decile of living standard. The richer the households, the lower their burden expressed as a fraction of their incomes. It is 0.3% for the top decile, compared to 0.9% for the first decile. Thus, in the absence of any redistribution of the fiscal revenue, the carbon tax is regressive.

Figure 7 – Impact of increasing the carbon tax from €44.6 to €86.2/tCO_2 (plus diesel catch-up) on household disposable income



Source: Bureau, Henriet, and Schubert (2019)

One could easily increase the progressivity of the tax-and-dividend policy by concentrating the redistribution of the fiscal revenue of the carbon tax to the lower deciles, taking account of the fact that the social acceptability problem is mostly concentrated in that specific population. The think-tank Terra Nova proposed to pay a dividend in France that linearly decreases from €500 for the first decile to €100 for the fifth decile, leaving an unused net fiscal revenue of €2.3 billion on the table (Guillou and Perrier, 2019). Bureau, Henriet and Schubert (2019) estimates that this combined tax-and dividend policy would increase the disposable income of the first decile by €250/year per household. The first four deciles would see their disposable income increase with the reform. If properly explained, this policy could be perceived as socially acceptable and simpler than other approaches. Conditioning the payment of the carbon dividend to specific investments or expenses, as is currently the case with the energy voucher (*chèque énergie*) that must be used to purchase energy, might also complicate the access to the dividends for some households.

The carbon pricing mechanism should contain a transparent redistribution of its revenues. Redistributing the carbon dividend to the first few deciles of the population, with no condition attached to this dividend payment, can be a simple approach that can also be socially acceptable.

This redistribution should not affect the power of the price signal. For example, it is undesirable in the long run to link the redistribution of the carbon dividend to the geographic location of the household. The carbon tax should affect the incentive to telecommute, to share rides, and to incentivize people to live closer to their workplace. However, specific sustainable compensation to rural households would be detrimental to efficiency. Climate change is forcing us to rethink land-use planning. Without additional compensation, the rural world will probably suffer more than the urban one from most climate policies. In the absence of additional offsets or technological changes, poor rural households will inevitably lose if the carbon tax increases, even with an income-based carbon dividend. In France, the rise in property prices has been greater in cities than in rural areas, so an increase in the carbon tax further increases the loss of relative wealth realized by rural residents except if they do benefit from increased teleworking and public transport provision. Grandfathering rules for the redistribution of the carbon dividend could alleviate this problem. These losers of the climate transition could be compensated by a well-calibrated “green cheque” based on their initial location. But there should be a predictable path in removing the “green cheque” in the medium and long terms. This “horizontal inequity problem” that cannot be satisfactorily solved by the carbon dividend may justify using non-price policies (Stiglitz, 2019). It also provides an argument for taxing more land rents.

Piketty (2019, pp. 1156-59) has proposed several options to combine the fights against climate change and against inequalities. He first proposes that each increase in the carbon price should be compensated by a corresponding transformation in the progressivity of the income tax system to compensate the regressivity of carbon pricing. Second, he proposes to distribute free allowances to the EU citizens on a per capita basis, so that the wealthy will have to purchase allowances from the lower deciles of the population. These two solutions are closely related to our proposal to sell EU-ETS allowances and to redistribute the carbon dividend to the lower deciles of the population. Third, in the spirit of Cremer, Gahvari and Ladoux (2003), Piketty proposes to tax more heavily the carbon-rich goods and services that are more intensively consumed by the wealthy, such as business class flights. His fourth option is more controversial. It consists of implementing a progressive carbon tax system. The marginal carbon price would be zero below 5 tCO_2. It would increase gradually to attain plus infinity above a certain threshold, thereby imposing an individual cap on emissions. Beyond the difficulties to implement such a mechanism, this system raises several issues. It breaks down the rule of a uniform carbon price that is necessary to minimize the global cost of the transition. In particular, it gives no incentive to low emitters who could face low marginal abatement cost and it wrongly suggests that climate change is the problem of the rich. It is true that, in a second-best world, carbon pricing should also be used to contribute to the reduction of inequalities. In our plan, this is done through the redistribution strategy of the carbon dividend. A non-linear carbon pricing mechanism is a less flexible solution, as it does not solve the horizontal equity problem of poor rural households with a high energy demand, for example. Finally, given the limited size of the fiscal revenue generated by carbon pricing, the incidence on inequalities of this complex non-linear carbon pricing will be much smaller than that of the income tax system.

Specific jobs will also be affected by the ecological transition. Coal electricity plants will soon be closed in France. In the absence of a predictable path to decarbonize the airline industry, one should expect a reduction of employment there. Some of these job losses will certainly be compensated by the partial transfer to the railways industry, particularly in countries that have already decarbonized their electricity mix. Other sectors will be booming, such as the renewable energy sector, or the retrofitting of public and private buildings. Network infrastructures, such as in rail and electricity transportation, should also be vastly expanded in the short future. The net effect on employment may well be positive thanks to a Keynesian multiplier effect, but there is another social problem created by the necessary redistribution of jobs in the economy. The issue of training the labor force adequately in France and elsewhere is addressed in Chapter Two.

The rising carbon price in Europe will affect countries asymmetrically. The core idea is that it will be the countries that have the larger reserve of least-cost abatement actions that will be more negatively impacted by the carbon pricing mechanism. France, which has already almost fully decarbonized its electricity mix, will lose less than other countries, such as those which continue to heavily depend on coal for electricity. This needs to be treated properly, in particular by training workers in anticipation of the new job opportunities. Within the European Union, the Just Transition Fund (JTF) should contribute to the solution. It is necessary to link the ambitious reform of the ETS with the reinforcement of the JTF in an EU grand bargain to attract the approval of the coal-rich countries.

The carbon dividend in the EU-ETS should be used to compensate the sectors and households most affected by the transition in a transparent manner. Land rents should also be further taxed to better share the burden of the reallocation of town planning and regional development.

2. Finalizing the Electricity Transition

The electricity sector is one of the areas in which progress towards zero-carbon targets is in reach within a relatively short time horizon. It is also the sector that has contributed the most to the lowering of European emissions in recent years. Thanks to the introduction of larger scale renewable projects and the growth in natural gas utilization in detriment of coal, carbon intensity decreased from 524 gCO_2/kWh in 1990 to 296 gCO_2/kWh in 2016.[1] Furthering the lowering of emissions intensities will require increasing sources of renewable production and phasing out all thermal generation in the near future. Decarbonizing the electricity sector is particularly important because other sectors

[1] European Environment Agency (2018), Overview of electricity production and use in Europe – Indicator assessment.

(housing, transportation) have few other alternatives to decarbonizing their activity than electrifying their production processes, for example by using green hydrogen.

Renewable electricity has recently benefited from strong technological progress. According to Systemiq (2020),

> "in 2015, solar and wind were expensive forms of generation. Today, just five years later, solar/wind are the cheapest form of new generation in countries representing over 70% of GDP. […] This is driven by precipitous cost declines. Since 2015, prices have fallen 50-65% for each of solar, wind and batteries. These declines will only continue with projected falls of 30-60% across solar, wind and batteries in the next ten years."

Examining estimates of the levelized costs of energy for new projects, solar and wind are already cheaper than natural gas at modest carbon prices, as shown in Figure 8.[1] This is extremely good news, even if the comparison of levelized costs of electricity between dispatchable sources (gas, coal, nuclear, biomass, hydro) and non-dispatchable sources (wind and solar) is rendered complex by the difficulty to store electricity and to make electricity demand flexible to spot electricity costs.[2]

The cost of intermittency of wind and solar electricity will grow in parallel to their share in the EU electricity mix, especially when it comes to managing long spells with lack of sun or wind. Recent advancements in batteries, which have witnessed substantial cost reductions in recent years, will facilitate smoothing short-cycle intermittency. For longer-cycle intermittency (days or weeks), one could potentially use hydrogen storage and fuel cells, or increased pumped hydro storage. When it comes to hydrogen fuel cells, the technology uses electrical power to produce hydrogen by electrolysis. The hydrogen can be used for other purposes or be stored and used later in a fuel cell to produce electricity. Whereas fuel cells have a limited role in the power sector as of today, several countries, including France, are planning on investing in fuel cells to balance the electric grid.[3] Extra- or ultra-high voltage transmission projects that allow renewables to be harvested at different locations can also be very valuable, although it remains to be seen if an aggressive transmission roll-out will be feasible given the implementation difficulties and opposition that these projects often face.

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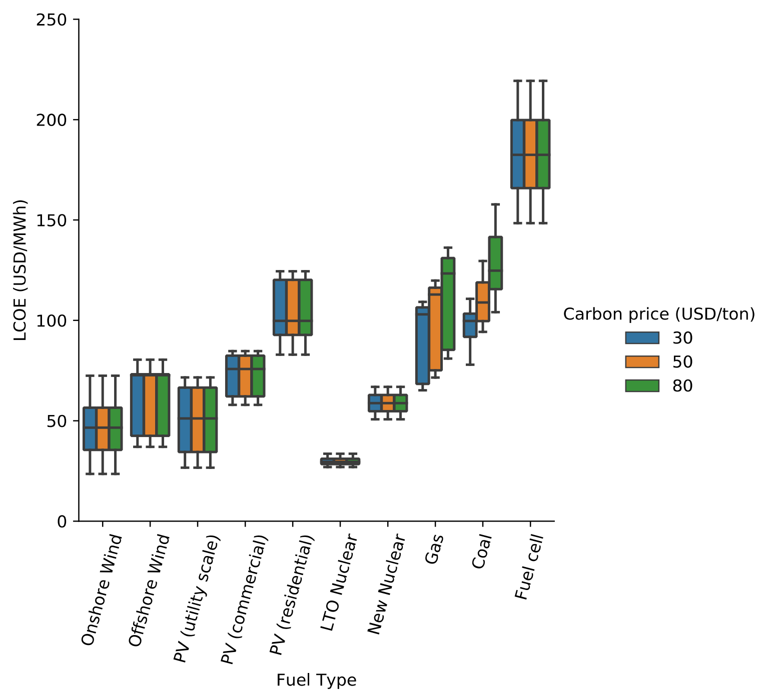
[1] In Europe, renewable projects come ahead in several LCOE calculations even absent carbon pricing. In the United States, and given the presence of "fracking", carbon pricing is necessary to displace natural gas.

[2] The International Energy Agency (IEA) has been expanding the ways LCOEs are computed to better account for intermittency. Even taking intermittency into account, renewables remain competitive at modest carbon prices for the purposes of LCOE calculations (IEA, 2019). Some more uncertainty remains on the operational issues at 90% renewable penetration.

[3] Given limited applications and the many assumptions that go behind these calculations, it is difficult to provide levelized costs of energy (LCOE). The EIA LCOE calculator has its LCOE around $200/MWh, suggesting steady technological progress in this area (or higher carbon prices) can make it viable.

Today, and no doubt for a long time to come, the problem of electricity storage is the number one technological hurdle for the energy transition.

Figure 8 – Levelized cost of electricity (in 2020) for new construction projects except life-time extensions for nuclear ("LTO Nuclear")



Note : Data taken from 13 European countries and 63 distinct power plants with an interest rate set to 7%. The number of observations in each Fuel Type category ranges from 2 (new nuclear) to 13 (onshore wind), with a median of 8.

Source: Own elaboration based on the "Projected Costs of Generating Electricity 2020" IEA Report.

What are the necessary steps towards the decarbonization of the electricity sector? How to accommodate growing renewables given their uncertain output? What should be reasonable goals? What battery technologies will emerge? What will be the role of green hydrogen and nuclear? Will carbon capture sequestration be part of it? How will electricity demand interact with the market? Deep uncertainties exist regarding what a decarbonized grid will look like. However, there is one obvious policy that should be implemented immediately: exiting from coal in Europe.

2.1. The need to eliminate coal

The elimination of coal extraction and consumption in Europe is among the lowest hanging fruit to reduce the emissions of greenhouse gases. In the absence of appropriate carbon prices, coal production and consumption are heavily subsidized, through various public aids and in view of the lack of pricing for local pollution related to mining and coal combustion. Removing coal from the electricity mix has a cost per tCO_2 of less than €40, without counting the other environmental co-benefits of the policy. Whereas France uses almost no coal in its electricity grid,[1] it is part of an interconnected European system that still heavily relies on the use of coal. One must be aware that production of electricity from coal, in the absence of proper pricing of externalities, is cheap and thus still used in several countries. Poland produces the highest amount of electricity from coal, and Germany follows closely. Indeed, coal still represents about 80% of electricity generation in Poland. In 2017, Germany remained the world's largest producer of lignite, the most emissions-intensive type of coal.

The production from coal decreased substantially in 2019 thanks to the stronger pricing signal in the EU-ETS, around €25/tCO_2, leading to a more decisive switch to natural gas.[2] Yet, it is unclear that such a relatively modest carbon price can trigger the necessary changes to fully stop coal production (and extraction) in Europe. Whereas Germany has announced the phase out of coal by 2038, this is too far out in the future considering the cost advantage of stopping production from coal sources as a mitigation strategy.

The coal sector in Poland employs a sizeable amount of workers in mining and production. It is also a flagship of coal mining regions, making the transition away from coal in these areas difficult. Once the job of over 300,000 workers in Poland, it still employs around 80,000 people nowadays. The presence of such strong ties to the labour market should be considered when reaching a European-wide agreement to phase out coal much more aggressively than currently planned. But such difficulties should not stall this necessary change in the operation of the European electricity market. If the exit from coal is organized through an increase in the EU carbon price, we believe that the carbon dividend should be used in part to compensate the low MAC countries which will be hit the hardest by the rise of the carbon price.

Given the low marginal abatement cost of phasing out coal, failing to phase it out decisively at the European level is detrimental to the credibility of its climate change policies. It is vital that all European countries sit down in conversations to phase out coal much more rapidly than currently stated in national plans, in particular Polish and German. It is our opinion that, given the gravity of the climate change challenge and the lack of international leadership with the same urgency as the formation of the European Coal and Steel Community, which facilitated peace after the Second World War. Even if such a parallel might seem dramatic, the lack of progress in the climate change front is likely to lead to

[1] The last four coal power plants in France will be closed in 2023.

[2] Sandbag (2019), "Europe's great coal collapse of 2019".

conflict. A European-wide agreement on coal could be a good first step towards more explicit cooperation on sensitive matters.

Achieving a European-wide agreement on the rapid phase out of coal, embracing the spirit of the foundational values of peace of the European Union with a sense of solidarity for the losers, is vital for the credibility of climate change policies in any other front.

2.2. The need for a timely elimination of baseload natural gas

Given the traditional role of coal providing electricity generation during most of the day and in a predictable fashion, natural gas has emerged as a natural substitute to coal (e.g., in the United States thanks to fracking, or in the EU thanks to higher carbon prices). Yet, natural gas production is still responsible for a large share of GHG emissions, both CO_2 and methane. While cleaner than coal power plants, output from natural gas needs to basically disappear if a net-zero electricity system is to be achieved. Therefore, it should be seen as a transitional technology.[1] The timing of this removal is uncertain, as it depends upon the emergence of mature technologies to store electricity. Moreover, in countries which currently heavily rely on coal, switching to natural gas looks like the only viable strategy to preserve a source of dispatchable electricity.

Given that natural gas is among the most competitive, dispatchable, and reliable technologies to generate electricity at the present time, it is useful to consider the shadow price of carbon and its implications for its competitiveness. At a price of €100/tCO_2, the marginal fuel costs of natural gas roughly double. At €250/tCO_2, its marginal costs would be above €120/MWh, including only fuel expenses, and therefore natural gas becomes less competitive to possibly renewable electricity combined with improved battery storage, which has seen dramatic improvements in recent years. Whereas these are not expected carbon prices, these are within the range of the shadow price of carbon.[2] Based on these considerations, investment in new combined-cycle power plants has an uncertain profitability from a social point of view and is likely to create an even larger stranded assets problem. Faced by the universal carbon price, gas companies should be left free to determine their investment strategy under the deep uncertainty relative to the place of natural gas in the energy mix over the next three decades. Their shareholders bear the risk in full knowledge of the facts. On the contrary, imperfect information and limited foresight on the side of

[1] A small set of plants could be maintained to add reliability in moments of extreme conditions, which would likely be preferred from a cost-benefit analysis to the complete loss of power of large areas, for example, under extreme temperature events. However, their production share should become residual.

[2] See Quinet (2019), who estimates the shadow price of carbon to be €100-€250/tCO_2 in 2030.

individual households may justify an early ban of home heating systems using fossil fuels.[1] The timing of this ban should be based a cost-benefit analysis of the alternative heating solutions. Finally, taking account of other pollution externalities, we recommend to (re-)confirm the prohibition of shale gas extraction in Europe.

Natural gas for electricity generation is a transitional (and residual) technology which remains crucial in the short run as a source of dispatchable electricity. Carbon pricing should drive its sequential exit.

2.3. The need to trade-off the value and risks of nuclear

French electricity is already almost fully decarbonized mostly thanks to its nuclear capacity.[2] The LCOE of nuclear electricity of the second generation (i.e., non-EPR) in France has been estimated between €50 and €60/MWh (Cour des comptes, 2014), (Grandjean and Hariri, 2020).[3] The *Commission de régulation de l'énergie* has evaluated it at €48/MWh in September 2020. Given the deep uncertainties surrounding the cost of alternative decarbonized technologies in the electricity sector, we believe that any plan to decommission nuclear plants should be made contingent on the emergence of viable baseload renewable alternatives.[4] Because the timing of this scenario is highly uncertain, it is crucial to preserve – and maybe extend – our nuclear capacity in the near future. Extending the lifetime to 50 years of most of the 56 existing nuclear plants after some retrofitting (*grand carénage*) is justified by standard cost-benefit analysis, taking into account the projected path of future carbon prices. The decommissioning of the Fessenheim plant in 2020 has probably been a mistake, given its high financial cost for France, and the fact that its production has been substituted by marginal gas and coal production elsewhere in Europe.

Maintaining existing nuclear power plants, as long as their safety is ensured, is preferable to producing from fossil fuel plants.

[1] Given the relatively temperate weather in France, heat pumps are already cost-efficient for many households, but wide adoption might require coordination due to its perceived lesser value in the housing market.

[2] France: 60 gCO_2/kWh, Germany: 450 gCO_2/kWh, Poland: 750 gCO_2/kWh.

[3] This includes all nuclear costs (decommissioning of power plants and long-term storage of nuclear waste) but not the cost of the risk of a nuclear accident.

[4] It is inappropriate to compare the levelized costs of electricity from dispatchable and non-dispatchable sources. As the share of renewable electricity increases in the EU mix, the mean sale price of this fatal electricity goes down, compared to dispatchable electricity which will be sold preferably at peak prices.

More credible information is required about the LCOE of the third generation (EPR) nuclear technology to evaluate its role in the optimal electricity mix.[1] Given the current failure of the EPR to demonstrate its cost-efficiency, other nuclear technologies such as the small modular reactors could be reexamined. The possibility to develop the International Thermonuclear Experimental Reactor (ITER) and fourth generation nuclear technologies (project Astrid) should also be taken into account, as they generate decarbonized electricity with (almost) non-exhaustible resources. The next five years will be critically important to plan the future of nuclear electricity in France.

The Cigéo project to store the medium- and high-activity nuclear waste generated by the first two generations of nuclear power plants in France has seen its cost dramatically increase over the last decade. ANDRA estimated the cost at €35 billion in 2017, from around €7 billion 10 years earlier. This inflation is mainly due to the legal necessity to implement a permanent storage of these wastes that could be reversed by 2156 when the storage site in Bure should be closed. These costs were not anticipated at the time when the law imposing this reversibility was passed in Parliament in 2006. Given this new information, we believe that the environmental and health benefits of the reversibility should be compared to its estimated cost to reoptimize the architecture of the project. Beyond the nuclear issue, all sources of decarbonized electricity should be optimized in order to level the playing field, and to provide the socially desirable energy mix to the economy.

2.4. The need to incentivize demand

Demand reductions and demand response are an additional avenue for facilitating the decarbonization of the electric grid. Due to the electrification of part of the transportation fleet, demand for electricity is likely to rise in the medium term, putting additional pressure on the decarbonization progress. Reducing (or limiting) these demand increases also makes the decommissioning of existing fossil fuel generators more palatable. Demand response also needs to be engaged in the presence of extreme weather events, which trigger peaks in demand and can put additional pressure on the grid, as recently experienced in California.[2]

Increasing electricity prices via the pass-through of carbon costs and renewable subsidies already provides incentives towards energy efficiency. There have also been plenty of

[1] Grandjean and Hariri (2020) observes that the UK government offered a fixed price contract of €120/MWh for the electricity that will be produced by the EPR of Hinkley Point. They also estimate the LCOE of the EPR of Flamanville around €160/MWh.

[2] The lack of effective load management during the wildfire season has led to numerous blackout periods in which consumers are left without power for several hours or days in 2020.

programs for appliance standards and subsidy programs. More stringent building codes can help minimize the need for water and electric heating and air conditioning going forward. The Convention citoyenne pour le climat proposes some extreme measures (with strict limits on the temperature settings in the home). Whereas this seems to go too far in the restrictions of individual freedoms, smart meter technologies coupled with smart thermostats could be used to perform non-linear pricing based on thermostat settings. These policies can incentivize reducing consumption of air conditioning while ensuring a minimum of comfort at reasonable costs. Because the steep pricing would depend on comfort measures, they could be perceived as more fair. These technologies can also ease the management of load during extreme events, such as the wildfires experience recently in California.

Critical pricing mechanisms have been successfully used to curve demand in moments of extreme weather events (Wolak, 2010; Jessoe and Rapson, 2014). One could also increase their prominence and effectiveness by making them the default tariff (Meredith Fowlie et al., 2017). Pricing mechanisms can be more effective than purely informative persuasive campaigns (Ito, Ida and Tanaka, 2018). One major concern of these price mechanisms is that the most vulnerable households might face large surprise bills unexpectedly, which they might not be able to afford. An important aspect to consider is how to prevent large negative impacts through energy poverty safety valves.

Lowering demand and/or increasing its response to high frequency prices can help minimize the larger costs of grid reliability in the presence of growing renewables. It can also make the phase-out of fossil fuel generators more economical. Incentive schemes should be improved, and ex post assessment of costs and benefits should be enacted to provide the right signals for investment and innovation by private firms and utilities. Coordination with electric vehicle and appliance manufacturers could also ensure that these capital investments are ready to respond in the smart grid, enhancing the ability of consumers to contribute to reducing the costs of the transition while lowering their bills.[1]

Demand efficiency and demand response can ease the process of decarbonization, contribute to limiting the increases in electricity prices, and make the grid more reliable in the presence of extreme events. Safety valves for low-income households during extreme pricing conditions should be considered.

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[1] For example, electric vehicle manufacturers have been reluctant to allow electric vehicles to act as a battery, i.e., send power to the grid. However, such demand response would be extremely valuable as more and more electric vehicles come online. Clear policies and incentives should be put in place.

3. Energy Efficiency in the Housing Sector

A recent report by the Haut Conseil pour le climat (HCC, 2020) demonstrates the need for a combination of various policy instruments (subsidies, regulation, certification, norms) to tackle the challenge of decarbonizing the housing sector. We support these recommendations, which require important reforms in the current existing mechanisms. Energy efficiency in buildings is crucial to reduce the need for energy and to protect households in the face of extreme weather events, such as prolonged heat waves. Energy efficiency will be important as heating becomes electrified via heat pump (which could also work with natural gas or biogas) and puts pressure to the electricity grid. Solutions based on heat pumps fueled by natural gas or biogas should therefore also be included in the system, at least in a transitional period until the problem of intermittent renewable electricity has been solved. Geothermal technologies can also contribute to limiting fossil-fuel heating. Retrofits and upgrades in housing should require a collection of policies, including better standards and norms, consumer information, and well-calibrated subsidies based on realized efficiency gains.

Each housing unit in France generates more than 3 tCO_2/year on average. Electrification will not solve the problem in the short run because high electricity demand for heating typically materializes when marginal electricity production is carbonized. Several public programs already exist in France to help households to improve the energy efficiency of their apartment: a tax credit (*crédit d'impôt pour la transition énergétique*, CITE), a direct subsidy (*certificats d'économies d'énergie*-CEE, *opération "coup de pouce"* in 2019-2020), a zero-interest eco-loan (*éco-prêt à taux zéro*, EPTZ), and the reduced VAT rate. According to (Giraudet et al., 2019), these subsidies saved energy in 2015 at a cost of 4 to 12 cents per lifetime discounted kilowatt-hour, which is large compare to the cost of energy. But observed efficiency gains are smaller than gains predicted by the experts. Economists call this puzzle the "energy efficiency gap" according to which the realized energy efficiency gains are systematically lower than the anticipated gains. In an ex post evaluation of the efficiency of housing retrofits in France, Blaise and Glachant (2019) showed that for every additional €1,000 spent, the average reduction in the annual energy bill amounts to only €8.29. In a more recent analysis of the CEE program, Glachant, Kahn and Lévêque (2020) showed that the average retrofitting investment amounts to €11,750 that generates an average reduction of the annual energy bill by €160. They estimated the abatement cost of the CEE program at €350/tCO_2 saved.

An important problem is the systematic optimistic bias of the energy gain of the retrofit. In France, this may be due to the fact that the subsidy is paid unconditionally, and to the low quality of labeling process for the professionals (Belin and Lefort, 2017). This creates a lemons problem that tends to reduce the private demand. In France between 2014 and 2016, 75% of the renovations (over 1.3 million actions) did not have an impact on the energy efficiency category (DPE) of the renovated housing unit (ADEME, 2018). This should be corrected by conditioning the public subsidy to an ex post evaluation of the energy efficiency gain, as in Germany. Observing the low take-up of free energy efficiency programs in the U.S., Fowlie, Greenstone, and Wolfram (2018) conclude that high non-monetary costs and asymmetric information are higher than usually assumed.

Even when accounting for the broader societal benefits derived from emissions reductions, the costs still substantially outweigh the benefits; the average rate of return is approximately − 7.8% annually in that study. These results raise doubts about the effectiveness of non-selective and blind public support for renovation, at least in the short run. Another explanation for the energy efficiency gap is based on the “rebound effect,” when demand for energy end uses increases as a result of greater efficiency, in the absence of a carbon price. In short, public support in energy efficiency is not a substitute to a carbon tax on emissions by the housing sector.

More competition among energy efficiency companies should be promoted, and the regulation of this key industrial sector should be reinforced, in terms of quality control and consumer protection and information (ATEE, 2020; CEDD, 2019).

The recommendations of the CCC in this domain is to ban fuel and coal heating systems by 2030, and to force homeowners to retrofit their housing unit by 2030 (for units ranked F and G in the energy efficiency scale) or 2040 (for units ranked D and E). In the long run, decarbonizing heating systems will probably require their electrification (potentially through heat pumps) and increasing the use of geothermal in houses and neighborhoods. Due to the impact on electricity consumption from electrifying heating, energy efficiency standards and building codes can interact with the decarbonization costs of the electricity sector. One must be aware that energy efficiency standards for electricity-heated units will generate fewer climate benefits in the future once electricity is fully decarbonized. Given the existing inefficiencies mentioned above, we believe that the current flow of subsidies of €4.5 billion per year allocated to retrofit subsidies under the French recovery plan is satisfactory. This policy should be reevaluated once those regulatory inefficiencies and skill shortages are removed.

Public support programs for energy efficiency should be focused on retrofitting the worst housing units, and these subsidies should be paid in relation to the actual energy efficiency gains. The quality labelling and certification of the operators should be better regulated.

4. Priorities in Innovation

Innovation is an area with large coordination failures and spillovers, which has traditionally benefited from the role of public intervention via R&D policies (Aghion, Akcigit, and Howitt, 2014). Innovation policies should play a crucial role in the fight against climate change, given the technological bottlenecks that are preventing a faster (and more economical) decarbonization of our economies. Carbon pricing alone is unlikely to provide the necessary incentives for the necessary level of innovation due to the high level of uncertainty, the lack of complete future markets, and the path dependence in innovation that makes transitioning away from fossil fuels difficult (e.g., see Acemoglu et al., 2012 and Aghion et al., 2016). Innovating aggressively in clean technologies can also avoid locking additional capital investments in fossil-fuel emitting assets.

But how should such policies be designed? Should particular innovation areas be subsidized, or should more generic approaches that incentivize climate change solutions be adopted? It is useful to differentiate technologies in separate categories depending on their relationship to the climate change problem:

- **Green technologies that can become a substitute to fossil fuels,** such as *economically viable* and *scalable* renewable-plus-storage solutions.
- **Technologies that reduce emissions from fossil fuels** but that, at the margin, cannot be cheaper than burning fossil fuels alone, such as carbon capture sequestration (CCS) at power plants.
- **Technologies that reduce the need for energy**, such as energy efficiency solutions (e.g., as experienced with LEDs).
- **Technologies that capture emissions directly (negative emissions),** such as direct air carbon sequestration, rock weatherization, or agricultural sequestration.
- **Technologies that directly modify the climate** without capturing CO_2 (geoengineering).

We believe that more emphasis in funding should be given to technologies that make fossil fuels irrelevant (i.e., they are cheaper than burning fossil fuels), such as renewable sources of energy and cheaper battery solutions.[1] These technologies are crucial to ameliorate the global climate change problem and are maturing quickly. Technologies making emitting technologies irrelevant have the desirable property that, with intellectual transfer, they are incentive compatible even for countries that do not have the resources or the willingness to contribute to the effort of reducing emissions. More emphasis should be put on the

[1] Green hydrogen also falls in this category. It can be particularly helpful if it is made sufficiently economical and, thus, incentive compatible for non-compliant countries.

impact of these innovations on resources at a very large scale, e.g., on rare minerals, focusing on technologies with lean resource footprints, with the goal of rapid worldwide adoption in mind. Given that renewable technologies are already more attractive than fossil fuels in several geographies (even in the absence of carbon prices, e.g., in Hawaii or Chile), innovations that can help further cut costs and make adoption more scalable seem within reach and particularly valuable.[1]

Technologies making fossil fuels less dirty (at a cost, such as carbon capture sequestration at power plants) will be useful in countries with a high carbon price that have large sunk investments and resources in fossil fuels, such as the United States.[2] Indeed, the carbon price itself should provide a signal for fossil fuel companies to invest privately in carbon capture sequestration technologies. These technologies can also help other countries more actively abate emissions, which will positively contribute to mitigating climate change. However, given the tragedy of the commons and the global nature of the climate challenge, fossil-fuel enabling technologies are unlikely to bring the necessary global reductions in emissions, as they sustain a fossil-fuel based economy that is likely to substantially leak in other parts of the world.[3] Even if focused on making fossil fuels cleaner, public subsidies to R&D can become a transfer to an industry that is likely to significantly contribute to global emissions in non-compliant countries, even under best-case scenario conditions.[4] In other words, using public money to fund R&D for carbon capture and sequestration means subsidizing Saudi Arabia and Russia. We thus discourage the use of public funds for fossil-fuel related R&D and appeal to the signal sent by carbon pricing, which should be improved by properly including all fossil fuels under the EU-ETS and increasing the carbon price.

Energy efficiency is an area in which public policy has taken a very active role, not only in the form of explicit R&D support but other means such as subsidies and energy efficiency standards, e.g., in the car sector (with mixed results due to concerns about compliance), buildings, and appliances. We should note that the presence of larger energy prices

[1] Renewable technologies might have additional valuable features in a developing context. For example, poor countries that are not rich in fossil fuels often face contracting issues and an unreliable supply of fossil fuels. Even if renewable power can be intermittent, it can be more reliable on these other dimensions.

[2] Fracking has contributed to the phasing out of coal power plants in the United States. Yet, it has also led the United States to a path of dependence of natural gas for many years to come, due to the large investments in long-lived capital assets (Acemoglu et al., 2019). The recent target in the US of a net-zero carbon electricity by 2035, if achieved, is likely to invoke carbon capture sequestration.

[3] Brown hydrogen would be another area in which one keeps relying on fossil fuels that can leak (methane and CO_2) and in which sequestration during extraction and combustion is unlikely to be appealing for non-compliant countries.

[4] For example, Fossil Energy R&D public budgets in the United States are considerable, with over $500 million being spent in 2019 for clean coal projects together with almost $200 million on reserve exploration, out of a total budget of $2.5 billion for the DOE energy-specific projects. See Deparment of Energy (2018), "FY 2019 budget request fact sheet," February.

through more ambitious carbon pricing should already provide a re-energized private incentive for energy efficiency innovation. However, special attention could be given to regulated sectors that might lack the incentives to innovate, such as distribution companies of both natural gas (to reduce leaks using sensors and smart meters) and electricity (to reduce losses and adopt innovations, either technological or with regards to innovative pricing schemes, to encourage demand-reducing behavior).

Negative emissions technologies can contribute substantially to limit the extent of damages from climate change, and, as discussed in Section 1 (point 3), will be crucial to ensure that modest temperature targets are still within reach. Therefore, an aggressive battery of R&D spending towards negative emissions seems useful, precautionary, and necessary to mitigate climate change. Emphasis should be placed on negative emissions technologies that can demonstrate their additionality and long-term reliability, e.g., in the face of increased storm and fire risk for soil storage and afforestation innovations. Emphasis should also be placed on carbon capture not directly linked to human activities, to avoid perverse incentives.[1]

We believe that a potential way to approach the issue of negative emissions is via innovation tournaments. Given their importance in solving the global nature of the problem, international competitions should be in place to achieve measurable sequestration of emissions that can be ensured to be additional, and that are not directly related to the active production of man-made emissions. A potential way to implement the tournament is to guarantee the purchase of a large amount of negative emissions at a strike price, e.g., €150-€200/ton CO_2, to the first one or two projects that can deliver economical negative emissions. R&D during the tournament would be eased by substantial amounts of public funds. As witnessed recently with the Covid-19 vaccine, companies and innovation are unleashed in the presence of high stakes (economical and societal).

Current targets in warming are unlikely to be satisfied in the absence of these breakthroughs. That said, one should not bank on a breakthrough to avoid the necessary transition towards a decarbonized economy. Additionally, negative emissions that cannot be properly measured should not be used as a safeguard to limit climate policy ambition. Given previous experiences with offsets in several markets (EU-ETS, California), it is important to ensure that negative emissions are additional. It is important to clarify that such a tournament would not include carbon capture sequestration of human-made

[1] Such perverse incentives have in the past been the source of concern in the market for Clean Development Mechanisms (CDMs), by which it was more profitable for industrial producers of HFCs to generate emissions and re-capture them than to produce them for sale, leading to limited additional reduction in spite of high transfers of payments (Wara, 2007).

emissions, due to the perverse incentives described above. It would also not include emissions from power plants.

Indeed, "negative" emissions from power plants are already covered under the EU-ETS. Rather than "negative" emissions, one should think of carbon capture sequestration at power plants as "less positive" emissions (or "zero" at best). If power plants can verify their reductions, the total cost of their allowances will substantially decrease or even cancel. Unfortunately, the carbon price at the EU-ETS has been too low to encourage aggressive investment by power producers. This could be another potential benefit from increasing the EU-ETS carbon price.

Regarding geoengineering, we consider these technologies a last resort in dealing with the climate challenge, although possibly one that countries will unilaterally consider (Wagner and Weitzman, 2018). Geoengineering, which is focused on directly changing the climate, does not stop the underlying threat to life and ecosystems of our current system, which is the growing presence of CO_2 in the atmosphere. Therefore, it is at best a temporary fix. In addition to having extremely uncertain geopolitical and environmental consequences, geoengineering can harm the credibility and commitment of governments to reduce emissions (Acemoglu and Rafey, 2018).

While not the focus of this report, substantial public investment in R&D should be devoted to research on how to adapt to a changing climate, with an emphasis on those areas that are unlikely to receive private attention, such as cheap structures to protect vulnerable households from extreme events or research on how to better manage and adapt forests to changing climates, e.g., to slow down desertification. Governments and private parties should also publicly invest in R&D to understand how extreme sustained temperatures can affect critical infrastructures (e.g., the electric grid).

Innovation efforts should be devoted to those areas that can generate positive spillovers to non-complying countries, such as innovations that make zero-emissions technologies cheaper or negative emissions technologies that can enable the European Union to go above and beyond its stated targets.

5. Involvement of Consumers, Corporations, Investors and Financial Institutions

The energy transition has already begun. In recent years, progress on low-carbon solutions and markets has been faster than ever. Today, a stealth technological revolution is propelling us towards a low-carbon future. In Europe, a growing fraction of the population is imposing a constant pressure on governments and corporations to face our collective responsibility to protect our environment. They exercise their power as citizens by penalizing irresponsible politicians in the ballot box, as consumers by boycotting high-carbon products, and as savers by divesting from brown assets. Private institutions have also initiated a revolution in the way they evaluate their own role in our society, in particular in relation to climate change. In this section, we review some of the difficulties associated to these welcomed initiatives, and we explore the solutions to improve their efficacy.

Greening a production process is often costly and is thus hardly feasible in a competitive environment without losing market share (another form of carbon leakage) in the absence of carbon pricing. Consumer activists expect to pay a premium for greener products, but this growing fraction of the population can exercise its power only if they can access the right information on the carbon content of these products. For example, can we measure the carbon intensity of a tomato grown in a field in Spain but transported by truck relative to a tomato grown in a greenhouse heated with natural gas in France? If one wants to maximize the positive effect of consumers' activism, this comparative evaluation must be done. Empowering consumers thus requires imposing a carbon accounting system to the whole economy, in parallel to the monetary accounting system that gradually emerged in the 19th century. The carbon account of all legal institutions should be made compulsory and public information, in particular to consumers and investors. Scope 3 in the existing carbon accounting standard, which covers all GHG emissions along the value chain, is the key concept to be promoted, but double-counting should be avoided. This proposition is aligned with the recommendation of the Convention citoyenne pour le climat to impose green labels.

One should empower consumers and investors to promote decarbonized products by implementing a transparent carbon accounting and labeling system.

Corporations are often said to green-wash their business strategy, with limited real environmental effect. This is made possible because of asymmetric information and the ambiguities surrounding the existing labelling and ESG reporting systems. The European Taxonomy should be developed and extended to further help investors identify climate compliant investments.[1]

The concept of corporate environmental responsibility, or its dual concept of naming-and-shaming, are useful to mobilize private initiatives. A growing number of corporate leaders, realizing that carbon-intensive assets face the risk of being stranded soon, are willing to tackle the challenge of climate change, and want to be recognized as doing so. This is not an easy task, in particular because of the mimicking strategy of the green-washers and the absence of a clear methodology. Climate finance is lacking a clear narrative as an efficient instrument to play a central role in the energy transition. Bankers and

[1] This EU taxonomy should recognize the merits of nuclear electricity in this domain.

responsible corporations, as well as any economic agent willing to act responsibly in the face of climate change, should use an internal carbon value to evaluate their actions. Many companies are already using an internal carbon price as a common management tool. In doing so, they seek to replicate the effective climate policy we have described in this report, at their level, and to replace failing states in using their sovereign power to implement it at the level of their entire economy. If this price is close to the collective shadow price of carbon, these firms' investment strategies will be socially desirable. In the short term, this strategy may negatively affect profitability, but it serves as a hedge against the risk of the emergence of more ambitious public policies penalizing unambitious firms. It is an insurance against holding "stranded assets." It will reassure investors who anticipate the rise in the price of carbon on the EU-ETS market. Many large corporations around the world have already incorporated an internal price of carbon to shape their investment strategy, but they should make their internal carbon pricing more transparent and subject to scrutiny.

To align their institutions with the common good, responsible corporate leaders should use a transparent internal carbon price to shape their corporate strategy.

Financial markets should also play a role. Climate change creates two new sources of risk for investors: 1. future climate damages, and 2. rapid obsolescence of carbon-intensive investments. Sadly enough, the waiting game observed on the international climate negotiation continues to limit the investors' trust about the future profitability of greener technologies. The bottom line is that too many investors around the world continue to bet on the profitability of carbon-intensive sectors and to be reluctant to finance green projects. This creates a systemic risk associated with the scenario of an abrupt emergence of stranded assets. There is a misconception that the energy transition is hampered by capital rationing directed towards green sectors. Under this assumption, it would be sufficient for the States to give credit to these sectors to solve the problem. The reality is that if the energy transition is struggling to take place, it is because most low-carbon projects are not able to withstand competition from their more carbon-intensive counterparts, because of the low price of carbon and its future prospects. Recent recovery plans have promised large sums of public funding to green our economies, but this is vastly insufficient to finance the transition. The private sector has to play a central role in the ecological transition. Although public funding is absolutely necessary to finance the greening of our public infrastructures (railways, schools, hospitals, etc.) and services (public transportation, etc.), these plans cannot solve the problem of the lack of profitability of the energy transition whose keys are in the hands of the private sector. This is why these plans should be associated with the reinforcement of the carbon price signals.

The financial return of brown assets remains based on an overestimation of the true social value creation of the corresponding activity, potentially by a wide margin. Responsible investors and financial intermediaries could restore their right social valuation by subtracting the value of carbon emissions of the asset from its financial performance. This should be done by using a transparent internal carbon price. Socially responsible (SRI) climate funds should be optimized on a risk-return efficient portfolio estimated on the basis of the social valuation of firms. It is completely clear, for example, that coal assets will be excluded from these climate funds. This is why this methodology is fully supportive of the coal divestment movement. A good example of a responsible methodology of internal carbon pricing is provided by the European Bank for Reconstruction and Development (EBRD, 2018).[1]

But one must be aware that the divestment movement currently has a limited impact on the allocation of capital in the economy, due to the financial carbon leakage problem. Banks that divest from the coal sector are usually replaced by other banks that invest in it. Divesting should have increased the cost of capital of brown assets, but the effect has been limited due to this financial carbon leakage, or to this easy capital substitution. Real carbon leakages due to national carbon pricing are harder to implement, since it means dismantling a plant to rebuild it physically on the other side of the frontier. The divestment movement should have reduced the return of low-carbon indices around the world, symmetrically to the intended reduction of the cost of capital of low-carbon firms. However, this effect has been quite limited in the past (Andersson, Bolton and Samama, 2016).[2] At the same time, investing in climate funds, i.e., divesting from carbon-intensive assets, is a hedging strategy that insures investors from the risk of a rapidly increasing carbon price in the future.

Financial institutions are weaker than governments to induce the ecological transition of our economies. To illustrate, it is not the divestment movement that has weakened the tobacco industry, but the high taxes that have been imposed on cigarettes in the western world. Because of the financial carbon leakage problem, responsible financiers face a much harder challenge than sovereign powers to induce the necessary ecological transition. The divestment movement could play an important role in the future, but this would require most capital-rich countries to join that movement too.

The quantitative easing policies that have been implemented by the Fed and the European Central Bank (ECB) have transformed them into key financial market makers. Should the ECB become a new climate activist by divesting from carbon-intensive industries? This interesting proposal raises various legal and financial issues. First, the ECB, contrary to the EU Parliament, has no mandate to fight climate change. Second,

[1] The EBRD uses an internal carbon price of $50-$100 per tCO_2 in 2030, then growing at a rate of 2.25% per year. The methodology also imposes for each project the calculation of the switching carbon value at which the investment decision changes, i.e., the cost per tCO_2 saved.

[2] On September 17, 2019, Bill Gates explained that “divestment, to date, probably has reduced about zero tonnes of emissions”.

national and European democratic institutions have been very reluctant to penalize brown sectors, and it would be problematic for a non-democratic institution such as the ECB to serve as a proxy to perform this task. Our proposal is that the ECB should comply to the EU climate ambition by using an internal carbon price when valuing the collateral of its loan programs.

Climate finance is a poor substitute for state-controlled climate policies within the state jurisdiction. Responsible finance principles should be based on an internal carbon price, to be used by responsible investors, financial intermediaries and central banks.

Two additional financial innovations should also be considered. We support the issuance of green bonds by public and private institutions, under stricter rules for their labeling. In theory, the existence of responsible investors in the economy should introduce a “green premium” (greenium) at equilibrium for this class of assets. This premium should help improving the competitiveness of green activities. In reality, the green premium is currently close to zero. This may be due to the lack of credibility of the green label. It should be reinforced.

Finally, financial indices represent a powerful tool to rapidly reallocate the flow of private capital toward more sustainable sectors. Many FCP, SICAV and ETF in France aim at duplicating the composition of the CAC 40 portfolio. We support a strategy to create a “Climate CAC 40” index, whose composition would be compatible with the 2°C target of the Paris Agreement. Euronext, the operator of the indices of the CAC family, has announced the creation of such an index. This is likely to have an important effect on the cost of capital of the assets included in the index, and to create an incentive to reduce emissions by all large corporations in France (Voisin et al., 2020). Currently, market indices such as the CAC 40 contain the 40 largest capitalization of the Paris market. Our recommendation would be to define the “Climate CAC 40” with the 40 largest capitalization net of the present value of the flow of the GHG emissions of their current physical assets, valued at the shadow carbon price of the Quinet 2 report. This is simple and transparent, and it incentivizes firms to immediately modify the portfolio of their physical assets. We expect this new climate index to rapidly replace the classical CAC 40 as the financial market reference in France.

Financial indices such as the CAC 40 should be made compatible with the 2°C target by modifying their market capitalization rule to include the carbon value of their assets’ emissions.

6. The Role of Agricultural Policy[1]

Food accounts for about 31% of the EU's total GHG impacts (Garnett, 2011). For example, one kg of beef implies an emission of methane equivalent to 40 kg of CO_2. Current trends suggest that aligning agricultural practices with the EU climate ambition will not be an easy task. EU agricultural GHG emissions went down until around 2010, but have slightly increased since. According to (Guyomard et al., 2020), "significant changes in farming practices and systems are now required to achieve further substantial reductions, including a reduction in the use of nitrogen fertilization and in the number of animals farmed."

Despite its large contribution to climate pollution, the food sector is not concerned by most existing climate regulatory schemes such as a carbon tax or ETS. Food has been considered as the single strongest lever to optimize human health and environmental sustainability on Earth (EAT-Lancet, 2019). Most emissions from food come from the production stage, namely agriculture, through emissions of methane and nitrous oxide (manure, urine and nitrogen fertilizers) in particular. The biggest share of emissions come from animal agriculture, with life-cycle impacts of the lowest-impact animal products typically exceeding those of vegetable substitutes per kg, calorie or protein (Poore and Nemecek, 2018). The recent IPCC report on land use (IPCC, 2019) states: "Balanced diets, featuring plant-based foods, such as those based on coarse grains, legumes, fruits and vegetables, nuts and seeds, and animal-sourced food produced in resilient, sustainable and low-GHG emission systems, present major opportunities for adaptation and mitigation while generating significant co-benefits in terms of human health (high confidence)."

The carbon footprint of food/agriculture is significantly higher if one accounts for the opportunity cost of carbon, namely the opportunity for storing carbon in the vegetation and soil by changing land use practices. As an example, more than 85% of the deforestation in South America is caused by animal farming, namely the forest is converted for pastures and for producing animal feed (Sy et al., 2015). Importantly, a significant portion of this production is imported in Europe, such as soy for feeding the European cattle. Accounting for this opportunity cost, it has been estimated that the carbon impact of animal food products may be three to four times higher than previously estimated (Searchinger, Wirsenius and Beringer, 2018). The cumulative potential of CO_2 removal on land currently occupied by animal agriculture is comparable in order of magnitude to the past decade of global fossil fuel emissions (Hayek et al., 2020).

It is widely and increasingly recognized that the price of food products does not reflect their environmental footprints, and that immediate action is necessary. The greening of the EU

[1] We gratefully acknowledge Nicolas Treich (TSE and INRAE) for his valuable inputs to this section.

agricultural policy has been recognized to be a failure for decades (Navarro and López-Bao, 2019), one reason being that it pursues many objectives such as providing income to farmers and ensuring food security. Moreover, climate change raises a particular challenge for the agricultural sector, both in terms of the adaptation to the changing environment and to the cost of greening their activities. The agricultural sector is well known to be politically powerful, and difficult to regulate in general (Bonnet et al., 2020). This issue, together with the difficulty to measure emissions and sinks at the production level, explains why we do not recommend to price carbon upstream in the case of food production. Many argue that directly targeting consumers rather than producers would be more efficient (Poore and Nemecek, 2018). We support this recommendation. Moreover, using novel environmental impact tools such as Agribalyse makes it now fairly easy to assess the full environmental impact of each food product over their entire lifecycle, and thus to compute the relevant tax that must be applied on each food product. Various studies have estimated the impact of the implementation of a carbon tax on food products. This carbon tax should of course be aligned on the price of EU-ETS. Springmann et al. (2016) for instance show that the global climate change mitigation potential of emissions pricing of food commodities could be substantial, and further emphasize much higher health co-benefits. Pieper, Michalke and Gaugler (2020) have evaluated the impact of carbon pricing on the production cost of various foodstuffs in Germany. Using a carbon price of €180/tCO_2, they showed that the impacts are highest for conventional and organic animal-based products (146% and 71% surcharge on producer price level), followed by conventional dairy products (91% surcharge) and lowest for organic plant-based products (6% surcharge).

Rather than asking farmers to pay for their greenhouse gas emissions, food products should be taxed in proportion to their contribution to climate change.

Agricultural production is subject to important leakage problems and, therefore, the taxation of carbon footprints at the consumption level is desirable to mitigate deforestation pressures in other parts of the world. If the EU taxed production of agricultural products only if produced in the Union, it would incentivize land use changes in other areas that would likely negatively contribute to climate change. By taxing food consumption, the carbon footprint of both domestic and imported production are by design accounted for. The introduction of a carbon adjustment at borders should also be considered for imported agricultural products.

The risk of shifting land use change pressures to other parts of the world also applies to other aspects of the agricultural policy. Apart from the negative impacts on deforestation to these other areas, it is important to avoid the growth of unmanaged vegetation areas in the Union, which are now subject to increased fire risk. More generally, agricultural policy will likely also take the form of many complementary policies, as considered under the Common Agricultural Policy (CAP), some not directly targeted to climate change but to biodiversity and sustainable agriculture. It is crucial to take into consideration the climate change implications of these other policies, with an eye on the potential for deforestation and leakage in other parts of the world, which could lead to even larger biodiversity loss and contribute to global warming.

A consumption-based environmental footprint tax can be effective at avoiding leakage. The leakage implications of other policy tools need to be examined.

Finally, concerning the reform of the CAP, we support the recent recommendations made by Guyomard et al. (2020) in a report submitted to the EU Parliament:

> "General principles of public economics and fiscal federalism help to clarify the goals and roles of the various CAP tools. First, it is vital to more effectively apply the 'polluter-pays principle,' upon which conditionality relies, in order to better justify the increased implementation of the 'provider-gets principle' that underlines both the eco-schemes and climate- and environment-related measures. Second, the Pillar 1 eco-scheme measures that are fully financed by the European budget must target global public goods; that is, climate mitigation, biodiversity preservation and restoration, as well as animal welfare. Third, the eco-schemes must be supplemented by Pillar 2 measures that are focused on local public goods; notably, water quantity and quality, soil fertility and diversified landscapes."

7. Contributing to the Transformation of Transportation and City Systems

In 2017, 27% of total EU-28 greenhouse gas emissions came from the transport sector (22% if international aviation and maritime emissions are excluded).[1] In France, given the relatively low carbon intensity of the electricity sector, it represents an even larger share of emissions (around 40%). Given the important network effects in transportation, and the lack of viable alternatives in some areas, e.g., aviation, decarbonizing this sector will require substantial policy action.

Public policy can play a central role in coordinating the phase out of fossil fuel cars, for which carbon capture sequestration is not possible. There are also large co-benefits from removing cars from highly dense areas that are not fully priced in the cost of gasoline (e.g., see Coady et al., 2019 or Holland et al., 2018, in the United States). The recent announcements in Paris and Strasbourg (excluding diesel engines from the city in 2024 and 2025 respectively, and all combustion engines by 2030) go in the direction of

[1] European Environment Agency 2020), « Greenhouse gas emissions from transport in Europe », indicator assessment, 18 décembre.

coordinating city planning with the phase out of combustion engine cars from cities.[1] Recent announcements from the executive also point at providing clear dates for which fossil-fuel engines need to be phased out. Indeed, the *Loi d'orientation des mobilités* (LOM) of 2019 has fixed the prohibition of new combustion engines for transportation for the year 2040. Similar announcements have been made in other jurisdictions, with a phase out of all fossil fuel vehicles in 2025 in Norway, 2030 in the Netherlands and Ireland, and 2035 in the United Kingdom, for example (International Energy Agency, 2020). In this context of rapid change, the French law of 2019, the first announcement of this kind, might not be as binding as initially thought. We believe that the necessary carbon pricing mechanism presented earlier in this report will eliminate most fossil fuel engines on our roads much earlier than in 2040. Given that the phase-out of cars from cities, and eventually out of roads, might be accelerated, it is important to publicly plan for alternatives. Efforts should be put in place to ensure that the transition does not leave behind low-income households without reliable means to travel, e.g., by ensuring the presence of public transport or public ride-sharing electric vehicles. The costs of this urban transformation, direct or indirect through the differential growth of land rents, should not be transferred to the suburbs. This requires a strong push in public transportation infrastructures, an increase in population density by changing building standards, and a reform of the local tax system.

Since 2008, the automobile market in France is regulated by a bonus-malus (feebate) system in which low-emission cars get a bonus that is funded by a penalty paid by buyers of high-emission cars. Because this system does not incentivize consumers on the basis of actual emission, it is a second-best mechanism to reduce emissions. In particular, once a high-emission car is purchased, its buyer has no incentive at all to limit its use (rebound effect). Also, the bonus for low-emission cars attracted people who would not have purchased a car otherwise, since the non-purchase option is not subsidized. In fact, the implementation of that system in 2008 yielded an initial increase in emission by 1.2%. D'Haultfoeuille et al. (2014) showed that this feebate mechanism would have increased emissions by 9% in the long run if its parameters would have not be adapted. As explained earlier, a bonus-malus system could be justified for its redistributive advantage over a direct carbon pricing system only if the state remains unable to redistribute the carbon dividend efficiently.

At a broader level, re-thinking the transportation sector will require re-thinking the end goal. Rather than thinking of a solution in which each household replaces their traditional car with an electric car, it is an opportunity to transform the way we travel, with the need to enhance clean public transportation. This presents an opportunity to reduce the use of cars in cities, improving congestion, noise, and particulate matter pollution, which is

[1] Similar announcements have been made by other cities such as Madrid and Barcelona (only zero-emissions vehicles allowed in the city by 2030).

still present with electric vehicles. It is important to highlight the advantages of reducing cars in cities in terms of space. Parked cars occupy valuable space in cities that can be used for alternative uses, such as enhancing mobility (safer and faster) with alternative vehicles (such as bicycles and scooters) or more greening of cities, which is crucial to regulate temperatures.

Finally, when it comes to shipping and aviation, the solutions to the decarbonization are much further away from being economical. And too many local railway lines in France use diesel as an energy source. For this reason, public policy should combine a carbon price on shipping and aviation emissions, together with active R&D efforts for decarbonizing these sectors, possibly using green hydrogen. In the short term, forcing the transportation sector to face a carbon pricing system that takes into account its environmental damages will have the positive effect to favor short-circuit systems of production and consumption.

The Convention citoyenne pour le climat has made several proposals to decarbonize air transport. Some of them are in the direction of carbon pricing. For example, the CCC proposes an eco-contribution on all flights (with the surprising exception of flights to French overseas departments and territories). A similar solution, but much more efficient and transparent, would be to force airlines to buy quotas on the EU-ETS system. The multiplication of sectoral mechanisms is inefficient, since it creates several carbon prices. This proposal illustrates the natural tendency to design sectoral policies, despite the global nature of the problem. Since all CO_2 molecules have the same climate impact, proponents of carbon pricing should support the principle of a single instrument pricing all emissions. As justified in Section 3 (1.2), targeted measures should respond to sectoral specificities (co-benefits, other externalities, information problems...), and should be justified on this basis.

The CCC also proposes to force airlines to fully offset their emissions (this time including flights from the French overseas departments and territories) by financing carbon sinks. The introduction of this proposal into the draft law, as we have seen, would go further by forcing airlines to offset their emissions through specific instruments, in particular through the financing of French carbon capture and storage (CCS) projects. It is inconsistent to impose both an eco-contribution (or coverage by the EU-ETS) and a complete offsetting of emissions, a fortiori by financing highly random R&D on decarbonation. This would duplicate the carbon pricing mechanism for the sector, which is inefficient. And it would impose two parallel instruments for a single objective. Why would we impose this double system on this sector and not on others? Moreover, if governments want to specifically finance certain carbon sinks, such as CCS in France, they can, for example, use the revenues from the ETS to do so.

CONCLUDING REMARKS

The time of the awakening is now over. Here comes the time of the action in the face of our responsibilities towards future generations. The von der Leyen EU Commission, the new Biden's administration, and many other countries around the world are aligned in their ambition to fully decarbonize their economies within the next three decades. This is a herculean ambition. A myriad of actions needs to be implemented by a myriad of actors. Sovereign powers must orchestrate this societal transition to insure efficiency, effectiveness, and fairness. Up to now, the tragedy of the horizons, the free-rider problem, and the lack of a clear vision and a strong political leadership, have limited progresses.

France counts for less than 1% of greenhouse gas emissions. But the French public opinion strongly supports efforts to reduce these emissions, which is an important political asset in international negotiations. With Germany and other ambitious European countries, France should drive the EU Green Deal agenda, and help create a climate club with the United States under the Biden administration. In particular, the climate club should strive to put in place a uniform and universal carbon price for the coalition, together with a WTO-compatible carbon border adjustment at its frontier. We may expect that such a club will soon become very attractive to join – the benefits, in terms of trade and carbon dividend, outweighing the costs, in terms of losing the advantage of environmental dumping if remaining outside the club.

The pricing of carbon is crucial to render profitable individual and corporate mitigation actions that are socially desirable. This should be done at the European level rather than at the national level. Because most mitigation actions are investments whose environmental benefits will be scattered over several years or decades, more visibility, predictability, and credibility about future carbon prices should offered. This should be done by reshuffling the EU-ETS market for emission permits. The system should cover all EU emissions, with no exemption. Free allowances to sectors exposed to international competition should be eliminated since the argument of environmental dumping will be taken care of by imposing the carbon border adjustment mechanism. The credibility of future carbon prices should be organized through an EU agreement about a carbon price floor that should grow at a real rate of around 4% per year, or by the creation of a "Carbon Central Bank." The carbon dividend generated by the selling of permits should be redistributed to members in proportion of their national emissions. National governments could use this carbon dividend to compensate the lower deciles of their population, in order to make the whole carbon pricing mechanism progressive. To raise the political acceptability of this reform during the EU grand bargain, losing parties, and in particular coal-rich countries, should be compensated through the use of the EU Just Transition Fund, whose budget should be made sensitive to the agreed-upon level of the carbon price floor and its growth rate.

Because of several market failures, the presence of large uncertainties, incomplete markets and co-benefits, carbon pricing will not be enough to reorganize our economies efficiently in the face of this formidable climate challenge. The decarbonization of the electricity, industrial, and transportation sectors, the greening of agricultural practices and of cities, and the improvement of the efficiency of markets for housing retrofitting raise specific issues that need to be individually addressed. This report is not aimed at exploring them in detail. We stress the importance of performing cost-benefit analyses of the specific policies (subsidies, bans, norms, etc.) to address these market failures. In particular, their merit order should be based on the estimation of the cost per tCO_2 saved, taking account of all other social and environmental benefits and costs of these policies. Their timely implementation should be based upon the time at which their cost per tCO_2 saved becomes smaller than the value of carbon that should grow over time. For example, replacing coal by natural gas in the EU electricity mix should be implemented as soon as possible, given its very low cost per tCO_2 saved. Phasing out natural gas should come later. Nuclear energy, hydroelectricity and biofuels should be recognized as the only dispatchable sources of decarbonized electricity, a crucial property in the absence of a mature technology to store electricity. We also stress the importance of a massive investment program in green R&D, in particular for projects that are likely to develop renewable sources of energy able to compete with fossil fuels even in the absence of political will to act for the climate, i.e. in the absence of carbon pricing. Such technological discoveries would have significant benefits on the willingness and ability to decarbonize the world with global impacts.

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