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Working Paper

Climate policies and nationally determined contributions: Reconciling the needed ambition with the political economy

IDB Working Paper Series, No. IDB-WP-818

Provided in Cooperation with:
Inter-American Development Bank (IDB), Washington, DC

Suggested Citation: Vogt-Schilb, Adrien; Hallegatte, Stephane (2017) : Climate policies and nationally determined contributions: Reconciling the needed ambition with the political economy, IDB Working Paper Series, No. IDB-WP-818, Inter-American Development Bank (IDB), Washington, DC,
https://hdl.handle.net/11319/8319

This Version is available at:
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IDB WORKING PAPER SERIES Nº IDB-WP-818

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June 2017

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Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library
Vogt-Schilb, Adrien.
Climate policies and nationally determined contributions: reconciling the needed ambition with the political economy / Adrien Vogt-Schilb, Stephane Hallegatte.
p. cm. — (IDB Working Paper Series ; 818)
Includes bibliographic references.
1. Climatic changes-Government policy. 2. Greenhouse gas mitigation-Government policy. 3. Environmental economics. 4. Environmental policy. I. Hallegatte, Stéphane. II.Inter-American Development Bank. Climate Change Division. III. Title. IV. Series.
IDB-WP-818

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Climate Policies and Nationally Determined Contributions: Reconciling the Needed Ambition with the Political Economy

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Abstract

Countries have pledged to stabilize global warming at a 1.5 to 2°C increase. Either target requires reaching net zero emissions before the end of the century, which implies a major transformation of the economic system. This paper reviews the literature on how policymakers can design climate policies and their Nationally Determined Contributions (NDCs) to reach zero-net emissions before the end of the century in a socially and politically-acceptable manner. To get the ambition right, policymakers can use sectoral roadmaps with targets and indicators that track progress towards zero emissions (e.g. regarding renewable power or reforestation). Indeed, monitoring economy-wide emissions reductions alone would not ensure that short-term action contributes meaningfully to the long-term decarbonization goal. To get the political economy right, climate policies can be designed so that they contribute to non-climate objectives and create coalitions of supporters. For instance, revenues from carbon taxes can fund social assistance and infrastructure investment, while reducing tax evasion and informality. To minimize social and economic disruptions and avoid stranded assets, policymakers can start with a low carbon price level and use complementary policies. Designed at the sector level, complementary policies such as performance standards or feebates for cars, building norms, or moratoriums on new coal power plants can be negotiated in partnership with local stakeholders and trigger a transition to zero carbon without creating disruptive stranded assets.

Keywords NDC implementation, social acceptability, dynamic efficiency, climate mitigation, carbon price, green innovation, zero carbon, climate policy, political economy, stranded assets, green growth, infrastructure, performance standard, carbon emissions, distributional impacts
JEL L50, O13, O15, O33, O44, Q52, Q54, Q58, F53

When it abolished slavery in colonial plantations in the 19th century, the United Kingdom paid 20 million pounds in compensation to plantation owners. The sum is substantial: it corresponds to about $21 billion in today's value, and 40% of the government's budget at that time. Trebilcock (2014a) uses this example to illustrate how ambitious policy reforms (such as slavery abolition), even when they improve global welfare, create groups of losers (here, the slave-owners), who could have the power to veto the reform. In implementing reforms, governments have to balance the required ambition of the change with its social and political acceptability.

The international climate change agenda will require ambitious policy reforms. During the 21st conference of parties of the UNFCCC and through the resulting Paris Agreement, global leaders have pledged to make efforts to stabilize the increase in global temperature well below 2°C, and preferably below 1.5°C (United Nations, 2015). These are ambitious targets: they require reaching zero net emissions of carbon dioxide (CO_2) and drastically reduce emissions of other greenhouse gases (GHGs) before the end of the century(IPCC, 2014). To implement this long-term goal, countries around the world agreed to submit Nationally Determined Contributions (NDCs), which are more or less detailed plans to reduce GHG emissions domestically. Many of the first NDCs set emission-reductions plans for 2025, and all NDCs are supposed to be updated – and strengthened – every five years.

Policymakers in all countries need to design those NDCs and the policy packages that will deliver them taking into account both the need for rapid and profound changes in the economic structure, and the importance of political economy considerations in making reforms successful (Fay et al., 2015). This paper investigates how they can develop policy packages over the short-term – for the next 15 years – that combine the ambition needed to achieve the objectives of the Paris Agreement and the navigation of political economy issues that constrain what can be done in practice.

First, we focus on the ambition of climate action and lay out explicitly what NDCs and climate policies should try to achieve in the long term. Stabilizing climate change requires a net decarbonization of the world economy (Rogelj et al., 2015). CO_2 stays in the atmosphere for hundreds, if not thousands of years; as long as we emit more than what we capture or offset through carbon sinks (for instance using reforestation), concentrations of CO_2 in the atmosphere will keep rising, and the climate will keep warming. Climate stabilization thus requires reaching zero net emissions, a scientific consensus that has been elevated to an international objective in the Paris Agreement, in which parties pledge "*to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century*" (United Nations, 2015).

To track progress over time toward decarbonization, it is not enough to track the *quantity* of emission reduction in the short term. It is essential to also monitor *how* emission reductions are delivered, and in particular in which sectors and with which technology (del Rio Gonzalez, 2008; Vogt-Schilb et al., 2014). Even if short-term action leads to significant emission reductions, it is likely to be off-track if it misses key sectors of the economy: those, like public transportation, which are more difficult to decarbonize because low-carbon alternatives are expensive and/or take long to deploy. In that case, even if emissions are reduced, the economy risks getting locked into carbon-intensive development pathways, from which it is then unnecessarily costly to diverge. To monitor NDC ambition and implementation in a meaningful way, and to design climate policies, this paper proposes to use sectoral targets, such as the 27% renewable in 2030 target of the European Union.

In the second part of this paper, we turn toward the political economy of the transition to zero net carbon emissions, and approaches to support those who lose from it. Governments today are not less subject to political economy constraints than the United Kingdom in the 19th century when slavery was abolished. Emission reduction policies have substantial potential to create losers: poor and middle-class households facing higher energy and food prices due to energy subsidy removal or carbon pricing; energy-intensive and trade-exposed companies losing competitiveness due to environmental regulations; powerful lobbyist and thousands of coal workers opposing the phase down of coal-based energy.

The first option is to price carbon emissions at a level that is acceptable in a given country context (Jenkins, 2014; Parry et al., 2015), and to use carbon revenues to protect those negatively affected or generate other growth and development benefits (Franks et al., 2015; OECD, 2017). For instance, cash transfers can be used to correct distributional impacts of carbon taxes, and other taxes can be reduced to enhance the efficiency and fairness of the fiscal system (Combet et al., 2010; Metcalf, 2014; Parry and Williams, 2010).

Another approach is to select policy instruments that minimize abrupt disruption, such as performance or energy efficient standards and feebates scheme that redirect investment toward zero-carbon capital without affecting directly those responsible for today's emissions (Rozenberg et al., 2017).

Increasing further their social and political acceptability, emission-reduction policies can frequently be designed to be aligned with domestic development agendas, for instance when a public transport system reduces global greenhouse gas emissions while also improving congestion and the health of local population (World Bank, 2014), or a shift to carbon taxes is used to reduce evasion and informality (Bento et al., 2013).

Finally, we also argue that a sectoral approach can answer to many of the obstacles to decarbonization – from knowledge spillovers to imperfections of capital markets and behavioral bias – and enhance political feasibility. Sectoral targets facilitate the design of climate policies since the policy instruments to enforce them, such as performance standards on new vehicles or renewable portfolio standards, can be more easily negotiated with civil society, academia and industry stakeholders than economy-wide targets and instruments.

Getting the Ambition Right: The Long-Term Target Needs to Drive Short-Term Climate Action

While some aspects of the economic evaluation of emission reduction strategies are controversial, policymakers, scientists and many economists have emphasized a need for climate stabilization at a safe level (Cai et al., 2016; Lemoine and Traeger, 2016). What exactly is a safe level is still an open question, which will remain a political one (Jasanoff, 1987; Kalra et al., 2014). Global leaders, in the Paris Agreement, have pledged to limit global warming well below 2°C, and preferably below a 1.5°C increase compared to the pre-industrial era. This in turn will require reducing carbon emissions to zero, and even to net negative values, well before the end of the century (IPCC, 2014). The Paris Agreement sets such a goal: parties pledged "*to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century*" (United Nations, 2015).

Several studies by academics, think tanks, governments and international agencies concur that a world with zero net GHG emissions is technically possible. What all models and modelers agree on is that action will be needed on five fronts (Bataille et al., 2016; Fay et al., 2015; IPCC, 2014; Sachs et al., 2014):

1. Decarbonizing the production of electricity (e.g. using renewable power).
2. Undertaking massive electrification (e.g. using electric vehicles and electric boilers), and where not possible, switching to cleaner fuels (e.g., biofuels).
3. Switching to less carbon-intensive materials (e.g. wood instead of cement) and diets (e.g. away from beef)
4. Improving efficiency and reducing waste in all sectors.
5. Preserving and increasing natural carbon sinks, through improved management of forests and other vegetation and soils.

The fact that both decarbonization of electricity supply and electrification of the energy system play a decisive role in reaching climate stabilization is a very well established result from both integrated assessment models (IAM) and simpler energy models (IEA, 2014a; Krey et al., 2014; Luderer et al., 2012; McCollum et al., 2014; Sugiyama, 2012). The IPCC reviews possible pathways to achieve full decarbonization by 2100, derived from various energy and economic models that examine what it would take to achieve decarbonization under a number of different scenarios of economic growth and technological innovation, and notes that "*virtually all integrated modelling studies indicate that decarbonization of electricity is critical for mitigation*" (Clarke et al., 2014), even if the specific technologies needed for reaching this goal, in particular the relative shares of CCS, nuclear and renewable power, are subjected to debate (Audoly et al., 2014). Since carbon-free electricity is required, switching other energy usages to electricity is an effective way of reducing GHG emissions in other sectors (Williams et al., 2012).

Energy efficiency has been described as a natural trend in development (Duro and Padilla, 2006; Stern, 2004; van Benthem, 2015), a cost-effective way to reduce emissions (Allcott and Greenstone, 2012; Gillingham and Palmer, 2014), and a factor helping with the technical feasibility of renewable power and electrification (Clarke et al., 2014). But efficiency and electrification have their limits. Some activities, such as beef and cement production, are difficult to decarbonize, and may need to be downsized. Others energy usages, for instance in the case of civil aviation, may be difficult to switch to electricity, and will need to use other low-carbon fuels, from natural gas to biofuels. Finally, carbon sinks, mainly through afforestation, is essential to offset residual GHG emissions in some sectors particularly difficult to decarbonize (see also the discussion on negative emissions above).

A Roadmap Toward Full Decarbonization, and a Set of Sectoral Targets

A key question for NDC implementation is how much effort countries should do in the short term, say by 2025. The literature suggests two aspects are important: (1) the total amount of emission reductions (the *quantity* of reductions); and (2) how they are implemented, and especially in which sectors and with what activities (sometimes called the *quality* of reductions).

Several studies using complex Integrated Assessment Model (IAMs) stress the importance of aligning the quantity of short-term emission reduction action with long-term emission reduction targets: given the limited ability of economies to switch overnight to low-carbon technologies, if short-term emission reductions are too modest, subsequent efforts will need to be much stronger (Bertram et al., 2015a; Clarke et al., 2014; G. Iyer et al., 2015; Riahi et al., 2015) – an argument that has also been made using simple toy models (Ha Duong et al., 1997).

While collectively, NDCs ambitions represents a net progress compared to the earlier Copenhagen pledges, they still fall short of what is considered necessary to reach in a cost-efficient manner the 2°C target, let alone the 1.5°C target. One study estimates that collectively, NDCs are consistent with a 2.6–3.1°C warming (Rogelj et al., 2016). Current NDCs therefore create a large risk of much higher costs in the medium and long terms (after 2030), especially in the form of stranded assets (Johnson et al., 2015). With more ambitious NDCs, the 2031–2035 transformation could be facilitated and require 84% fewer premature retirements of power generation capacity and 56% fewer new-capacity additions than a pathway that would start from current NDCs and catch-up on reductions towards 2°C after 2030. (G. C. Iyer et al., 2015)

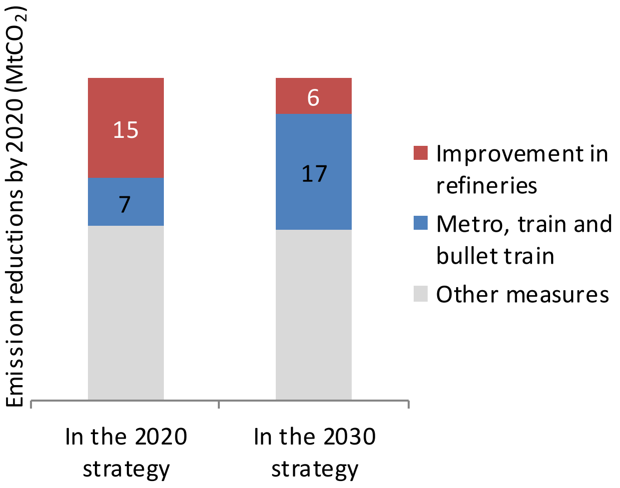
What matters is not only the amount of short-term effort, but also in which sectors it happens (Bataille et al., 2016). If the objective was simply to achieve a moderate reduction in emissions by 2030, say by 30 percent, it would be optimal to focus on the cheapest opportunities to achieve these reductions. For instance, the European Union could simply replace its coal power plants with gas power plants. But 2030 target is actually just a milestone on a path toward zero emissions. Focusing short term action of the cheapest options could lead to a carbon-intensive lock-in, where emission reductions needed between 2030 and 2050 become extremely expensive (del Rio Gonzalez, 2008; Vogt-Schilb and Hallegatte, 2014). Keeping the same example, the EU would need to strand the new gas power plants and replace them with renewable or other carbon-free power plants (Lecuyer and Vogt-Schilb, 2014).

A particularly important factor of possible carbon-intensive lock-ins for developing countries is urbanization, if fast-growing cities continue to grow like today, with low density and high reliance of individual vehicle. In the 2030s, when decarbonizing transport becomes necessary to achieve more ambitious target, decision-makers will find themselves facing an impossible task and will regret not to have considered the long-term climate objectives earlier (Avner et al., 2014).

Short-term emission reduction should not only occur in the sectors that are easier to decarbonize. Quite the opposite: taking into account the dynamics of emission reductions and the time it takes to change sectors with long-lived infrastructure, emission-reduction efforts should be concentrated on sectors that will be more difficult and longer to decarbonize, such as transportation and urban planning (Vogt-Schilb et al., 2015, 2012).

Take the illustrative case of a low-carbon strategy analysis for Brazil, looking at two different time horizons. **Erreur ! Source du renvoi introuvable.**Figure 1 shows on the left-hand side the optimal 2010-2020 strategy with a 2020 objective only. In that case, the optimal strategy includes large efforts in improved energy efficiency in refineries, a marginal improvement that is cheap and easy to implement but has limited potential to deliver a transformation into a zero-carbon economy. In contrast, the pre-2020 strategy with a 2030 objective leads to the same quantity of emission reductions, but to different actions: the strategy that takes into account the longer term includes actions that are more expensive and take longer to implement, but have the potential to contribute to a deeper decarbonization: metro and train. If the goal is simply a 10 percent reduction in 2020, limited use should be made of investments in metro, train, and waterways; but investing in those before 2020 is critical to ensure the feasibility of a 20 percent reduction by 2030.

Figure 1: Using a Longer Time Frame Changes the Optimal Short-Term Policy Mix for Brazil



Note: The 2020 and 2030 bars amount to an equivalent amount of emission reduction, although they include a different mix of measures. See details in the original paper (Vogt-Schilb et al., 2015).
Source: The authors.

The key to designing an emission-reduction plan that accounts for the long-term is to consider three characteristics of each option: cost, mitigation potential, and time needed to implement (and the risk of lock in that it creates). Options with "negative costs" (such as energy efficiency) or large development co-benefits should be implemented as soon as possible.[1] But options that are expensive but slow to reach their full potential (like clean transport) may also have to get started early if the long-term goal is to be reached. This approach has been used by the French agency for sustainable development in a recent study (Perrissin Fabert and Foussard, 2016).

To enforce this approach, governments can design "roadmaps", or operational short-term targets to ensure that they make progress in all sectors, and especially along the five dimensions needed for full decarbonization. For instance, a set of targets may include (Fay et al., 2015):

- producing 30 percent of the electricity from renewable sources by 2030;
- new cars emit less than 80 gCO2/km by 2025;
- phase out inefficient lighting by 2025;
- 50 percent of buildings using wood materials – from sustainably managed forest – instead of steel and cement by 2035;
- Share of population living less than 2 kilometer from a public transit station increases by 10 percent by 2030;
- a 20 percent reduction in consumption of meat;
- restoring one million hectares of forest, or halting deforestation by 2025.

Such sectoral roadmaps have recently been produced by academic teams for Argentina (Di Sbroiavacca et al., 2016), Brazil (Lucena et al., 2016) and Colombia (Calderón et al., 2016) and Mexico (Veysey et al., 2016) . In the last few years, the Deep Decarbonization Pathways Project has gathered technical teams

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[1] When thinking about the cost of options, government should include in particular benefits in terms of learning by doing (Bramoullé and Olson, 2005; Rosendahl, 2004).

in Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, South Africa, South Korea, the UK and the US to perform similar studies (Bataille et al., 2016). The International Energy Agency has also released technology (and policy) roadmaps (IEA, 2015a), for instance on solar energy and plug-in and hybrid vehicles (Frankl et al., 2010; Tanaka, 2011). Many governments around the world are starting to think about their NDCs in terms of a first step in a decarbonization roadmap (Comité Consultivo de Energía 2050, 2015), sometimes called a mid-century strategy, and submitting them to the UNFCCC secretariat (Canada and Environment and Climate Change Canada, 2016; SEMARNAT and INECC, 2016; White House, 2016).

Another advantage of short-term sectoral targets is that they could be directly submitted as countries' NDC (Schmidt et al., 2008). This is especially appealing for developing countries that can then focus on the sectors that are easier to monitor and administer to them (e.g. electricity generation for which emissions are concentrated in a few points and investment decisions are often under the control of the government), and/or for which it is easier to benefit from international assistance.

Once sectoral targets are agreed upon, the main question for policy makers is what policy instruments, or policy packages, can be used to enforce them. In principle, a carbon price should be the preferred instrument, because they create incentives for markets to use all available levers to reduce emissions (Nordhaus, 1991; Pearce, 1991; Pigou, 1932). But relying on prices alone to implement NDCs will not be enough: price hikes may not be politically or socially acceptable, and may not even be effective at enforcing the transition to net zero emissions.

In the following, we discuss how pricing instruments can create losers that can oppose the reform, and how additional compensation measures can help tackle this challenge. We then show that all losers from carbon pricing cannot be monitored and compensated. To tackle this issue, policymakers can complement low carbon prices, or even temporarily substitute for them, with alternative instruments at the sector level, such as performance standards for cars or renewable portfolio targets. We argue these can effectively enforce sectoral targets in a socially acceptable fashion, while also tackling other market failures (e.g. path dependency in knowledge accumulation or split incentives) as well as government failures (e.g. inability to commit to long term carbon prices).

Getting the Political Economy Right: Domestic Objectives and Constraints Determine Which Climate Policies Are Possible and Desirable

In this section, we show that climate policies cannot and do not need to be designed based on the climate objective alone. In contrast, starting from other policy goals – such as those linked to poverty reduction and infrastructure development – can offer a better starting point to discuss and assess possible climate policies. We start with fossil fuel subsidy removal and carbon pricing policies, showing how they can be fully justified by development, growth, and distributional objectives, leaving the impact on emissions as "co-benefits." Then, we turn to the potential negative side-effects of climate policies, looking at how these impacts can be avoided to ensure that policies are sustainable over the long term. Finally, we discuss the sectoral approaches that can complement pricing policies and tackle the many market failures and imperfections that impair the transition toward full decarbonization.

Carbon Pricing as a Development Policy

Experience from Fossil Fuel Subsidy Reform: the Political Economy Is at the Core

Assessments of global spending on fossil fuel subsidies vary in terms of scope and methods (Jones and Steenblik, 2010; Kojima and Koplow, 2015), but there is wide agreement that fossil fuel subsidy are weight on public budgets and encourage wasteful overconsumption of energy. According to the International Energy Agency, they reached $548 billion in 2013 in, or 5% of the GDP and 25-30 percent of government revenues in forty mostly developing countries (IEA, 2014b). The OECD estimates that its member countries spent $55-90 billion a year subsidizing fuels in the period 2005-2011 (OECD, 2013). In a more recent assessment covering most countries in the world, IMF estimates suggest that fiscal fossil fuel subsidies reached $650 billion in 2015 (Coady et al., 2016).[2] And subsidies on fossil fuel are only part of the problem. Government also routinely subsidize electricity (IEA, 2015b; Tongia, 2003).

The welfare cost of subsidies (their cost to human society as a whole) can be lower than their fiscal costs (their costs as paid by government budgets) because subsidies are mostly transfers from tax payers to fossil fuel consumers. However, subsidies do set a large cost on societies, because they significantly distort price signals, which is inefficient. Published estimates suggest that each dollar spent on subsidizing oil products reduces welfare at least 40 cents, just for its effect on oil depletion (Davis, 2014). In addition, subsidizing fuels has detrimental effects because it encourages the emissions of greenhouse gases, and local pollutants that hurt the health of local populations. It also encourages driving, which produces traffic congestion, and accidents. Accounting for these other externalities, Davis estimates that on average, each $1 spent of subsidizing oil products globally reduces global welfare by 69 cents.

The IMF estimates that accounting for externalities, the global cost of subsidies rises to $5.6 trillion. It also estimates that internalizing all these externalities with Pigovian taxes on fossil fuels, including the carbon price component, global CO_2 emissions would drop 21%. Interestingly, most of the reductions would come from reduction in coal use incentivized by Pigovian taxes on local pollutants, not carbon. This highlights how a local development agenda focused on reducing local air pollution for the benefit of local population, a policy that makes sense in all countries including developing ones, could result in reducing significantly global warming. Indeed, it has been argued that a large chunk of what countries need to do to implement their NDC can be seen as *good development* (World Bank, 2012).

Recognizing the inefficiency of energy subsidies, their formidable fiscal cost, and the perverse incentive they create to emit pollutants in general and GHG in particular, governments around the world have committed to phase out energy subsidies. In September 2009, the leaders of the G20 pledged to "phase out and rationalize over the medium term inefficient fossil fuel subsidies *while providing targeted support for the poorest*", a goal which is also reflected in the United Nation's Sustainable Development Goals (Rentschler and Bazilian, 2016).

Indeed, subsidies cannot be reformed without understanding and tackling the political economy reasons explaining why they were put in place in the first place. Subsidies exist because they are a visible mechanism for governments to provide benefits to poor and middle-class voters, and sometimes to industrial interests, in exchange for political support (Victor, 2009). Worsening the political economy of

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[2] We added "pre-tax subsidies" and "Foregone consumption tax revenue" from IMF numbers to calculate this total, that we call "fiscal subsidy". The IMF adds the failure to internalize externalities related to fuel usage to get its headline "fossil fuel subsidy" number.

subsidy reform, subsidies contribute to the phenomenon of carbon-lock in: once put in place, the benefits of the policy are capitalized—for example, through the construction of energy-intensive equipment—, making the removal of subsidies costlier for their beneficiaries, and thus raising the political costs of the transition. In particular, increasing the price of energy could hurt the poorest households, and, in developing countries, jeopardize access to modern energy (Rao, 2012). This situation is typical of efficiency-improving reforms that have large distributional impacts (Fernandez and Rodrik, 1991).

Many governments have tried to pass reforms focusing on technical soundness and administrative feasibility, without taking into account the political economy of energy subsidies, and those reforms have often failed (Bazilian and Onyeji, 2012; Rentschler and Bazilian, 2016; Sdralevich et al., 2014). Reforming subsidies requires a policy package that either accommodates vested interests, or finds a way to impose reforms against their will.

The good news is that ex-ante analysis and ex-post experience both show that reconciling subsidy reform with the interests of poor and middle-class households is feasible in theory, and has worked in practice (we treat the case of industrial interests in the next section). Indeed, fossil fuel subsidies and artificially low energy prices are a very inefficient way to help poor and middle class voters, making it easy to replace by better instruments such as efficient spending on social assistance. An IMF review of fossil fuel subsidies in 32 developing countries found that for $100 spent on subsidizing fuels, only $18 go to the bottom 40%. In other words, for each $1 of benefit provided to the poorest 40 percent of households in each country using energy subsidies, governments spend on average $5.6 (Coady et al., 2015). Gasoline subsidies are the most regressive ones: since rich households are more likely to own vehicles and tend to spend much more on gasoline than poor households, it costs $13.5 on average for governments to provide $1 in benefits to the bottom 40% using gasoline subsidies. Even subsidies on kerosene, the less regressive subsidy as this heavy fuel is mainly used by poor households for cooking and heating, set a cost of $2.6 for each $1 disbursed to bottom 40% households on average (Coady et al., 2015).

These figures compare unfavorably to the cost of direct cash transfer programs, recognized as one the most efficient ways for delivering social assistance to poor households in developing countries (Bastagli et al., 2016; Blattman and Niehaus, 2014; Cecchini and Madariaga, 2011) – and increasingly advocated as such in developed countries(Van Parijs, 2004). In Ecuador, half the money spent for the *Bono de Desarollo* cash transfer program, sometimes described as suffering from targeting problems, goes to one of the 40% poorest household in the country. It thus costs only 2$ to the government for each $1 received by the bottom 40% (Expresso, 2015). In fact, among 56 social assistance programs in Latin America, cash transfer are the best performers in terms of targeting poor people (Lindert et al., 2006); an study from the Inter-American Development Bank found that, on average over 18 countries, it costs US$1.9 to transfer US$1 to poor households in LAC using existing cash transfer programs (Inter-American Development Bank, 2016). Cash transfers in Africa are as effective (Handa et al., 2012): In Malawi, 97% of the Social Cash Transfer spending goes to households below the national ultra-poverty line; In Kenya, 85% of the Cash Transfer for Orphans and Vulnerable Children goes to kids in the bottom 40% of the population.

Moreover, instead of the perverse incentives that energy subsidies create, a wealth of ex-post empirical studies have found conditional and unconditional cash transfers to reduce poverty, especially on girls and women, improve school attendance (with some evidence of improved cognitive development), increase the uptake of health services, improve dietary diversity and mass and weight indicators, reduce stunting and malnourishment, encourage savings, investment in productive assets and livestock, foster business creation, increase labor force participation for adults and reduce child work, and increase employment rates (Bastagli et al., 2016; Cecchini and Madariaga, 2011).

Comparing the incidence and secondary effects of fossil fuel subsidies and cash transfers, it thus appears that government could remove energy subsidies while putting in place cash transfer programs or expanding existing ones, at a lower total budgetary cost and for better outcomes. Doing so would reduce the incentive to waste fossil energy (the IMF estimates that 21% of GHG emissions could be avoided by removing subsidies), and promote several aspects of human development instead. Comparing the costs of social assistance and subsidy programs, it appears that roughly half the current financial cost of subsidies could be saved in in the process, and used for any other purpose (see below the discussion on carbon revenue).

Of course, cash transfers are not exempt of problems. Most importantly, the coverage of existing cash transfer programs among poor people is sometimes low. While most of the money spent on conditional cash transfer actually end up in the poor's pocket, it does not follow that most poor people do receive money from existing cash transfers. According to World Bank estimates, the median cash transfer coverage among households in the poorest quintile is 27% (World Bank, 2015). An Inter-American Development Bank study suggests that in the average Latin-American country, only 40 percent of poor people benefit from these schemes (Robles et al., 2015). Subsidizing energy upstream (for instance through state owned energy enterprise that set below-market prices) can be more effective at reaching more poor people, provided however that poor people do have access to energy services. Recycling the fossil fuel subsidy budget in cash transfers might be able to compensate for higher consumer prices at the quintile level, but be inefficient for some poor and lower-middle class households excluded from social protection. Another issue is the geographic incidence of fossil fuel subsidy reform, which may not coincide with the geographic coverage of existing social protection schemes (Rentschler, 2015).

Making sure that all or most of the losers from subsidy reform are compensated with cash transfers may require expanding existing programs, or creating new ones. Many countries have actually taken this route, and some have moved toward universal transfers to ensure that everybody is covered. For instance, Iran implemented a quasi-universal cash transfer (about $45 per month per capita) as part of its energy reforms. The Indian government is considering taking this path (Safi, 2017). Universal or quasi-universal transfers may help with the political economy of the reform, since nobody is excluded from the benefits of the reform (even though some will remain net losers). Because opposition to subsidy reforms is often stronger in the middle-class than among the poorest, having the middle-class covered by the compensation – even partly – may make the reform more acceptable. When countries do take this path, their chances of successfully phasing out subsidies improve significantly. After reviewing subsidy reform projects in the middle east and north Africa, the IMF concludes that *"of the cases where cash and in-kind transfers were introduced* [as compensatory measures for energy price hikes*], 100 percent were associated with a successful outcome, while only 17 percent of the cases where these transfers were not introduced resulted in a successful reform"* (Sdralevich et al., 2014).

When cash transfers cannot be used, another way to ensure poor people benefit from fossil fuel subsidy removal is with in-kind measures. Ghana's 2005 fossil fuel subsidy reform increased the price of transport fuels by 50 percent but also included an expansion of primary health care and electrification in poor and rural areas, the large-scale distribution of efficient light-bulbs, public transport improvements, and the elimination of school fees at government-run primary and secondary schools (IMF, 2013; Vagliasindi, 2012).

Whatever the compensation measures, appropriately communicating about them is essential. In Egypt, 70 percent of the population did not know the scale energy subsides in 2014; in Morocco, a 2010 survey found 70 percent unaware that energy was subsidized at all. (Vagliasindi, 2012). The governments' strategies included explaining that the subsidy absorbed a huge part of government revenues (39 percent in Egypt and 17 percent in Morocco) and that the compensation package would spoke to citizens' concerns about "what's in it for me?" (Vagliasindi, 2012).

Carbon Pricing Faces the Exact Same Distribution Problem

The economics and politics of carbon pricing are very similar to the economics and politics of energy subsidy removal. Both measures increase energy prices and provide incentive to save energy and reduce GHG emissions. Both can hurt some consumers and industries in the country. And both provide revenue to governments that can be used to contribute to local development needs and/or to tackle the political economy constraints of the reforms.

Governments can use revenues from carbon pricing in at least two manners: to fund social assistance and reduce inequalities, and to finance general government operations without relying on more distortive taxes. These are not necessarily self-exclusive. In the US, a study highlights that policy design leaves a wide range of possibilities for policymakers, from focusing on reducing inequalities to maximizing economic output (Parry and Williams, 2010). In Germany, simulations conclude that a reduction in unemployment, an improvement of inequality, and a reduction of CO_2 emissions could happen at a trivial GDP cost (Bach et al., 2002). In France, an environmental fiscal reform combining welfare-improving payroll taxes reductions and cash transfers funded by carbon revenues could leave all income categories better off while reducing emissions (Combet et al., 2010). This section reviews the literature on distributional impacts of carbon prices, and the next one the literature on the benefits of carbon taxes as fiscal instruments.

Many academic studies assess the impact of carbon pricing on consumer prices and household welfare. The simplest approach is to use input-output tables (using a simple Leontief model to propagate the carbon price to consumer price hikes), and then use consumption surveys to determine the incidence of putting a price on carbon. Early studies in Canada, the UK, France, Spain, Italy, Germany, Denmark and the US highlighted that consumer price hikes due to carbon prices are typically regressive (Grainger and Kolstad, 2010; Hamilton and Cameron, 1994; Symons et al., 2002; Wier et al., 2005). In developing countries where a large share of the poor population does not have access to commercial energy, particularly sub-Saharan African and south Asian countries, energy price hikes due to carbon pricing may have a progressive impact (Bacon et al., 2010; Datta, 2010). It does not follow, however, that carbon prices would be exempt of political economy challenges in those countries: as noted below, universal access to modern energy (for instance, the shifting from traditional biomass to natural gas for cooking) is recognized as a development goal and could be slowed down by higher fossil fuel prices. To tackle this issue, plans to impose carbon prices in these countries can be complemented with measures that support the adoption of modern fuels (Pachauri et al., 2013).

More sophisticated approaches to assess the distributional impact of carbon pricing build a computable general equilibrium model around the input-output tables, or even use more detailed energy-economy models to project the response of the economy to carbon taxes, and sometimes take into account that wages and rents may also be affected by carbon price (Dissou and Siddiqui, 2014; Fullerton and Heutel, 2011). Some studies also look at the impact on regions within countries, as well as ethnic groups, in addition to look at the distributional impacts in terms of income groups (Hassett et al., 2009; Rausch et al., 2011).

There is a wide consensus that the main determinant of the distributional impact of carbon pricing is how the proceedings of the reform are used. This finding was established as soon as the 1990s in the UK (Symons et al., 1994), then replicated to Australia (Cornwell and Creedy, 1996), and has been generalized in the 2000s, for instance with studies on the US (Bento et al., 2009; Burtraw et al., 2009; Rausch et al., 2011), Mexico (Gonzalez, 2012), Ireland (Callan et al., 2009), and China (Brenner et al., 2007; Liang and Wei, 2012). All these studies agree that recycling a fraction of carbon revenues into transfers to poor and middle class household can neutralize any regressive impact and make the reform progressive. Instead of using cash transfers, governments can reform income and payroll taxes to correct distributional impacts (Metcalf, 1999), but only in cases where affected households do pay taxes.

So like in the case of fossil fuel subsidy reform, using carbon receipts to increase cash transfers seems to be a promising way of aligning climate policy with the development goal or reducing domestic inequalities. Transfers can also help the most vulnerable households or regions gain access to modern energy despite increased prices.

This can also be framed the other way around – starting from the resources government need to fund development and the provision of public goods. All countries, especially developing ones, face urgent development needs: some need to finance infrastructure deployment, health services, social assistance and inequality reduction. A growing literature argues that carbon taxes are an appropriate way of financing these needs.

Carbon Pricing as a Fiscal Instrument

In deciding what production factors to tax to finance the functioning of the government and investments in public goods, finance ministers have several options, including taxing wages, capital or investment, land, energy, or imports.

Carbon prices could provide substantial revenues to government. In 2015, auctions in existing carbon markets and taxes labeled as carbon taxes provided governments with an estimated $26 billion (Vivid Economics, 2016). But the potential is much higher than that. Domestic carbon pricing consistent with the 2°C target (from 20$ to 120$/t$CO_2$ in 2020 depending on the model) could provide about $2 trillion per year to governments globally, and would be enough to finance infrastructure that would close existing access gaps in developing countries for water, sanitation, electricity, and telecommunication, even without international transfers (Jakob et al., 2016). In 60 out of 87 developing countries analyzed in a world bank study, a $30/t$CO_2$ domestic tax would provide the government with enough resources to more than double current spending on social assistance (Hallegatte et al., 2016).

Taxes on fossil fuel energy may be much easier to administrate than other fiscal instruments, with smaller negative impacts on economy activity. In the United States, for example, tax collection covering 80 percent of CO_2 emissions from fossil fuel consumption could be accomplished by monitoring fewer than 3,000 points, mainly refineries, coal mines, and natural gas fields (Metcalf and Weisbach, 2009). This contrasts with dozen of millions households paying income taxes, businesses paying corporate taxes, and trillion of sales transactions happening every year.

The easiness to administrate taxes on fossil energy can explain why they tend to suffer much less from evasion. In Sweden, which has had a carbon tax since 1992, tax evasion is under 1 percent for the carbon tax, much less than for the VAT. In the United Kingdom, evasion on energy taxes is about 2 percent, much lower than the 17 percent for income tax (HM Revenue & Customs, 2014). This is a substantial advantage for the many developing countries that struggle with tax evasion (Bento et al., 2013). In addition, upstream taxes on fossil energy will be paid by all actors in an economy, while labor and sales taxes are paid only by formal businesses. Switching to carbon taxes can reduce the gap between the formal and informal sector, and decrease the incentive for agents to engage in informal activities (Bento et al., 2013).

And in a globalized world, many businesses can decide to relocate their physical production plants, or just the legal entity cashing profits, outside of the jurisdiction levying taxes on capital or profits. This contrasts with taxes on carbon emissions from imported fossil fuels. The price of fossil fuel is mainly derived from scarcity rents, which are net profits for fossil fuel exporters. If many fuel importers levy a tax on imported energy, the answer from fuel exporters will be to reduce the scarcity rent they charge on their exports (Goulder and Schein, 2013). For the governments in importing countries, this boils down to capturing part of the scarcity rent of exporters in their public coffers (Rozenberg et al., 2010). Finance ministers in fossil fuel importing countries who disregard the climate agenda and are just interested in the efficiency of their fiscal system could thus favour carbon taxes over capital taxes (Franks et al., 2015).

Even in the absence of informality and evasion, taxes on productive factors such as labor and capital directly reduce the incentive for economic agents to engage in productive activities. Carbon pricing offers a potential “double dividend” by providing both environmental benefits and the possibility of reducing those distortionary by recycling carbon revenues (Bovenberg, 1999; Carraro et al., 1996; Goulder, 2013). Many studies find that this effect alone can make carbon prices welfare improving, even if avoided climate change impacts are not accounted for (Combet et al., 2010; Parry and Williams, 2010).

Some governments have used this thinking when imposing carbon prices. British Columbia recycled proceedings of its carbon tax both in redistribution and in a reduction of conventional taxes. The result was an estimated small macroeconomic cost and a progressive incidence (Beck et al., 2015). When governments engage in this type of reform, it is important for political acceptability that they communicate it adequately (Harrison, 2012). In Germany, businesses were aware of higher energy taxes, and would oppose them; but were not aware of the associated cuts in payroll taxes. Once they were informed, they were much more likely to approve of the energy tax (Dresner et al., 2006).

Setting the Level of A Carbon Price

If climate change was the only rationale to implement a carbon price, then the price level could be determined based solely on climate challenge arguments, for instance by setting the price level that is needed for the country to reach the objective set in its NDC. But in a broader context, where the carbon pricing scheme is designed to also contribute to policies goals like revenue raising or redistribution, the appropriate price level may be very different.

One approach is to calibrate a carbon tax based on the local benefits and constraints in the country implementing the carbon price, disregarding altogether the question of greenhouse gas emissions. Carbon prices reduce many non-climate externalities related to fossil fuel use, chiefly emission of local pollutants that affect heath and agricultural yields (Shindell, 2015; Thompson et al., 2014; West et al., 2013; World Bank, 2014), but also congestion and road damage. The IMF provides country-by-country estimates of the benefits of reducing fossil-fuel carbon emissions (Parry et al., 2015). The non-climate benefits from carbon pricing may be up to several orders or magnitude higher than what is needed to achieve climate objectives, suggesting that non-climate rationales may dominate the decision on the appropriate price level. Another way is to set the level of the carbon tax based on revenue needs to fund specific development programs, such as increased social assistance, disregarding as a first step their impact on any externality.

However, for a carbon price to provide credible incentive to reduce long-term emissions, the rate should increase steadily over time, at least at the risk-free interest rate, regardless of its initial level (Golosov et al., 2014; Rezai and Van der Ploeg, 2016). This is to give investors, who discount future costs and benefits of different projects at the interest rate, a clear long term signal. If the effect on GHG emissions of a carbon tax is a key issue, and acknowledging that models give limited understanding of how much a given carbon tax will reduce emissions, governments can make the temporal evolution of the rate contingent on actual GHG emissions: if GHG emissions are dropping faster than scheduled, stop increasing the tax for a year, if they are not decreasing enough, increase the tax rate more than the interest rate (Metcalf, 2009). Such an “adaptive management” approach is typical in contexts of deep uncertainty on the efficiency of public policies (Lempert and Schlesinger, 2000).

Managing Disruptive Stranded Assets and Stranded Jobs

Stranded assets are another political economy issue surrounding NDC implementation and climate policies. The words *stranded assets* are used to describe various things (Caldecott, 2017): (1) assets, such as land suitable to produce coffee or tourism-attracting reefs that are lost because of the impact of climate change itself (Caldecott et al., 2016); (2) fossil fuel resources that cannot be burnt into the atmosphere if a given climate target is to be reached, also called *unburnable carbon* (Jakob and Hilaire, 2015; Matthews, 2014; McGlade and Ekins, 2015); and (3) man-made capital that has to be retired prematurely because of climate policies, such as coal power plants that become unprofitable after a carbon price is implemented or whose operation is made illegal due to new regulations (Guivarch and Hood, 2011). Here, we focus on man-made stranded assets, because current investment patterns are increasing the stock of assets that may become stranded in the future – making action on this issue particularly urgent.

The Potential for Man-Made Stranded Assets Increases with Delay in Climate Action

The potential for stranded man-made assets in the transition to zero emissions stems from the fact that existing capital in the transportation, building, industry, and energy sectors have lifetimes that range from about a decade — in the case of a car — to half a century — for power plants — or even centuries — for city shapes and transportation systems (Davis et al., 2010; Guivarch and Hallegatte, 2011; Sachs et al., 2014). Davis, Caldeira and Matthews (2010) estimate that the continuing usage of existing emitting capital and infrastructure in 2009 would translate in CO_2 emissions consistent with a warming of about 1.3°C. Adding non-CO2 emissions and infrastructure that drives the demand for energy consumption, particularly in the transport sector, makes the committed warming already approach 2°C (Guivarch and Hallegatte, 2011). For example, the fossil fuel power plants built in 2012 alone will emit some 19 billion tons of CO_2 over their expected 40-year lifetime, more than the annual emissions of all operating fossil-fuel power plants in 2012 (Davis and Socolow, 2014). The fact that the committed warming is so close to 2°C already suggests that if it is still theoretically possible to reach the 2°C target without stranding existing asset, doing so would require all new investment to be close to zero carbon (Rozenberg et al., 2015), particularly in the power sector (Pfeiffer et al., 2016). More realistically, it suggests that some stranding of existing assets would be needed to reach the 2°C target.

It is thus no surprise that most integrated assessment models find that efficient pathways towards deep decarbonization require to strand man-made assets (Guivarch and Hood, 2011; Rogelj et al., 2013). Existing studies have focused on quantifying global stranded assets in the electricity sector in several emission reduction scenarios. For instance, Johnson et al. (2015) estimate that a carbon price consistent with the 2°C target will strand at least US$ 165 billion worth of coal power plants worldwide, and (G. C. Iyer et al., 2015) estimate that pledges made in Paris followed by a rushed reduction in GHG emissions to catch up with 2°C-consistent pathways would lead to strand about 1 500 GW of coal and gas power plants worldwide after 2030. (While carbon capture and sequestration may reduce the need to strand fossil fuel power plants, its potential is uncertain as most plants cannot be easily retrofitted and costs could be very high.) At our best knowledge, assessment of stranded assets in emission-reduction scenarios in other sectors than power generation, and reported at the finer country (or even regional) level are not available yet in the literature.

Other sectors have received attention for a closely related issue, however: the trade-exposed, energy-intensive sectors (such as aluminum, cement, steel and glass production). The literature has looked extensively at how environmental regulation, and in particular carbon pricing, if enforced in a particular jurisdiction but not worldwide, has or could reduce competitiveness of those industries. In terms of past experience, a review of the literature found no significant impact of existing environmental policies on firm competitiveness, even in heavy industries (Branger and Quirion, 2014). Part of the reason is that existing climate policies are not very ambitious: the price of carbon on the EU-ETS, for instance, has an impact on aluminum cost that is smaller than annual exchange-rate variations (Demailly and Quirion, 2008). Pollution abatement costs have thus represented a small fraction of production costs for most industries, and factors such as the availability of capital and skilled labor, proximity to markets and sunk costs in capital-intensive firms have been more important determinants of firm location and competitiveness (Copeland, 2012; Ederington et al., 2005).

The financial system as whole, and particularly pensions funds, is also deemed to be vulnerable to stranded assets (Battiston et al., 2017; Caldecott, 2017; Caldecott et al., 2016). Today, many carbon-intensive companies, and in particular fossil fuel reserves, are valued by the market at about the current price for fossil fuels, while recognizing that much of that fossil fuel cannot be burnt in a 2°C world should lead the market to significantly reduce the value of those assets (Carbon Tracker Initiative, 2012; Griffin et al., 2015). The governor of the Bank of England expressed in a recent speech concern that the magnitude of stranded assets in a too abrupt transition to zero emissions could be a threat for the stability of the financial system (Carney, 2016).

Solutions to Protect Those Affected by Stranded Assets

Stranded assets are a financial loss for the owners of the discarded capital. Normative views diverge on how to tackle those losses. At one end of the spectrum, some authors like Kaplow consider any government relief as free insurance that must always be avoided (Kaplow, 1992). If industries are assured that they will be compensated in case of policy changes, they will overinvest ex-ante in policy-dependent assets. Kaplow stresses that firms are used to take investment decision under uncertainty, including policy changes (in a way, that is exactly the job of an investor). At the other end of the spectrum, authors like Epstein defends the view that "all regulations, all taxes and all modification of liability rules are *takings* of private property *prima facie* compensable by the government" (Epstein, 1985). If a government decides to build a highway in a location currently occupied by a privately-owned building, most would agree that the government must provide adequate compensation to the owner. Epstein argues that more subtle changes in fiscal rules or policies are no different than expropriations, in that they suddenly reduce the wealth of those affected. Trebilcock (2014a) offers a more complete review of normative views on government relief.

To contradictory normative views, Trebilcok answers with a more pragmatic argument: climate policy gains tend to be diffuse across economic actors, and the benefits of climate change stabilization are intangible "avoided losses," which mostly take place in the future. These characteristics do not help create a vocal group of policy supporters. In contrast, policy costs tend to be visible, immediate, and concentrated over a few industries, for instance the coal industry in the case of climate mitigation, which may have a *de facto* ability to veto the reform. Indeed, the theory of the political economy of reforms establishes that concentrated interest groups find it easier to organize themselves, while large and diffuse groups face much higher costs of organization and are thus less audible in the policy debate (Olson, 1977; Peltzman et al., 1989; Stigler, 1971; Trebilcock, 2014a). For reforms proposals to be more likely to pass, governments may thus try to avoid, or compensate homogenous groups of losers from those reforms.

Under a carbon tax, a way to compensate the owners for stranded assets is with partial exemptions or rebates (Goulder and Schein, 2013). Cap-and-trade carbon markets can also be designed to compensate firms for stranded assets they may create: the owners of polluting firms may be fully compensated if a fraction of emissions allowances are grandfathered for free (Goulder et al., 2010). Making *all* permits free however, as the EU-ETS and many other carbon markets did in their first days, is likely to result in overcompensation, that is in windfall profits for the owners of polluting capital (Sijm et al., 2006; Woerdman et al., 2009), and may even reduce efficiency (Goulder et al., 1999). The literature on competitivity of the energy-intensive, trade exposed industries (EITE) has arrived to a similar conclusion: output-based rebating of carbon receipts can avoid competitivity losses (Branger and Quirion, 2014).

More generally, governments could use their general revenues and buy stranded assets from their owners. For instance, governments could decide to buy existing coal reserves from the extractive industry, and then simply not exploit them (Asheim, 2013; Harstad, 2012). While this could certainly compensate the owners of coal and tar oil reserves for climate mitigation policies, the political acceptability of such a bold move is yet to be investigated in the academic literature, at our best knowledge.

A problem with these approaches is that they would not compensate other potential losers of climate policies: the many workers (and voters) who depend on potential stranded assets directly (such as coal miners and the staff of carbon intensive power plants) or indirectly (such as the food industry in a town where coal power plants are a major employer).

Many academic studies analyze the job impact of emission reduction pathways, and in particular the impact of switching to more renewable energy. In general, the results suggest that a transition to a low-carbon energy system (using renewable energy, energy efficiency, but also nuclear and carbon capture and storage) will result in net job creation. Detailed literature reviews have been published, and they compile estimates of employment factors of different power generation technologies, that is the amount of job needed for each MW of installed and used capacity (Cameron and van der Zwaan, 2015; Wei et al., 2010). Focusing on jobs per MW introduces however a bias towards more expensive technologies, and it has been argued that the relevant metric is jobs per dollar of value added (Perrier and Quirion, 2016). Even with that metric, the switch to low or zero carbon electricity is a net job creator.

Two main different techniques have been used to assess the job impacts of switching to renewable power (Perrier and Quirion, 2016). "Simple analytical models", based on interviews and case studies of existing business, simply trace down how many jobs are directly involved in the building, installation, and maintenance of different power generation technologies. And more complex models based on Input-Output tables (sometimes completed with a CGE model) that consider indirect jobs impacts. Models based on IO tables are often used to assess the net impact of simultaneous phase down of some technologies (e.g. coal power) and uptake of others (e.g. wind power), and frequently report "direct" and "indirect" job impacts separately.

Despite this agreement in the literature that the net impact of a phase down of fossil fuel will likely result in net job creation, the potential disruption for job markets has not been emphasized in the literature and there is a large uncertainty on the total impact. For instance, a study on the macroeconomic impacts of renewable energy policies in Europe (Ragwitz et al., 2009) does acknowledge that gross jobs creation and gross job destructions will be important, but seems to conclude that the positive net impact is the most important information. We argue that job destructions do matter for the political economy of climate policies, except if the new, green jobs can be taken by roughly the same population group affected by stranded assets from emission reduction policies, which appears unlikely to us.

To inform the policy debate on this topic, it may be useful to compare the job and carbon contents of value added of different sectors, as shown in Figure 2 for the French economy (Perrier and Quirion, 2016). This is a first step towards identifying (1) potential losers from emission reduction policies (here suggesting a large vulnerable from agriculture); and (2) sectors that could be grown to absorb workers from the dirty industries.

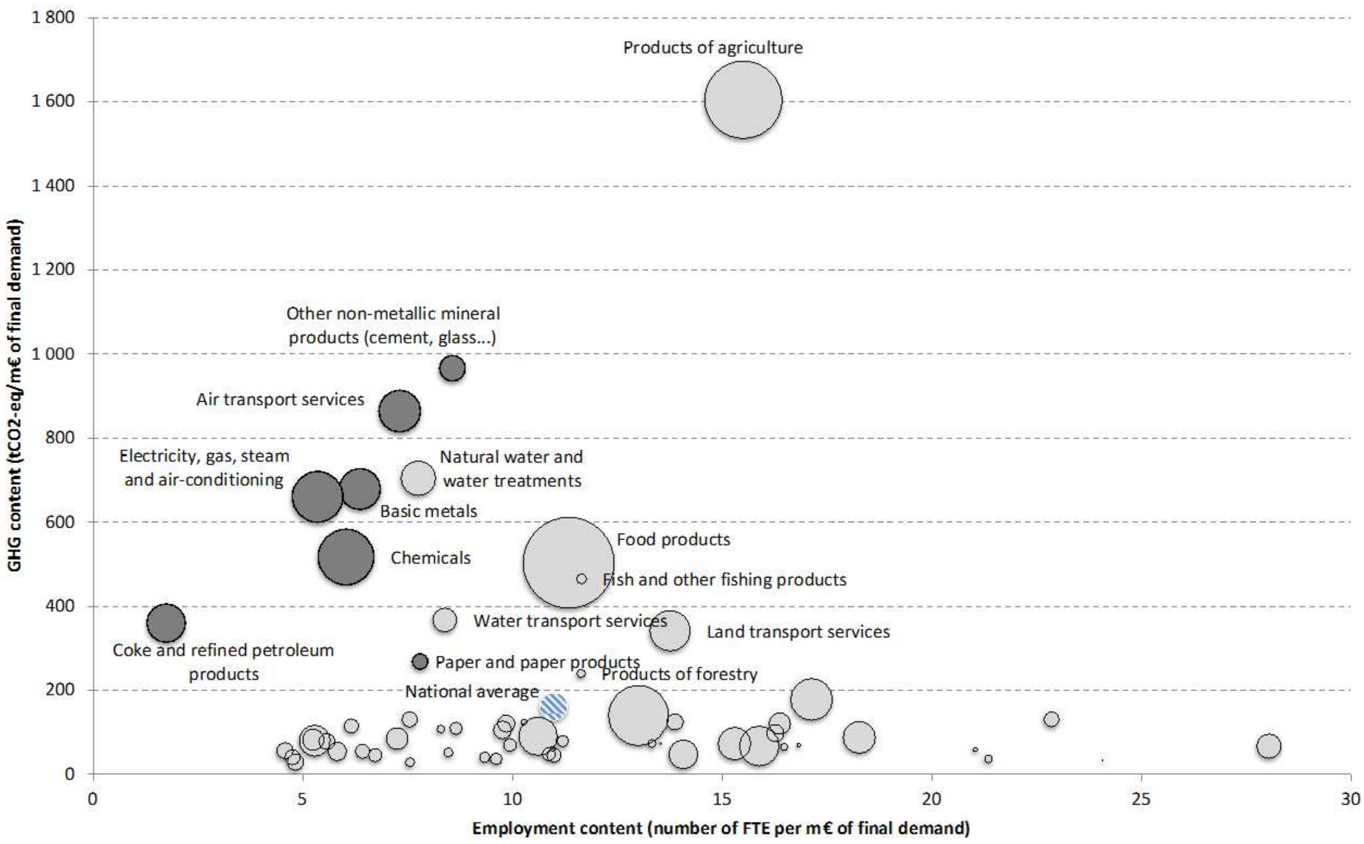

Figure 2: GHG content And Employment Content of The Value Added By Sector Of The French Economy.
Source: Perrier and Quirion (2016). Used with permission.

Many lessons can be learnt from previous industrial policies or trade agreements that resulted in job disruption (Hallegatte et al., 2013). Standard social protection systems, such as unemployment insurance and responsive social assistance programs can help minimize the impact of job destructions in down-sizing carbon-intensive sectors. Countries where such schemes are not present could find it more difficult to aggressively reduce emissions from carbon-intensive sectors in their NDCs.

Targeted instruments can also be implemented, as Japan's support to traditional textile and shipbuilding industries in the 1960s and 1970s. Japan relied on fiscal policies, and starting in 1978, planned capacity reduction, providing assistance to troubled firms and mitigating negative impacts on labor (Krauss, 1992; Peck et al., 1987). One goal of these policies was to ensure that the downsizing of productive capacity in declining sectors started with the closure of the least efficient firms, to ensure the efficiency of the downsizing process (Peck et al., 1987). Similarly, a high carbon price may not lead to the closure of the least-efficient or highest-emitting plans first, since a closure decisions rely on many criteria, or may lead to a collapse of the industry that would be difficult to manage politically. This is why several countries or regions, such as Alberta in Canada, have coal phase-out agreements to ensure an efficient, progressive, and politically-acceptable reduction in coal power generation (Alberta government, n.d.).

The U.S. Trade Adjustment Assistance (TAA) also provides re-employment services to displaced workers and financial assistance to manufacturers and service firms hurt by import competition. Experience from trade liberalization has shown that support such as wage subsidies to encourage hiring in the expanding sectors and unemployment insurance for the displaced workers can effectively help mitigate most of the losses and have generally modest costs (Porto, 2012). In the past, however, people losing from the reforms have not always been compensated and protected against the negative side-effects of reforms, and adjustment assistance programs have been criticized for the cost (Fernandez and Rodrik, 1991).

Designing Effective and Politically Acceptable Policies to Enforce Sectoral Targets

To minimize disruption of financial markets, job markets, and opposition from powerful vested interests, a more radical option may be to avoid stranded assets altogether in the transition to zero emissions. Here we explore possible approaches to do so, discussing in turn their ability to minimize negative side-effects of climate policies, and their potential to improve the overall efficiency of the transition.

Minimizing Disruptions and Increasing Acceptability

To reduce future stranded assets, the risk of stranding should be taken into account in today's investment decisions (Caldecott et al., 2016). Policy options to achieve this include increasing disclosure and transparency on climate-related financial risks (Carbon Tracker, 2013). The pricing of assets need to reflect the risk of stranding (Lecuyer and Vogt-Schilb, 2014), so that the asset price adjustment can be smoothed over time, instead of generating a financial shock that may trigger a financial crisis. Some have also suggested spreading awareness about the risk of stranded assets and "change the culture" of agents in the financial industry so that they consider it part of their due diligence to beware of potential stranded assets (Inquiry, 2015; Kruitwagen et al., 2016). A radical policy option is to simply forbid the construction of assets that are deemed likely to be stranded by emission reduction policies, for instance enacting moratoriums on new fossil fuel power plants, or new fossil fuel fields (Bertram et al., 2015b; Pfeiffer et al., 2016; Rozenberg et al., 2017).

In addition, emission reduction policies can be designed in a way to smooth the transition and avoid or minimize stranded assets. One way is to phase-in carbon prices, that is to start with carbon prices that are low enough to prevent any stranding (Rozenberg et al., 2017; Trebilcock, 2014a; Williams, 2011). It has been suggested that carbon prices higher than $8/tCO2 could create politically unpalatable risks for stranded assets in the US, thus requiring that emission reductions are delivered using other policy instruments (Jenkins, 2014). One risk we see with that approach, however, is that politically acceptable carbon prices may be too low to provide a significant incentive to transition towards a zero-carbon economy. An $8/tCO2 carbon price, for instance, would increase gasoline prices less than $0.02/L.

Another way is to use alternative policy instruments. Complementing a carbon price, or even temporarily substitute for it, with alternative policy instruments such as performance standards, feebates, or targeted financial instruments (e.g., subsidized loans) that apply only to new capital is a way to avoid man-made stranded assets, preserve the revenues of vested interests, and smooth abatement costs over individuals and time (Bertram et al., 2015b; Rozenberg et al., 2014). In contrast to a high carbon price, standards, mandates or feebates on new investment do not prompt producers to underutilize existing polluting capital, and thus do not create man-made stranded assets – they only redirect new investments toward greener options, so that the stock of potentially stranded assets does not grow over time, and even decrease thanks to capital depreciation and retirement of emitting assets (Rozenberg et al., 2017).

Many exiting climate policies apply to new investments only (Trebilcock, 2014b). In Brazil, Canada, China, European Union, India, Japan, Mexico, Saudi Arabia, South Korea and the United States, minimum energy efficiency requirements (or maximum carbon intensity levels) are imposed on new vehicles, while the owners of old vehicles can continue to use them, and even resell them with little constraint (ICCT, 2016). Many of those are negotiated with automakers and the civil society, then publicly announced years in advance, ensuring technical feasibility and allowing auto manufacturers to develop the required technology in time (figure 3). Similarly, many countries including the United States, European Union, China set minimum energy efficiency standards on new buildings, without requiring old buildings to be retrofitted immediately (IEA, 2015c). Bans on investments based on some technologies – such as a moratorium on new coal power plants without CCS – are also available to avoid building the stock of future stranded assets without affecting existing capital owners and the workers who depend on this capital.

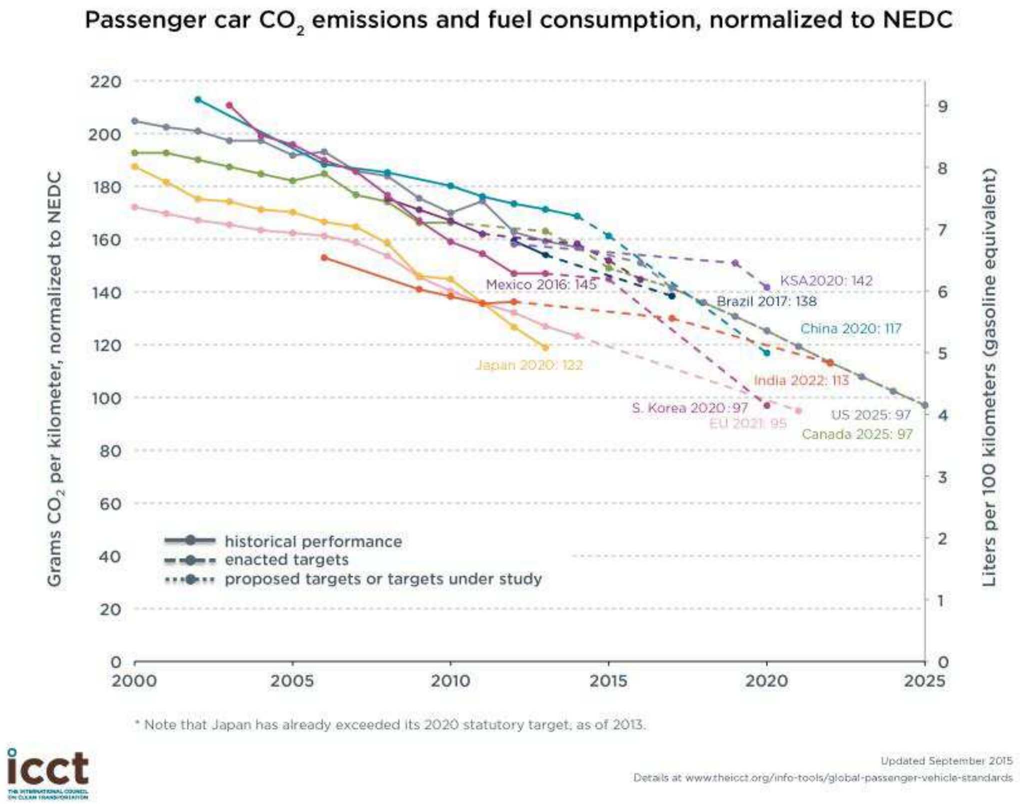

Figure 3: Existing Energy Efficiency Standards for New Road Vehicles
Source: ICCT. Used with permission

This approach may be less efficient from an economic point of view than immediately introducing a carbon price, and cannot reduce emissions as fast as the radical approach of stranding large chunks of the carbon intensive equipment. Indeed, it does not create an incentive to reduce emissions from existing assets, and it may have undesired side-effects, such as a lengthening of the economic lifetime of polluting assets (Anderson et al., 2011). But it has the advantage of triggering a transition toward a low-carbon path without hurting owners of existing man-made capital, hence reducing resistance (Rozenberg et al., 2017). It may thus be more socially acceptable and make it easier to build coalitions of economic and political actors supporting climate action.

To investigate such a politically-acceptable reform, Bertram et al. (2015b) use an Integrated Assessment Model to simulate a policy package with three components: (1) a carbon price starting at US$7 per ton of CO2 in 2015 to incentivize economy-wide mitigation, flanked by (2) support for low-carbon energy technologies in the form of mandates for global installation of renewable electricity generation capacities, CCS deployment and electric vehicles, and (3) a moratorium on new coal-fired power plants to limit future stranded assets. They find that such package could indeed deliver less than 2°C global warming, while drastically limiting stranded assets (assuming massive retrofitting of existing power plants with CCS deployment is possible).

Performance standards, feebates, moratoriums, or targeted financial instruments need to be implemented at the sector level. They can thus be linked to the sector targets required to align short-term reductions with long-term decarbonization. Sometimes, the link between the target and the policy can be straightforward: a target to stop deforestation can be implemented by outlawing deforestation, a renewable energy target can be enforced with renewable portfolio standards or renewable capacity auctions, and energy efficiency mandates on new vehicles and buildings can be calibrated to meet the respective efficiency targets. Price instruments, such as subsidies on new electric vehicles and tax new gas guzzlers, may be less easy to calibrate and require periodic adjustment (Metcalf, 2009).

Tackling Other Market and Government Failures

Another advantage of this type of sectoral instruments is that they help to tackle other market and government failures that constitute barriers to zero-carbon investment.

Economic theory suggests that policy instruments should be individually designed to solve one unique problem (Tinbergen, 1956). In the case of the transition to zero net emissions, however, the objective of avoiding stranded assets interacts with a government failure and (at least) two major market failures in a way that is difficult to disentangle.

First, governments have to navigate a tension between commitment, predictability and flexibility. What matters for the transition is investment in long-lived capacity, but government cannot commit to future carbon prices (Brunner et al., 2012; Ulph and Ulph, 2013). It has been argued that the apparently high discount rates attributed to investors making energy conservation investments may result from uncertainty on future energy prices (Hassett and Metcalf, 1993). Alternative policy approaches (different from carbon prices) may then be more efficient, such as (1) mandatory efficiency or performance standards (e.g., performance standards for cars, such as CAFE standards; building energy efficiency standards) that directly constraint today’s investment, instead of influencing their future returns; and (2) subsidies or taxes that apply on the investment itself, to reduce the sunk costs of investments. Examples include the feebates applied on cars, making efficient cars less expensive to buy and inefficient car more expensive, and targeted financial instruments such as loans with reduced interest rates for projects consistent with zero net emissions.

Predictability cannot be implemented at the expense of flexibility (Lempert and Schlesinger, 2000). Flexibility is important because mistakes will happen, or changes will happen that are unexpected. Climate policies may have to be adjusted if they cause undesirable consequences (e.g., regarding food security or access to modern energy), if technological change makes emission reductions much easier or cheaper, or if the global warming target is revised due to new information on climate change and its impacts. For instance, the rapid decrease in the cost of solar electricity was not anticipated and affected the viability of European feed-in tariffs. To make this process more transparent, rules regarding when and how policies will be revised based on what new information can be enacted in advance (Aldy, 2017; Jakob and Brunner, 2014; Metcalf and Weisbach, 2009).

Because flexibility increases the odds that the policy will survive unexpected shocks and changes, a flexible policy is also more credible over the long-term (Nemet et al., 2017). For instance, energy efficiency standards typically include flexibility: in the US, CAFE standards are negotiated, announced far in advanced, and revised at mid-road to adjust to new information on compliance costs and benefits.

In addition to temporal flexibility, another important aspect of flexibility is avoiding to micromanage the transition by "picking the winners" and imposing too specific choices to the markets. There is a balance to maintain between enforcing the transition to technologies that can deliver deep decarbonization in the long term, and letting markets choose what is most efficient locally (Azar and Sandén, 2011). For instance, CAFE standards set objectives in miles per gallon of new sold vehicles, and let car manufacturer achieve these with a large set of available options: improvements in the internal combustion engine and gear boxes, hybrid powertrains, lighter vehicles, etc.

In addition to the limited ability of the government to commit credibly to very specific climate policies, multiple market failures and externalities complicate the transition to zero carbon. First, markets are frequently lacking relevant information and incentives to promote the adoption of energy efficiency or emission reduction measures. For instance, imperfect incentives and lack of risk management instruments in capital markets may create a bias against investments with long-term returns (Fay et al., 2015). And often, people and investors are not aware of more efficient alternatives or technologies. Labels and certification schemes can provide the information consumers need to influence their choice of technologies (Davis and Metcalf, 2014) and promote sustainable natural resource management (for instance for forest management). Lack of information is also magnified by behavior failure and cognitive biases, and split incentives magnify this issue. For example, landlords may buy inefficient equipment because tenants pay the electricity bills, resulting in suboptimal investment in energy efficiency (Gillingham et al., 2012; Maruejols and Young, 2011). Again, regulations and mandates can be a solution where externalities and market failures cannot be easily fixed. And the cost of capital for low-carbon investment can be reduced through targeted financial instruments (such as preferred conditions for loans for energy efficiency projects). And many people do not perform full analyses of the costs and benefits of various technologies and options to make choices: instead they use rules of thumbs and social norms (Weber et al., 2008; Weber and Johnson, 2011). Promoting changes in social norms can be part of the solution (Nyborg et al., 2016).

Second, economic actors prefer to innovate where they have innovated before and where there is a combination of well-known demand and mature markets – a bias that favors marginal innovation in traditional domains, not radically new green innovation. This market failure is magnified by imperfections in capital markets – for instance the lack of instruments to manage risks. Policy can kick-start the transition by temporarily supporting R&D in low-carbon technologies (Acemoglu et al., 2012).

In addition, governments may even need to target specific green technologies. For instance, solar energy is still more expensive than wind energy, and not likely to be massively deployed with only generic support to carbon-free electricity production, despite its greater potential for reducing cost through economies of scale. Announcing performance standards in advance may be another way to foster R&D in the right technologies. In addition to generic energy efficiency standards in the auto sector, some governments apply a specific subsidy to electric or hybrid vehicles that may be a way to nudge even further R&D efforts to focus on technologies that have the potential to deliver zero emissions in the long term.

Finally, decarbonization will face issues linked to network effects, infrastructure gaps, and coordination failures. The deployment of electric cars requires coordination between automakers, power generation, and infrastructure to charge cars, and lack of coordination may stall the diffusion of this technology (Budde Christensen et al., 2012; Cowan and Hultén, 1996; Dijk and Yarime, 2010; Liebowitz and Margolis, 1995). Thus, government will not just need to enact policies, they also have to plan for infrastructure deployment, in particular for public transportation and to accommodate electricity generation from intermittent sources. Infrastructure also makes a carbon price more effective by making demand more elastic to price changes. A modeling exercise done for Paris finds that public transport reduces by half the carbon tax needed to achieve a given emission reduction (Avner et al., 2014). Similarly, some countries have struggled to ensure that the needed electricity transmission lines and network capacity are in place to handle increased shares of renewable energy (Fay et al., 2015). Coordination failures, infrastructure gaps and network effects can be tackles thanks to (1) planning exercises that combine the public and the private sector and give some visibility to private actors (e.g., that they can invest in electric cars assuming that charging infrastructure will be deployed); (2) direct investments in infrastructure – which can be public, private, or through public-private partnerships – to provide the infrastructure needed for the transition to take place and incentivize further private investments in the transition.

Since government will likely rely on policy packages, it is important to pay attention to how different policies will interact. A literature finds that ill-designed sectoral or local policies (for instance subsidies for renewable power decided at the municipal level) may dampen the efficiency of policies with a wider scope – geographical or sectoral (Bento et al., 2009; Böhringer and Behrens, 2015; Böhringer and Rosendahl, 2010; Goulder and Schein, 2013; Hood, 2013; Weigt et al., 2013). The main danger is when the wider-scope policy is a quantity-based policy, typically a carbon market: for instance, renewable targets for the power sector in the UE will reduce the allowance price on the EU-ETS, and emission reductions achieved thanks to renewable power will be compensated by fewer reductions in another sector covered by the ETS. This may not necessary be a bad thing: this literature does not acknowledge that emission reductions achieved with renewable power, a certain way to achieve zero net emissions, may be more valuable than reductions in another sector covered by the ETS, for instance energy efficiency in refineries. Similarly, reductions achieved thanks to electric vehicles covered by a subsidy will be offset under stringent CAFE standards by sales of more energy-inefficient vehicles, but could also make guarantee that the CAFE standards are met in a way consistent with deep decarbonization in the long term. In any case, interactions should be considered when designing all instruments.

Conclusion

Policymakers have to design their short-term climate policies and their NDCs in the face of two tough constraints: their policies need to be ambitious enough to provide a credible pathway toward zero net emissions by the end of the century; and they need to be socially and politically acceptable. From this difficult situation, this paper proposes a set of three complementary recommendations.

First, carbon prices, and in particular carbon taxes, seem to be a promising policy instrument that can help reduce other distortive taxes or finance social assistance, infrastructure deployment and other government operations. High carbon prices may however face political opposition, even if the distributional consequences of price hikes are avoided, because they can create stranded assets and stranded jobs. A potential solution for policymakers is to implement a moderate carbon price based on the needs for fiscal revenue and the political constraints, and to complement this instrument with sector-level policies that incentivize a progressive shift to zero-carbon capital without creating stranded assets (Bertram et al., 2015b; Jakob et al., 2014; Rozenberg et al., 2017).

Second, the short-coming of pricing instruments need to be compensated by supporting actions at the sector level. These actions need to be designed focusing on the long-term goal of delivering zero emissions, for instance through the negotiation of sectoral targets (e.g., for 2030) with stakeholders. They need to be implemented through policy instruments that are predictable, effective, and minimize economic disruptions.

More generally, any climate action will be more efficient if the economic system is more efficient. Climate action will benefit from the actions aiming at accelerating development. A financial system able to attract long-term investment would contribute to development and growth while making climate policy more efficient. Better enforcement of norms and regulations would also enhance the environmental benefits from existing and future regulations. Symmetrically, any climate policy will be more efficient, and more likely to be accepted by the public and the political system, if it contributes to development. There is therefore a synergy between development policies and climate policies – this synergy can be better captured if the climate and development agenda are merged into a single sustainable development agenda.

Acknowledgments

This paper builds on the World Bank book *Decarbonizing Development: Three Steps to a Zero-Carbon Future* (Fay et al., 2015). A version of this article is forthcoming in *WIREs Energy and Environment*.

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