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Supply-side climate policy: the road less taken

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Cover photo: The Mount Thorley Warkworth coal mine in New South Wales, Australia, which has been in operation since 1981, includes two adjacent open-cut mines. In 2013, it supplied international and domestic markets with more than 12 million tonnes of semi-soft coking coal and thermal coal. © Jerry Buckingham / Flickr

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ABSTRACT

Reducing fossil fuel combustion is a top priority for climate policy. For decades, policy-makers and international agreements have sought to achieve this goal through energy efficiency, low-carbon technology, carbon pricing, and other measures designed to reduce demand for fossil fuels. Focusing on the point of combustion makes intuitive sense, but efforts have yet to put fossil fuel use on a trajectory consistent with keeping global warming below 2°C. Recognizing this shortcoming, policy-makers, researchers and activists have begun to look at the potential for policies and actions aimed at limiting fossil fuel supply. However, options for supply-side climate policies and how they might complement or replace more traditional demand side policies remain poorly understood. This paper explores reasons why supply-side policies have not been pursued and why they deserve more attention. It provides a typology of supply-side policies and frameworks for assessing their effectiveness, efficiency, and feasibility. It finds that supply-side policies, such as removal of producer subsidies, compensation of resource owners for leaving fuels "unburned", or outright restrictions on resource development, could bring important benefits. Such policies could allow for greater emission reductions at the same (or lower) cost than demand-side policies alone. They could also help to reduce carbon lock-in effects, making it easier for lower-carbon alternatives to compete with fossil fuels. Many questions related to feasibility and effectiveness remain. Further research and policy development can help address these questions and explore how a new supply-side policy "toolkit" might complement demand-side approaches.

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1. INTRODUCTION

The combustion of fossil fuels is by far the largest human source of global greenhouse gas emissions, releasing more than 30 billion tonnes of CO_2 into the atmosphere each year (IPCC 2014). Reducing fossil fuel combustion is thus a top priority for climate policy. For decades, policy-makers and international agreements have sought to achieve this goal through energy efficiency, low-carbon technology, carbon pricing, and other measures aimed at reducing demand for fossil fuels. Focusing on the point of combustion makes intuitive sense, but efforts so far have yet to put fossil fuel use on a trajectory consistent with keeping global warming below 2°C.

Recognizing this shortcoming, policy-makers, researchers and activists have begun to look at the supply side of the fossil fuel economy – and the potential for supply-side measures to complement demand-side climate policies. A key insight driving these new approaches is that the political and economic interests and institutions that underpin fossil fuel production help to perpetuate fossil fuel use, and even to increase it. From this emerging vantage point, continued investment in fossil fuel exploration, extraction, and delivery infrastructure makes global climate protection objectives much harder to achieve, and should therefore be handled with care and, in many cases, reduced or avoided.

The focus on fossil fuels supply in climate policy has high-profile proponents. U.S. President Obama has said he would only approve the Keystone XL pipeline, connecting Canadian oil sands with U.S. refineries and ports, if it "does not significantly exacerbate the problem of carbon pollution" (The White House 2013). OECD Secretary General Ángel Gurría has emphasized the challenge posed by decades of investment in fossil fuel supply and the "carbon entanglement" it creates, as governments depend on the profits they accrue (Gurría 2013).

The intersection of climate policy and fossil fuel production is also the subject of a growing body of economic and policy research. Studies have examined, for example, the extent to which achieving climate protection objectives would dramatically curtail fossil fuel profits, or "rents" (Bauer et al. 2013), and render a significant fraction of coal and unconventional oil reserves and resources "unburnable" (McGlade and Ekins 2015). Researchers and financial advisory institutions have highlighted the risk that climate and broader environmental concerns might lead to the premature retirement of fossil fuel reserves and supply infrastructures – and thus result in "stranded assets" and associated financial losses for investors and governments (Leaton et al. 2013; HSBC 2013; HSBC 2012; Caldecott et al. 2013; Hsueh and Lewis 2013; Clark 2015). At the same time, it is clear that fossil fuel producers – and the political and economic interests tied to them – can pose formidable obstacles to climate action.

With these considerations in mind, several economists have proposed supply-side approaches to climate policy (Sinn 2008; Collier and Venables 2014; Harstad 2012; Faehn et al. forthcoming). Climate activists are increasingly targeting the supply side of the fossil fuel economy as well, rallying opposition to new fossil fuel supply infrastructure – from Keystone XL, to coal terminals and gas pipelines – and the development of new resources, from exploratory oil drilling in the Arctic to new coal mines in Australia. Many are also pushing for divestment of major institutions from fossil fuel holdings (Ansar et al. 2013).

Yet despite the increased attention, supply-side climate policies have yet to take hold in most of the world, and there is still limited understanding of whether and how effectively they might complement or replace more traditional "demand-side" policies. This working paper explores the reasons why supply-side policies have not been pursued and why they deserve more attention. We discuss different types of supply-side policies, and examine some prominent examples. We then present new approaches for assessing them alongside demand-side policies, illustrating how supply-side measures offer the potential to increase the environmental and cost-effectiveness of climate action. We conclude with suggestions for how to advance the consideration, analysis and integration of supply-side approaches.

2. WHY THE ROAD IS LESS TAKEN

Climate policy is built on interventions that address the demand for, and only indirectly the supply of, fossil fuels: cap-and-trade systems, carbon taxes, renewable energy incentives, emissions performance standards, and energy efficiency programmes. As noted in the introduction, demand-side policies have a strong theoretical basis, and in many cases they have, even under limited application, substantially reduced greenhouse gas (GHG) emissions.

By contrast, supply-side policies are far less widespread. The lack of focus on the supply side can be explained by at least three factors: 1) the greater political attractiveness of demand as compared with supply measures; 2) standard GHG accounting rules that undervalue supply-side relative to demand-side measures; and 3) common perceptions of the nature of fuel markets. We explore each of these here in turn.

First, promoting the growth of solutions and the industries that support them – i.e. new low-carbon investments – is inherently attractive to politicians and community leaders, in part because it draws relatively little political opposition. By contrast, directly addressing fossil fuel production, by taxing or reducing such activities, could be expected to engender strong opposition from powerful coal, oil and gas interests. However, using *only* demand-side policy focus may lead to unintended negative effects that partially erode the expected benefits, particularly in the absence of widespread carbon constraints internationally. For example, as carbon pricing or regulation reduces domestic demand for fossil fuels, producers may find new markets (without such constraints) internationally, as producers of coal from the Powder River Basin in the U.S. have sought amid a declining domestic market.[1] The expectation of future carbon pricing might even encourage producers to accelerate production in the near term, as suggested by Sinn's "green paradox," described further in Box 1 (Sinn 2008).

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[1] See, e.g., Braasch, G. (2013). Powder River Basin: Coal on the move. *The Daily Climate*, 9 December. http://www.dailyclimate.org/tdc-newsroom/2013/12/western-coal-development.

Box 1: The green paradox

Arguably, no individual or concept has done more to promote the idea of supply-side climate policy – at least in economist circles – than Hans-Werner Sinn and his notion of a Green Paradox. Sinn (2008) holds that owners of fossil fuel resources will accelerate production when faced with the likelihood of increasingly stringent climate policies such as carbon prices or constraints. He argues that leakage – both international and, in particular, inter-temporal – will undermine climate policy effectiveness. Fossil fuel resource owners, seeing that climate policies and support for fossil fuel alternatives will erode their future profits, will maximize profits by speeding up production (and induce greater demand) in the near term. As a result, he argues, most demand-side climate policies have the effect of accelerating, rather than slowing, as intended, the production and consumption of fossil fuels. He argues that only internationally administered, binding emissions commitments by a majority of emitters/producers – a declining permit system similar to that envisioned in the Kyoto Protocol – offers an effective approach to climate policy. However, other economists have questioned the presence and relevance of a green paradox for climate policy (van der Ploeg and Withagen 2012; Cairns 2014; Edenhofer and Kalkuhl 2011). Hoel (2013) finds that supply-side climate policies would avoid a green paradox, i.e. an increase in near-term emissions, to the extent that they are aimed at higher-cost reserves.

Second, the way that nations account for their carbon emissions – on a territorial basis – strongly discourages supply-side measures, at times with perverse effects. Territorial GHG emissions accounting, as established by the United Nations Framework Convention on Climate Change (UNFCCC) and followed by all countries and most other jurisdictional entities, effectively places the onus on those who consume fossil fuels, and not on those who supply it. A nation that taxes coal exports but not domestic consumption, for example, might reduce coal consumption and emissions in other countries but, by indirectly encouraging domestic consumption, increase its own (Richter et al. 2015). Even though these and other supply-side policies could make important contributions to climate protection, because of how emissions are accounted, political leaders have less incentive to implement them. Not only would resulting reductions in global emissions not be reflected in national emissions accounts – in some cases they might even make it more difficult to reach national emissions targets. Box 2 explains in further detail how the standard, territorial accounting framework can create an unintended barrier to reducing emissions through supply-side measures.

Third, common perceptions about the nature of fossil fuel markets and of the climate problem can reinforce the focus on demand-side policies. It is more common to hear that the problem is that "we use too much" fossil fuel than that "we produce too much", perhaps owing to a presumption that if "we don't produce it, someone else will" – i.e. that restricting coal, oil or gas production would only result in shifting where, and not how much, fossil fuel is ultimately produced, an outcome known as "leakage". To be sure, some market leakage would reduce the effectiveness of supply-constraining policies, but leakage also affects demand-constraining policies, as we examine further in the section on assessing policies.

Arguably if demand-side policies were ambitious enough, and applied widely enough – for example, if binding, deep mitigation commitments covering the majority of global emissions were in place – they would suffice to achieve the 2°C target. Yet the reality is that such policies, as envisioned in the Kyoto Protocol, have not materialized. As the urgency of the climate problem has grown, so has the need for a broader range of solutions. To that end, supply-side policies could offer several benefits.

Box 2: How territorial emissions accounting may bias policy choices

The emissions accounting frameworks used by nations, sub-national entities, and institutions are almost exclusively territorial and demand-based, drawing largely from the methods established in the UNFCCC. In general, countries track only the greenhouse gases emitted within their territorial boundaries, and set targets to reduce those emissions. There are good reasons for this approach: authorities can best measure, control, and be held accountable for the activities that take place within their territories. The territorial accounting approach is also highly congruent with demand-side climate policies. Such policies, by and large, aim to reduce the demand for fossil fuels (and their resulting combustion) within a jurisdiction taking the action (e.g. through imposing a carbon price or energy efficiency standard). A successful policy is then manifested in a lower jurisdictional emissions account.

For a supply-side policy, on the other hand, the relationship between an action (e.g. one that reduces available oil supplies) and the outcome (reduced oil consumption) may be less immediately apparent. Resulting emission reductions may not be manifested in the emissions accounts of the jurisdiction taking action, especially where the fuels in questions are internationally traded. In such cases, the jurisdiction taking a supply-side action may claim substantially less "credit" than it would for taking a demand-side action that has the same overall effect on global emissions. Put differently, current "territorial" emissions accounting tends to under-credit (or under- attribute) a jurisdiction for its supply-side actions and may in fact, over-credit (or over-attribute) for its demand-side actions (if and as leakage results in increased emissions elsewhere). Even if authorities may be more interested in achieving global emission reductions rather than in improving their own emissions accounts (where the two may diverge), they are still strongly influenced by the metrics that they are accountable for. As long as territorial emissions accounting remains the exclusive framework used to measure progress, supply-side measures will likely remain underrepresented in climate strategies relative to their potential for effectively and efficiently achieving climate benefits.

3. POTENTIAL BENEFITS OF SUPPLY-SIDE POLICIES

The framework for the global climate agreement that world leaders hope to reach at the Paris Climate Change Conference in December is a bottom-up, "pledge and review" approach in which countries submit voluntary "intended nationally determined contributions" (INDCs) to limit emissions but are not subject to binding international limits. The INDCs submitted to date, covering 70% of global emissions, have been described as a "step change" in efforts to address climate change (Pwc 2015), but they are universally acknowledged to be insufficient to keep global warming below 2°C (Climate Action Tracker 2015).

In this context, supply-side policies – from removing fossil fuel subsidies, to taxing production, to retiring assets – could offer governments and coalitions valuable new tools to achieve climate goals as effectively, efficiently and rapidly as possible. More comprehensive and globally coordinated supply-side approaches, such as coordinated cap-and-trade systems for fossil fuel extraction (Collier and Venables 2014), could also serve as alternatives to traditional demand-side approaches, such as emissions-based carbon taxes and cap-and-trade systems.

As complements or alternatives to demand-side climate policies and actions, supply-side options could offer two important benefits:

- **Reducing more emissions for a given marginal cost:** Applying supply-side and demand-side measures together may increase the scale of emission reductions available at a given marginal cost, in effect "widening" the mitigation cost curve. For example, as discussed in Box 3, Faehn et al. (2013) show that actions to reduce investment and production in oil fields could more than halve the cost of achieving Norway's emission reduction target for 2020.

- **Avoiding the over-supply of fossil fuels:** In general, supply side policies and actions (e.g. removing producer subsidies) will tend to slow investment in fossil fuel production and trade infrastructure, limiting the extent of carbon lock-in associated with fossil fuel over-production.[2] This, in turn, can: a) lower future mitigation costs, as over-production would otherwise make fossil fuels cheaper and harder to compete with; b) reduce stranded-asset risks and the consequent market and economic inefficiencies; c) and reduce carbon entanglement and the socio-political influence of fossil fuel interests.

Supply-side policies may also be capable of increasing moral pressure and public support for climate action, because they target a narrower set of actors, and this may increase the likelihood of success (Collier and Venables 2014). Supply-side policies may shift some of the rents from regulation of emissions to the countries that produce fossil fuels – for example, by way of a tax on coal production levied by governments in coal-supplying countries, rather than a tax on coal use levied by importing countries; this could prove attractive to supplying countries (Richter et al. 2015). Supply-side policies may also help compensate for intertemporal leakage (Sinn 2008; Sinn 2015), by phasing down coal production in advance of expected demand-constraining policies (e.g. a rising carbon price), in ways that demand-side policies alone cannot.

Given these potential advantages, supply-side policies and actions merit a closer look. In the sections that follow, we inventory, classify and briefly describe supply-side policies and actions that have been suggested or implemented, and then turn to frameworks for assessing their effectiveness, efficiency and feasibility, and for integrating them with demand-side measures.

3.1 Supply-side climate policies and actions

While the literature is replete with lists and analyses of demand-side climate policies and actions (Kolstad et al. 2014; Somanathan et al. 2014), there are few, if any, that also cover the supply side. This may be due to the fact that they have received, until recently, far less traction among policy-makers and analysts, or to the challenges described above (e.g. incompatibility with emissions accounting). Although less familiar, supply-side climate policies and actions are similar in many ways to various demand-side analogues, as suggested by the taxonomy in Table 1, which is drawn from a taxonomy of sector policy instruments in the Intergovernmental Panel on Climate Change (IPCC) *Fifth Assessment Report* (Somanathan et al. 2014). Such policies can be categorized as follows, just as on the demand side:

- **Price-based economic instruments:** Supply-side options include resource production taxes, export taxes, or subsidy reform or removal. Such instruments can aim to remove distortions created by subsidies, to reflect the full social cost of extraction activities, or to otherwise achieve emission reduction goals. Take fossil fuel subsidies: most policy-makers have focused on reforming subsidies on consumption – which indeed account for the majority of subsidy value provided today (largely in developing countries). Far fewer have taken on the many producer subsidies that incentivize exploration, extraction and trade (Bast et al. 2014; Aldy 2013).[3] Other instruments that have been suggested or analysed include taxes on oil production (Faehn et al. 2013) or coal exports (Richter et al. 2015). Sinn (2012) has proposed source taxes on capital income – taxes on the financial capital or income created by bringing fossil fuel resources into

[2] See Erickson et al. (2015) for further discussion of supply-side lock-in effects and the risks of over-production.
[3] For example, several national governments provide support to fossil fuel exploration and development via tax credits or accelerated depreciation allowances for capital expenditures (OECD 2013).

potential production – as a means to induce resource owners to slow fossil fuel exploration and extraction and avoid the potential for a "green paradox" (see Box 1).

- **Quantity-based economic instruments**, such as emissions trading and crediting systems. As described in the next section, some have proposed the notion of a "ring-fenced" cap-and-trade system for fossil fuel extraction as a more effective alternative to emissions-based cap-and-trade and other demand-side policies. Another approach discussed in the next section is the concept of awarding emissions offsets for keeping fossil fuel assets in the ground.
- **Regulatory approaches**, such as prohibiting or limiting development of certain resources or use of certain technologies. For example, the U.S. has, at times, banned deepwater oil and gas drilling (Baker and Broder 2010), and the European Parliament has supported a moratorium on fracking for shale gas (Neslen 2015). Regulatory approaches could also include explicit consideration of long-term emissions impacts in the permitting and review of new production or distribution facilities. Such approaches have come into play, for example in the U.S., with President Obama's Keystone principle noted above and draft guidance from the White House Council on Environmental Quality that makes clear that GHG analysis of federal actions should include "downstream emissions" associated with combustion of new fossil fuel supplies enabled by the action (The White House 2014). Regulatory approaches can also include restricting fossil fuel supply to defined amounts, such as through production or export quotas; the Organization of the Petroleum Exporting Countries (OPEC) system of oil production quotas is one such case.
- **Government provision of goods, services or funds**, or the restriction thereof. For example, governments can choose to restrict leasing of state-owned lands and waters for coal, oil and gas development, or elect to not develop specific resources or infrastructure (oil pipelines and terminals, coal ports, etc.) that would stimulate further extraction.[4] Governments can also create funding or policy instruments designed to acquire production rights and compensate resource owners in order to leave fossil fuel reserves undeveloped or otherwise restrict their production (Harstad 2012; Larrea and Murmis 2015). Governments can also restrict the actions of financing institutions that they control or contribute to, with the intent of reducing privileged finance available to fossil fuel supply infrastructure. For example, while some government and multilateral finance institutions have moved to limit financing of coal power projects due to climate concerns, such concerns have not yet affected financing of fossil fuel supply activities.[5]
- **Information programmes, voluntary actions, accounting frameworks,** and other approaches that don't fit neatly under the categories above. Perhaps most prominent is the effort to affect the financing, perception and influence of fossil fuel supply industries through divestment (Ansar et al. 2013; McKibben 2013; Alexander et al. 2014; Skancke et al. 2014). As noted above, territorial emissions accounting represents a potential obstacle to supply-side policies; one way to reduce this bias would be to

[4] For example, in October 2015 the Obama administration announced it was cancelling plans to offer new leases for oil drilling in the Arctic, and would not allow renewals on existing leases (Jewell 2015).

[5] In 2013 the U.S Export-Import Bank (U.S. Ex-Im) decided to cease using public funds to support new coal power investments, and the World Bank and several European export credit agencies followed shortly thereafter with similar guidelines. Yet despite suggestions to discontinue such practices, the US Ex-Im, as with most other export crediting agencies and multilateral finance institutions, continue to consider financing coal mines and other fossil fuel supply infrastructure. See Schmidt, J. (2013). Another U.S. public funding institution will get out of coal power plants: New Export-Import Bank guidelines adopted. Natural Resources Defense Council Staff Blog, 12 December. http://switchboard.nrdc.org/blogs/jschmidt/exim_coal_guidelines_adopted.html.

make greater use of extraction-based emissions accounting as a means to track potential contributions to climate objectives (Erickson and Lazarus 2013a; Peters 2008).

These various supply-side policies can be implemented at the scale of **individual investments** (e.g. not building a coal port or oil pipeline), of (coordinated) **national policies** (e.g. reducing subsidies), or of **collective actions or instruments** by a coalition of countries (e.g. internationally harmonized fuel export limits or taxes, or international or linked cap-and-trade systems). Some could indeed become elements of national strategies and incorporated in future INDCs, though doing so would likely require new methods to estimate, if not directly account for, cross-boundary emission savings. As with product consumption policies (e.g. low-carbon diets or purchasing of smaller-footprint products), a large share of the emissions reductions may occur in other countries where, as the result of international trade, fuel consumption (or goods production) may be most affected.

To date, many of these supply-side policies have largely remained at the proposal stages, whether in the literature or advanced by political leaders (e.g. Ecuadorian President Correa[6]) or by non-profit organizations (such as those championing the reform of subsidies to fossil fuel producers). That said, the fossil fuel divestment movement has gathered considerable momentum in recent years, and governments, in particular in the U.S. and Norway, are actively considering measures to restrict fossil fuel infrastructure investments on climate change grounds (Merkley et al. 2015; Carrington 2015; The White House 2013).

[6] As described in the next section, President Correa had solicited payments from the international community in exchange for not extracting oil from the Ishpingo-Tambocochа-Tiputini (ITT) region of Yasuní National Park.

Table 1: Types and examples of supply-side and demand-side climate policies

	Supply-side policy	Demand-side policy
Economic instruments – taxes	Resource production tax Resource export taxes Taxes on fossil fuel capital (income)	Carbon or fuel use taxes Border carbon price adjustments
Economic instruments – subsidies	Removal of fossil fuel producer subsidies	Removal of fossil fuel consumer subsidies Renewable energy subsidies
Economic instruments – tradable allowances and credits	Cap-and-trade for production rights Offsets for leaving assets in ground	Cap-and-trade for consumption rights Emission reduction credits or offsets
Regulatory approaches	Prohibiting development of certain resources or use of certain technologies Limiting production or export (e.g. via quota) Comprehensive emissions assessment in environmental impact review of new fossil fuel supply projects	Coal plant emission standards Building codes
Government provision of goods and services	Restricted leasing of state-owned lands and waters for coal, oil and gas development. Decision to not develop specific resources or infrastructure (oil pipelines and terminals; coal ports, etc.) Funding to compensate resource owners for leaving reserves undeveloped Policies to restrict export credit agency or multilateral development finance for coal mining and other supply infrastructure	Infrastructure expansion (district heating / cooling; electric vehicle charging station; wind transmission) Policies to restrict export credit agency or multilateral development finance for coal power stations
Information programmes, voluntary actions, and other	Divestment by institutions and individual from companies involved in fossil fuel production Extraction-based emissions accounting by nations and sub-national governments; life-cycle based accounting of embedded GHGs in fossil fuels sold in marketplace	Energy audits Vehicle or appliance labelling Territorial emissions accounting

Source: Adapted from Somanathan et al. (2014), Table 15.2.

3.2 A review of three supply-side policy options

In this section, we take a closer look at three supply-side approaches, reflecting different levels of complexity and ambition: reforming fossil fuel producer subsidies; using oil rents to lock up coal assets through a ring-fenced cap-and-trade system; and one of the most widely discussed approaches to "keeping fossil fuels in the ground": the conservation and compensation models proposed for the Ecuadorian ecological preserve (Yasuní) and the oil reserves it contains (Ishpingo-Tambococha-Tiputini, or ITT).

Reform of fossil fuel production subsidies

Many national and local governments provide support to entities seeking to discover, develop and extract fossil fuels. Producer subsidies can take many forms, from tax credits on exploration and production equipment, to direct payments per unit of output, to sub-market-rate leasing of nationally owned lands (OECD 2013; Aldy 2013; Koplow et al. 2010). By reducing the costs of finding and developing new oil fields and by increasing net revenues for the fuels extracted, these subsidies affect the economics of fossil fuel extraction. They can also affect the quantity and pace of fuels supplied to regional or global markets and, ultimately, fuel consumption and CO_2 emissions (Erickson and Lazarus 2013b; Anderson and McKibbin 2000; Lunden and Fjaertoft 2014).

World leaders have long recognized the connection between fossil fuel subsidies and greenhouse gas emissions. In 2009, G20 leaders meeting in Pittsburgh agreed to eliminate fossil fuel subsidies, stating: "Inefficient fossil fuel subsidies encourage wasteful consumption, reduce our energy security, impede investment in clean energy sources and undermine efforts to deal with the threat of climate change" (G20 2009). This stance was reaffirmed by G7 leaders in 2014 (G7 2014) and has been underscored in numerous statements by international agencies. In fact, several nations have seized the opportunity created by the recent drop in global oil prices to scale back *consumer* subsidies, such as discounts on fuel or electricity prices. Researchers have shown that reducing consumer subsidies for fossil fuels could cut global CO_2 emissions by 10% or more annually by 2050 (Burniaux and Chateau 2014; Schwanitz et al. 2014). Few researchers, however, have explored the connection between producer subsidies and global emissions (Merrill et al. 2015; Anderson and McKibbin 2000; Allaire and Brown 2012; Fulton et al. 2015), and few policy-makers have undertaken producer subsidy reforms, even though they raise fewer concerns about distributional impacts (IMF 2013).

A proposal in the United States to repeal a popular subsidy for oil and gas exploration provides one example of potential impacts. Under the proposal, the U.S. would have repealed a tax credit in which producers can accelerate depreciation of certain investments for exploratory or production wells, a subsidy estimated at 1.6 billion USD per year (Pirog 2013). The extent to which subsidy repeal would affect oil and gas production, and CO_2 emissions as a result, remains under debate. One study commissioned by the oil industry concluded that the subsidy would cut U.S. oil and gas production by 15%, or 3.8 million barrels of oil equivalent daily (Wood Mackenzie 2013). By contrast, other research has concluded that the removal of the subsidy would affect industry profits, but have little impact on production (Aldy 2013).

Conservation and compensation (for leaving reserves undeveloped)

One of the simplest proposals to limit fossil fuel supply is to pay resource owners to leave fuels in the ground. In other words, resource owners would be compensated for not developing fossil fuel reserves that would otherwise be extracted. The Yasuní-ITT Initiative, proposed in 2007 by the Ecuadorian government, is the most prominent example of this approach. It was the first to advance "the novel concept that not developing fossil fuels should also be recognized as a valid tool to address climate change" (Finer et al. 2010). Another policy option that has been proposed is to use oil rents to compensate coal asset owners for leaving their assets undeveloped (Collier and Venables 2014), a concept we explore more in the next section. In several respects, such policies would resemble the strategies used to compensate forest owners under Reducing Emissions from Deforestation and Forest Degradation (REDD+) systems, as well as the "debt-for-nature" swap mechanisms that emerged in the 1980s (Davidsen and Kiff 2013).

In addition to housing large oil reserves, the Yasuní National Park of Ecuador is one of the most biodiverse regions on Earth; it is also a culturally sensitive area, home to several indigenous groups (Larrea and Warnars 2009). The initial proposal sought funding equivalent to at least half (350 million USD annually over 10 years) of the potential oil reserve earnings in return for not extracting nearly a billion barrels of oil (400 Mt CO_2) in a section of the National Park (Finer et al. 2010). Interest from an internationally administered trust fund would have provided a revenue stream to finance sustainable development, conservation and social development programmes (Davidsen and Kiff 2013; Finer et al. 2010). However, funding at the requested level never materialized, and in September 2013, President Correa announced the liquidation of the fund (Petherick 2013).

The Yasuní-ITT Initiative faced two of the principal challenges also faced by REDD+ programmes: leakage and permanence. Indeed, observers suggest that initiative proponents failed to assuage the concerns of prospective donors that oil not produced by Yasuní-ITT might be partly or wholly offset by increased production elsewhere (market leakage) or that decisions might be reversed in the future and the oil reserves subsequently developed (permanence) (Davidsen and Kiff 2013; Finer et al. 2010).

Another concern, which pushed Germany, an early supporter of the initiative, to back out, was the fear that other oil-producing countries might make similar demands for "opportunity cost payments" under the UNFCCC, thereby endangering the climate negotiations through large financial demands (Martin and Scholz 2014). Initiative proponents, meanwhile, have said financial demands could be limited by targeting only areas with unique characteristics, such as Yasuní-ITT (Larrea and Warnars 2009), where important co-benefits can be achieved for biodiversity (the national park is an ecological hotspot), poverty alleviation (Ecuador is a less developed country), and economic diversification (Ecuador is heavily reliant on oil exports).

During the climate change negotiations in 2011, Ecuador put forward the idea that the "net avoided emissions" associated with Yasuní-ITT and other commitments to leave fossil resources in the ground could be quantified and generate emission reduction credits or offsets under a market-based mechanism similar to the Clean Development Mechanism (van Asselt 2014; Ortega-Pacheco and Larrea 2011). In addition to leakage and permanence questions, such a mechanism would need to address the extent to which consumption of the fuel in question would be reduced and might be replaced by a more or less carbon-intensive alternative (Köhler and Michaelowa 2014).

Ring-fenced cap-and-trade for production rights: Using oil rents to 'close coal'

Building on a concept first proposed by Harstad (2012), the economists Paul Collier and Anthony Venables (2014) have suggested a supply-side approach to climate change mitigation that would use rents from oil production to sequentially close down coal mining operations. The rationale is fairly straightforward: coal accounts for over 40% of global CO_2 emissions but generates relatively low rents per unit of energy or carbon, especially in comparison with oil (Erickson et al. 2015). Therefore, the oil industry could part with only a fraction of its profits and still compensate the coal industry for the closure of coal mines. Indeed Bauer et al. (2013) estimate the net present value (using a 5% discount rate) of coal rents in a baseline scenario from 2010–2100 at 3.5 trillion USD, less than one-fifth of the 18 trillion USD in projected oil rents over the same period. Collier and Venables (2014) suggest that that this transfer could occur through adoption of a cap-and-trade system for extraction rights that expands in participation sequentially from higher- to lower-income countries. The system would be "ring-fenced" so that revenues from allowance sales would stay entirely within the system, to help ensure that sufficient value flows to the coal industry – including miners and coal-dependent communities – as it relinquishes its production allowances.[7]

[7] Collier and Venables (2014) do not define precisely in what manner the system would be ring-fenced; we impute the intent based on the goals of the system as discussed in their paper.

Collier and Venables (2014) argue that this approach offers two key advantages over demand-side approaches: enhanced moral pressure and reduced leakage. Enhanced moral pressure derives from more readily observable action (closing a finite number of coal mines vs. energy efficiency actions spread across countless individual investments), readily identifiable actors (coal industry vs. some homeowners), a solution that is "manifestly material" to the problem of carbon pollution (phase-out of the most carbon-intensive fuel), and direct consequences that are relatively certain and exact. They further argue that the sequencing of participating countries and the flow of rents from relatively "unearned rents" of oil extraction to the more "hard-earned labour"-dominated rents of coal extraction, and thus the compensation of coal miners by oil companies, "could invoke a supportive moral narrative of fairness" (Collier and Venables 2014, p.509). As noted in the IPCC *Fifth Assessment Report*, "an international collective arrangement that is perceived to be fair has greater legitimacy and is more likely to be internationally agreed and domestically implemented" (Fleurbaey et al. 2014, p.327). Increased agreement and implementation, in turn, can reduce the risk of international carbon leakage and further strengthen moral pressure on the remaining reserve owners.

As with any relatively new and ambitious policy proposal, this concept raises a number of questions. Might a cap-and-trade system have unexpected or unintended outcomes, as experience suggests it might (Aldy and Stavins 2012). For example, might it result in the closure of high-cost oil production, and leave high-valued coal production in operation? If so, would this matter for the effectiveness of the approach? Can the risk of more significant international leakage in its early stages (due to limited coverage) be effectively managed? What would be the consequences of such a policy on energy security, access and costs, particularly in developing countries? Would rents accrue only to those with direct coal industry connections, or would there be some effort to minimize the impact on consumers facing higher energy prices? Why would major oil-producing countries participate in a system that jeopardizes both their present (through rent redistribution) and future (through tightening cap on fossil fuel extraction) earnings? Such questions are akin to – and perhaps no more challenging to address than – those of other ambitious, yet more mainstream demand-side approaches (e.g. linked cap-and-trade systems for consumption rights or an internationally harmonized carbon tax) whose success is similarly predicated on broad international participation.

4. APPROACHES TO ASSESSING AND INTEGRATING SUPPLY-SIDE POLICIES

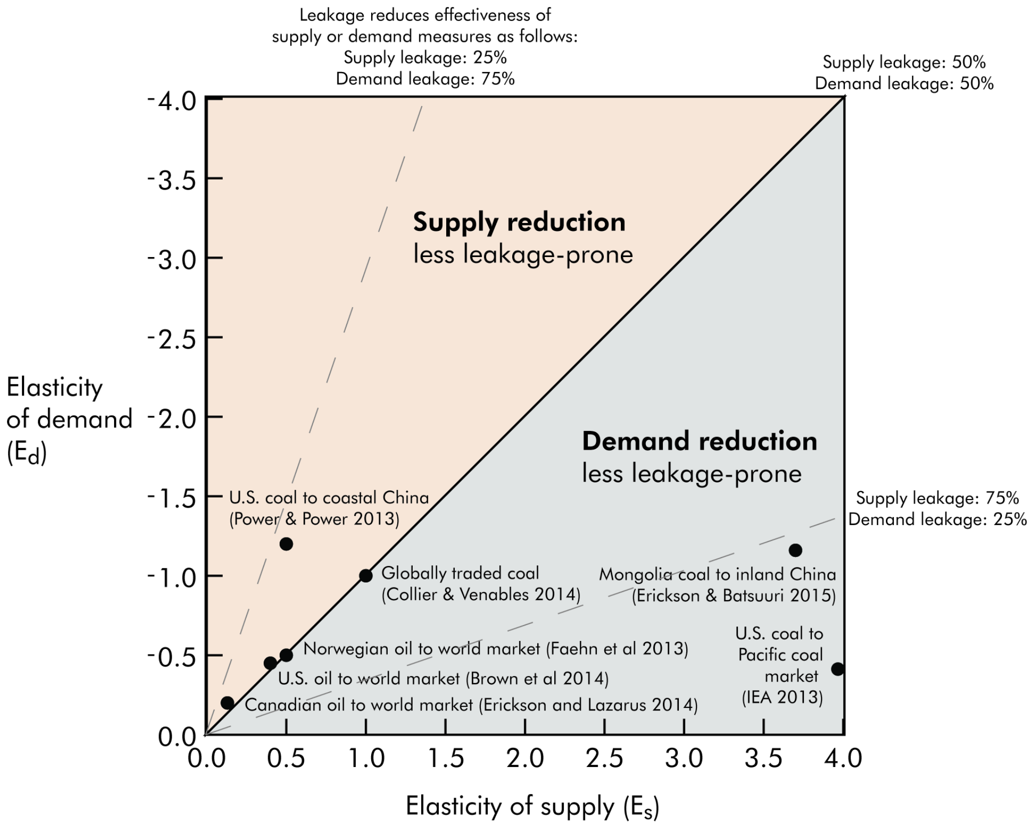
Common analytical frameworks and criteria can assist in comparing and evaluating supply-side approaches. Indeed, criteria commonly used for demand-side climate mitigation planning and decision-making can be readily applied to supply-side policy as well. In this section, we look at two such criteria – **environmental effectiveness** and **cost-effectiveness** – and explore some assessment approaches that could help decision-makers to compare and maximize the combined benefits of demand- and supply-side measures. We also briefly touch on additional criteria – **distributional incidence** and **feasibility** – that are important for the assessment of climate policies, but are largely unexplored on the supply side.

4.1 Environmental effectiveness

As defined by the IPCC *Fifth Assessment Report*, "a policy is environmentally effective if it achieves its expected environmental target", such as GHG emission reduction (Kolstad et al. 2014, p.236). The environmental effectiveness of a given policy or action can be evaluated as a function of its scale or ambition (tonnes CO_2 in expected reductions), carbon leakage (including rebound effects of energy efficiency actions, international leakage due to shifting of industrial activity or fuel market effects, and where relevant, intertemporal leakage), and the extent and duration of "follow-through" (enforcement, compliance, permanence, and other factors depending on the nature of the intervention). Some supply-side actions, for example, may be large in scale (e.g. closure of large coal mines), but limited in duration (relative to a counterfactual in which the mine closes a few years later, or else reopens later.

Leakage can undermine the effectiveness of both demand- and supply-side policies, as indirect effects lead to CO_2 emissions increases elsewhere. In particular, where policies are undertaken by individual jurisdictions or coalitions comprising less than a majority of global consumption or production, interjurisdictional (international) leakage associated with fuel price effects will be an important factor in determining policy effectiveness. The magnitude of leakage is commonly assessed with economic tools – such as supply and demand curves – and their associated metrics of price elasticity. As shown in Figure 1, where demand is more elastic than supply, leakage will be greater for demand policies, and vice-versa: where supply is more elastic than demand, leakage will be greater than supply policies (Collier and Venables 2014; Harstad 2012). Indeed, as Faehn et al. (2013) find, "assumptions regarding supply and demand elasticities, as well as the competitive environment on the fuel markets, are decisive for [their] results on the optimal distribution of demand versus supply side policies" (p.5).

Figure 1: Leakage risk from measures to reduce fossil fuel supply vs. demand



Where demand is more elastic than supply (top left), leakage will be greater for demand-side than for supply-side measures. Conversely, to the extent that supply elasticity exceeds demand elasticity (bottom right), demand reduction becomes less prone to leakage, and supply reduction more so.[8]

[8] For a given decrease in fossil fuel supply, the net decrease in consumption can be estimated as the change in fossil fuel supply times $E_d/(E_d-E_s)$, where E_d and E_s are the price elasticity of demand and supply, respectively, for that fuel (Erickson and Lazarus 2014). The expression 1- $E_d/(E_d-E_s)$, then, is a measure of the leakage due to a supply side policy. The leakage due to a decrease in fossil fuel demand is 1- $E_s/(E_s-E_d)$, which is equal to $E_d/(E_d-E_s)$. We use these expressions to plot the lines of equal leakage effect on Figure 1.

We found three studies considered supply and demand effects related to oil. Brown et al. (2014) looked at the effects of lifting the U.S. crude oil export ban. As described in Box 3, Faehn et al. (2013) examined the implications of curtailing Norwegian oil production. Erickson and Lazarus (2014) considered the impact of the Keystone XL pipeline and its potential to send additional Canadian crude oil to world markets. Each of these studies, based on a review of the literature, adopted different supply and demand elasticities for its central estimates, but in all the supply and demand elasticities were of similar magnitude. As shown in Figure 1, where this is the case, supply- and demand-side measures are subject to similar levels of leakage: for each barrel of oil supply (demand) reduced, the resulting increase (decline) in oil prices would stimulate a half barrel of additional production (consumption). Simply put, leakage reduces effectiveness by 50% for each type of measure.

While oil markets are largely global, as reflected in the widespread reference benchmark crude oil prices, coal markets are largely local or regional.[9] Not surprisingly, studies that have looked at coal markets diverge more sharply, particularly in their supply elasticities. Looking at the market for coal exports from the U.S. to the China-Pacific coal market, Power and Power (2013) use a coal supply elasticity less than one, while Burniaux and Chateau (2014) in their global model assume a coal supply elasticities as high as 10. Batsuuri and Erickson (2015), in their analysis of coal exports to China, find a supply elasticity between 3 and 4. All studies use a demand elasticity near 1, so the implications for leakage vary widely by study and region.

Collectively, these findings suggest that both supply- and demand-side measures can be subject to significant leakage, and that careful market analysis is needed to assess where each type of policy might be particularly effective. The greater the share of total fossil fuel supply (or demand) that is covered by supply-side (or demand-side) policies, the less "leaky" and the more effective they will be.

The market-induced leakage effects of supply- and demand-side activities also differ in another crucial respect. For demand-side activities that directly reduce consumption, market-mediated effects reduce the benefits of the policies, such as vehicle efficiency standards (Rajagopal and Plevin 2013). For supply-side activities, however, the market-mediated effect on consumption is what brings the emissions benefits. As a result, the emissions benefits of supply reductions are inherently more difficult to observe and measure, which may help explain why they have received less attention to date.

4.2 Cost effectiveness

Next we consider the *relative* economic efficiency of supply and demand-side measures. Climate policies are often assessed in terms of *overall* economic efficiency, accounting for the marginal benefits of reducing climate impacts, which requires valuing human and natural systems. A less fraught metric is cost-effectiveness, wherein policies are compared in terms of the net present value (NPV) cost of achieving emissions reductions, typically expressed as cost per unit of emission reduction. This provides a measure of the relative economic efficiency of reaching a given emissions target. The most common visual tool for representing cost-effectiveness is the marginal abatement cost (MAC) curve, which can be applied to both supply-side and demand-side measures. (However, unlike macroeconomic modelling approaches – which have challenges of their own – this method does not capture economy-wide effects that might result from changes in relative prices, investment or trade.)

[9] Nearly half of all oil is traded internationally, compared with 15% of coal (BP 2014).

Using separately but consistently determined demand- and supply-side MAC curves, the cost-effectiveness of demand and supply measures can be analysed and compared, and together, they can be used to develop an integrated suite of policies to meet climate protection objectives at a lower cost than either applied alone. Box 3 examines this approach, as pioneered by Faehn et al. (2013; forthcoming); it is a potentially powerful tool to support analysis and decision-making to increase the effectiveness of climate policy. At the same time, and as is central to consideration of many supply-side measures, this approach assesses environmental effectiveness in terms of global rather than national (or other jurisdiction) emissions. Policy-makers using this approach and wishing to document their contributions to climate protection objectives will need to find ways to supplement or depart from territorial emissions accounting frameworks.

4.3 Distributional incidence and feasibility

Additional criteria such as distributional incidence and administrative and political feasibility are important for evaluating the implications and prospects of potential climate policies. Indeed, distributional incidence – the extent to which the costs and benefits of a policy fall on different actors or segments of society – is a key determinant of feasibility. As noted earlier, perceived fairness is critical for both international climate agreements and domestic implementation of climate policies. The distributional effects of demand-side policies – in particular carbon taxes – have been well studied by economists (Williams et al. 2014; Hassett et al. 2009). Asheim (2012) found that they fared much better than demand-side policies in maintaining “the functional distribution of income between capital owners and resource owners”, which he suggests may facilitate international climate negotiations.

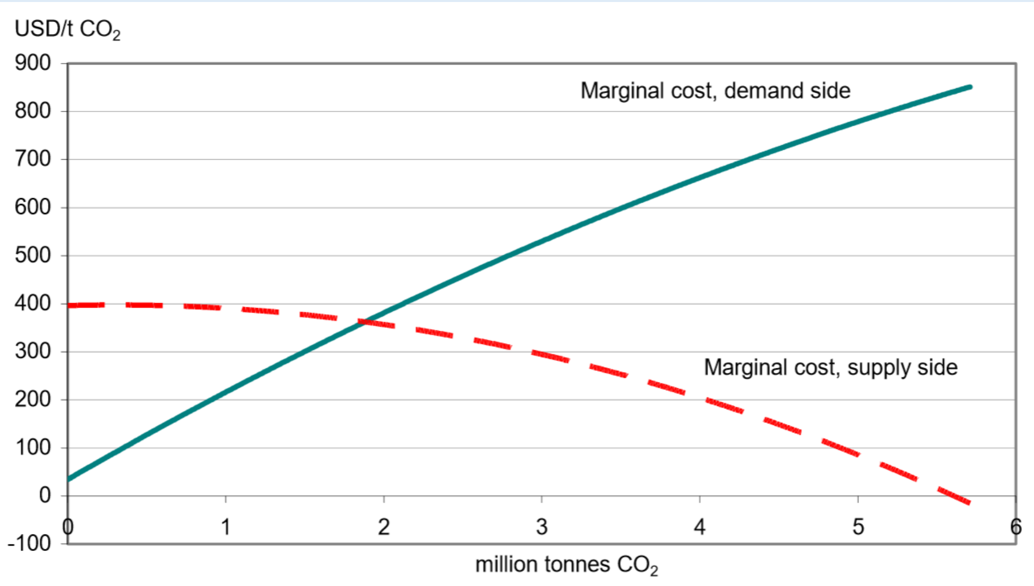
There are also broader political challenges to supply-side policy, and a key question that remains unaddressed in existing research is under what conditions a national government might forgo extraction and its associated rents. Responses are inevitably country- and context-specific, drawing attention to “the political economy of energy transitions”, which “is a vastly understudied area” (Goldthau and Sovacool 2012, p.238). Political economy analyses, for example, can shed light on the political origins of government decisions, draw attention to the winners and losers of such decisions, and, in so doing, help assess the political prospects of supply-side policies (Khan 2000). Unanswered political economy questions further extend to the conditions under which fossil fuel supplying governments may have incentives to use supply-side policies to partially pre-empt demand-side policies, and how government revenues from supply-side policies might need to be recycled to private owners of the resources in order for such policies to be politically sustainable (Folkestad 2013).

Box 3: Developing an integrated supply-demand strategy using leakage-adjusted MAC curves: the case of Norway

Norway offers an interesting context for considering how demand and supply-side policies can complement or conflict with each other. Norway's oil and gas sector has rapidly grown over the past decade and now represents nearly a quarter of the country's economic output. At the same time, the government has committed to reducing GHG emissions by 40% by 2030 relative to 1990 levels. Some have questioned whether the focus should be solely on domestic emissions, and whether continued oil production and export is consistent with Norway's overall climate policy aims.[7]

Faehn et al. (2013) have developed an innovative approach to addressing Norway's predicament. They start with Norway's traditional demand-side MAC curve, which given the hydro-based power system, lack of coal use, and presence of a carbon tax and ETS, offers limited and relatively high-cost abatement opportunities, largely in the transportation sector. They then adjust abatement potentials and costs to account for leakage effects (as discussed above), which has the effect of steepening the demand-side MAC curve significantly. As illustrated in the chart below, they then develop a supply-side MAC curve (dotted red line), which reflects forgone rents from planned investments in additional oil production as well as the emission reductions that might result from reduced production. They plot the supply-side MAC from right to left, starting at the level of *global* emission reductions (5.7 million tCO_2) associated with efforts planned to meet Norway's 2020 emissions target. Their findings suggest that this level of *global* emission reductions could be achieved by a mix of supply side (two-thirds) and demand-side (one-third) measures at a cost less than half of the current plan, which relies wholly on the demand-side measures charted in the blue line. "The combined policy will give the same *global* emission reductions as the *domestic* emission reductions suggested by the Norwegian government, but at a cost of only one-third of using only demand side measures" (Faehn et al. 2013, p.28).

Figure 2: Leakage-adjusted demand- and supply-side MAC curves



Source: Faehn et al. (2013), Figure 4.

5. ADVANCING THE CONVERSATION

Measures to influence the pace and location of fossil fuel extraction – what call "supply-side climate policy" – remain the road less taken by those seeking to reduce global GHG emissions. As we noted earlier, there are legitimate reasons for this: focusing on fossil fuel combustion is a more direct way to address CO_2 emissions, and it can be more politically viable than taking on the powerful interests that benefit from the extraction and distribution of fossil fuels.

Yet it is clear that supply-side policies could bring important benefits. They can "widen the mitigation cost curve", allowing greater emission reductions at the same (or lower) cost than demand-side policies alone, and can also help address carbon leakage risks. They can help to reduce carbon lock-in effects, making it easier for lower-carbon alternatives to compete with fossil fuels, and weakening the "carbon entanglement" that makes it hard for many governments to adopt strong climate policies. Lastly, focusing directly on fossil fuels and the actors that supply them can bring added pressure to bear on climate change mitigation efforts, and could help make the case for more ambitious global climate action.

In this paper, we have described some categories, and examples, of supply-side climate policy, and introduced approaches for assessing them alongside more conventional, demand-side approaches. Considerable work lies ahead. Beyond some theoretical economic assessments, it is not yet clear what types of supply-side policies might be most environmentally- and cost-effective, most scalable in terms of delivering substantial global reductions, and most promising in terms of support and implementation by a broad coalition of countries. Other questions also remain, such as how to consider international equity and fairness in adopting supply-side policies, under what conditions governments might forgo extraction and associated economic rents, and how jurisdictions implementing supply-side policies might take "credit" for their supply-side "contributions", given that emission reductions may occur largely beyond their borders. Further research and policy development are needed to address these questions and develop a new supply-side policy "toolkit" to complement demand-side approaches.

REFERENCES

Aldy, J. (2013). Eliminating Fossil Fuel Subsidies. In *15 Ways to Rethink the Federal Budget*. M. Greenstone, M. Harris, K. Li, A. Looney, and J. Patashnik (eds.). The Hamilton Project. Brookings Institution Press, Washington, DC. http://www.hamiltonproject.org/papers/15_ways_to_rethink_the_federal_budget.

Aldy, J. E. and Stavins, R. N. (2012). The promise and problems of pricing carbon theory and experience. *The Journal of Environment & Development*, 21(2). 152–80. DOI:10.1177/1070496512442508.

Alexander, S., Nicholson, K. and Wiseman, J. (2014). *Fossil Free: The Development and Significance of the Fossil Fuel Divestment Movement*. MSSI Issues Paper No. 4. Melbourne Sustainable Society Institute, University of Melbourne, Melbourne, Australia. http://sustainable.unimelb.edu.au/sites/default/files/docs/MSSI-IssuesPaper-4_Divestment_2014.pdf.

Allaire, M. and Brown, S. P. A. (2012). *U.S. Energy Subsidies: Effects on Energy Markets and Carbon Dioxide Emissions*. Prepared for the Pew Charitable Trusts. Resources for the Future, Washington, DC. http://www.pewtrusts.org/en/research-and-analysis/reports/2012/08/13/us-energy-subsidies-effects-on-energy-markets-and-carbon-dioxide-emissions.

Anderson, K. and McKibbin, W. J. (2000). Reducing coal subsidies and trade barriers: their contribution to greenhouse gas abatement. *Environment and Development Economics*, (4). 457–81.

Ansar, A., Caldecott, B. and Tilbury, J. (2013). *Stranded Assets and the Fossil Fuel Divestment Campaign: What Does Divestment Mean for the Valuation of Fossil Fuel Assets?* Stranded Assets Programme. Smith School of Enterprise and the Environment, University of Oxford, Oxford, UK. http://www.smithschool.ox.ac.uk/research/stranded-assets/SAP-divestment-report-final.pdf.

Asheim, G. B. (2012). A distributional argument for supply-side climate policies. *Environmental and Resource Economics*, 56(2). 239–54. DOI:10.1007/s10640-012-9590-2.

Baker, P. and Broder, J. M. (2010). Moratorium on deepwater drilling is lifted, and new rules are imposed. *The New York Times*, 12 October. http://www.nytimes.com/2010/10/13/us/13drill.html.

Bast, E., Makhijani, S., Pickard, S. and Whitley, S. (2014). *The Fossil Fuel Bailout: G20 Subsidies for Oil, Gas and Coal Exploration*. Overseas Development Institute, London. http://www.odi.org/publications/8678-fossil-fuel-bailout-g20-subsidies-oil-gas-coal-exploration.

Batsuuri, T. and Erickson, P. (2015). *The Net CO2 Impact of Increasing Exports of Coal from Mongolia to China*. Working Paper. Stockholm Environment Institute. https://www.researchgate.net/publication/282879836_The_net_CO2_impact_of_increasing_exports_of_coal_from_Mongolia_to_China.

Bauer, N., Mouratiadou, I., Luderer, G., Baumstark, L., Brecha, R. J., Edenhofer, O. and Kriegler, E. (2013). Global fossil energy markets and climate change mitigation – an analysis with REMIND. *Climatic Change*, online 22 October. DOI:10.1007/s10584-013-0901-6.

BP (2014). *BP Statistical Review of World Energy June 2014*. London. http://www.bp.com/statisticalreview.

Brown, S. P., Mason, C., Krupnick, A. and Mares, J. (2014). *Crude Behavior: How Lifting the Export Ban Reduces Gasoline Prices in the United States*. RFF Issue Brief 14-03-REV. Resources for the Future, Washington, DC. http://www.rff.org/research/publications/crude-behavior-how-lifting-export-ban-reduces-gasoline-prices-united-states.

Burniaux, J.-M. and Chateau, J. (2014). Greenhouse gases mitigation potential and economic efficiency of phasing-out fossil fuel subsidies. *International Economics*, 140. 71–88. DOI:10.1016/j.inteco.2014.05.002.

Caldecott, B., Tilbury, J. and Ma, Y. (2013). *Stranded Down Under? Environment-Related Factors Changing China's Demand for Coal and What This Means for Australian Coal Assets*. Smith School of Enterprise and the Environment, University of Oxford, Oxford, UK. http://apo.org.au/node/37143.

Carrington, D. (2015). World's biggest sovereign wealth fund dumps dozens of coal companies. *The Guardian*, 5 February. http://www.theguardian.com/environment/2015/feb/05/worlds-biggest-sovereign-wealth-fund-dumps-dozens-of-coal-companies.

Clark, P. (2015). Mark Carney warns investors face 'huge' climate change losses. *Financial Times*, 29 September. http://www.ft.com/intl/cms/s/0/622de3da-66e6-11e5-97d0-1456a776a4f5.html#axzz3olEauvgg.

Climate Action Tracker (2015). *Effect of Current Pledges and Policies on Global Temperature*. Ecofys, Climate Analytics, PIK, New Climate Institute. http://climateactiontracker.org/global.html.

Collier, P. and Venables, A. J. (2014). Closing coal: economic and moral incentives. *Oxford Review of Economic Policy*, 30(3). 492–512. DOI:10.1093/oxrep/gru024.

Davidsen, C. and Kiff, L. (2013). *Ecuador's Yasuní-ITT Initiative and New Green Efforts-Away from Petroleum Dependency?* Occasional Papers, Vol. 3, Issue 1. Latin American Research Centre, University of Calgary. http://larc.ucalgary.ca/sites/larc.ucalgary.ca.new/files/occasionalpapers/davidsen_kiff_yasuni-itt_ecuador_vol3iss1.pdf.

Erickson, P. and Lazarus, M. (2013a). *Accounting for Greenhouse Gas Emissions Associated with the Supply of Fossil Fuels*. SEI Discussion Brief. Stockholm Environment Institute, Seattle, WA, US. http://www.sei-international.org/publications?pid=2419.

Erickson, P. and Lazarus, M. (2013b). *Assessing the Greenhouse Gas Emissions Impact of New Fossil Fuel Infrastructure*. SEI Discussion Brief. Stockholm Environment Institute, Seattle, WA, US. http://www.sei-international.org/publications?pid=2384.

Erickson, P. and Lazarus, M. (2014). Impact of the Keystone XL pipeline on global oil markets and greenhouse gas emissions. *Nature Climate Change*, 4(9). 778–81. DOI:10.1038/nclimate2335.

Erickson, P., Lazarus, M. and Tempest, K. (2015). *Carbon Lock-in from Fossil Fuel Supply Infrastructure*. SEI Discussion Brief. Stockholm Environment Institute, Seattle, WA, US. http://www.sei-international.org/publications?pid=2805.

Faehn, T., Hagem, C., Lindholt, L., Maeland, S. and Rosendahl, K. E. (forthcoming). Climate policies in a fossil fuel producing country: Demand versus supply side policies. *The Energy Journal*.

Faehn, T., Hagem, C., Lindholt, L., Maeland, S. and Rosendahl, K. E. (2013). *Climate Policies in a Fossil Fuel Producing Country: Demand versus Supply Side Policies*. Discussion Paper 747. Statistics Norway, Research Department, Oslo. https://www.ssb.no/en/forskning/discussion-papers/_attachment/123895?_ts=13f51e5e7c8.

Finer, M., Moncel, R. and Jenkins, C. N. (2010). Leaving the oil under the Amazon: Ecuador's Yasuní-ITT Initiative. *Biotropica*, 42(1). 63–66. DOI:10.1111/j.1744-7429.2009.00587.x.

Fleurbaey, M., Kartha, S., Bolwig, S., Chee, Y., Corbera, E., et al. (2014). Sustainable development and equity. In *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, E., S. Kadner, et al. (eds.).

Cambridge University Press, Cambridge, UK and New York. https://www.ipcc.ch/report/ar5/wg3/.

Folkestad, S. (2013). Economists call Norway's climate policy hypocritical. *sciencenordic.com*, 4 May. http://sciencenordic.com/economists-call-norways-climate-policy-hypocritical.

Fulton, M., Buckley, T., Koplow, D., Sussams, L. and Grant, A. (2015). *A Framework for Assessing Thermal Coal Production Subsidies*. Energy Transition Advisors, IEEFA, Earth Track, Carbon Tracker Initiative, London. http://www.carbontracker.org/wp-content/uploads/2015/09/Thermal-Coal-Prod-Subsidies-final-12-9.pdf.

G7 (2014). *The Brussels G7 Summit Declaration*. Brussels. http://europa.eu/rapid/press-release_MEMO-14-402_en.htm.

G20 (2009). *Leaders' Statement: The Pittsburgh Summit*. https://g20.org/wp-content/uploads/2014/12/Pittsburgh_Declaration_0.pdf.

Goldthau, A. and Sovacool, B. K. (2012). The uniqueness of the energy security, justice, and governance problem. *Energy Policy*, 41. 232–40. DOI:10.1016/j.enpol.2011.10.042.

Gurría, A. (2013). *The Climate Challenge: Achieving Zero Emissions*. Lecture by the OECD Secretary-General. London, 9 October 2013. http://www.oecd.org/about/secretary-general/the-climate-challenge-achieving-zero-emissions.htm.

Harstad, B. (2012). Buy Coal! A Case for Supply-Side Environmental Policy. *Journal of Political Economy*, 120(1). 77–115. DOI:10.1086/665405.

Hassett, K. A., Mathur, A. and Metcalf, G. E. (2009). The Incidence of a U.S. Carbon Tax: A Lifetime and Regional Analysis. *The Energy Journal*, 30(2). DOI:10.5547/ISSN0195-6574-EJ-Vol30-No2-8.

HSBC (2012). *Coal and Carbon: Stranded Assets: Assessing the Risk*. HSBC Global Research, London. https://www.research.hsbc.com/midas/Res/RDV?p=pdf&key=dXwE9bC8qs&n=333473.PDF.

HSBC (2013). *Oil & Carbon Revisited: Value at Risk from 'Unburnable' Reserves*. HSBC Global Research.

Hsueh, M. and Lewis, M. C. (2013). *Thermal Coal: Coal At A Crossroads*. Commodities Special Report. Deutsche Bank Markets Research.

IEA (2013). *Medium-Term Coal Market Report 2013: Market Trends and Projections to 2018*. International Energy Agency, Paris. http://www.iea.org/publications/freepublications/publication/medium-term-coal-market-report-2013.html.

IMF (2013). *Energy Subsidy Reform: Lessons and Implications*. International Monetary Fund. http://www.imf.org/external/np/pp/eng/2013/012813.pdf.

IPCC (2014). *Climate Change 2014: Synthesis Report*. Intergovernmental Panel on Climate Change, Geneva. http://www.ipcc.ch/report/ar5/syr/.

Jewell, S. (2015). *Interior Department Cancels Arctic Offshore Lease Sales*. U.S. Department of the Interior, Washington, D.C. https://www.doi.gov/pressreleases/interior-department-cancels-arctic-offshore-lease-sales.

Khan, M. (2000). Rent-seeking as Process. In *Rents, Rent-Seeking and Economic Development: Theory and Evidence in Asia*. M. Khan and K. S. Jomo (eds.). Cambridge University Press, Cambridge. 70–144. http://eprints.soas.ac.uk/9843/.

Köhler, M. and Michaelowa, A. (2014). Limiting climate change by fostering net avoided emissions. *Carbon & Climate Law Review*, 2014. 55.

Kolstad, C., Urama, K., Broome, J., Bruvoll, A., Cariño-Olvera, M., et al. (2014). Chapter 3: Social, economic and ethical concepts and methods. In *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. O. Edenhofer, R. Pichs-Madruga, and Y. Sokona (eds.). Cambridge University Press, Cambridge, UK, and New York. 173–248. https://www.ipcc.ch/report/ar5/wg3/.

Koplow, D. N., Lin, C., Jung, A., Thone, M. and Lontoh, L. (2010). *Mapping the Characteristics of Producer Subsidies a Review of Pilot Country Studies*. International Institute for Sustainable Development, Winnipeg, Man.

Larrea, C. and Murmis, M. (2015). *An International Fund for Keeping Fossil Fuel Reserves in the Ground in Biodiverse Hotspots of Developing Countries*.

Larrea, C. and Warnars, L. (2009). Ecuador's Yasuni-ITT Initiative: Avoiding emissions by keeping petroleum underground. *Energy for Sustainable Development*, 13(3). 219–23. DOI:10.1016/j.esd.2009.08.003.

Leaton, J., Ranger, N., Ward, B., Sussams, L. and Brown, M. (2013). *Unburnable Carbon 2013: Wasted Capital and Stranded Assets*. Carbon Tracker and Grantham Research Institute on Climate Change and the Environment, London School of Economics, London. http://www.carbontracker.org/wastedcapital.

Lunden, L. P. and Fjaertoft, D. (2014). *Government Support to Upstream Oil & Gas in Russia: How Subsidies Influence the Yamal LNG and Prirazlomnoe Projects*. Sigra Group with International Institute for Sustainable Development and WWF, Geneva. https://www.iisd.org/publications/government-support-upstream-oil-gas-russia-how-subsidies-influence.

Martin, P. L. and Scholz, I. (2014). Ecuador's Yasuní-ITT Initiative : What can we learn from its failure? *International Development Policy*, 5.2. DOI:10.4000/poldev.1705.

McGlade, C. and Ekins, P. (2015). The geographical distribution of fossil fuels unused when limiting global warming to 2°C. *Nature*, 517(7533). 187–90. DOI:10.1038/nature14016.

McKibben, B. (2013). The case for fossil-fuel divestment. *Rolling Stone*, 22 February. http://www.rollingstone.com/politics/news/the-case-for-fossil-fuel-divestment-20130222.

Merkley, Heinrich, Markey, Whitehouse, Sanders and Franken (2015). *Stop Arctic Ocean Drilling Act of 2015*.

Merrill, L., Harris, M., Casier, L. and Bassi, A. (2015). *Fossil-Fuel Subsidies and Climate Change*. Nordic Council of Ministers. http://urn.kb.se/resolve?urn=urn:nbn:se:norden:org:diva-3744.

Neslen, A. (2015). Majority of MEPs support fracking moratorium in symbolic vote. *The Guardian*, 10 June. http://www.theguardian.com/environment/2015/jun/10/majority-of-meps-support-fracking-moratorium-in-symbolic-vote.

OECD (2013). *Inventory of Estimated Budgetary Support and Tax Expenditures for Fossil Fuels 2013*. Organisation for Economic Co-operation and Development, Paris. http://www.oecd-ilibrary.org/content/book/9789264187610-en.

Ortega-Pacheco, D. V. and Larrea, C. (2011). *Submission from Ecuador: The Yasuni-ITT Initiative - Enhancing Costeffectiveness Of, and Promoting, Mitigation Actions*. FCCC/AWGLCA/2011/MISC.4/Add.1. UNFCCC.

Peters, G. P. (2008). From production-based to consumption-based national emissions inventories. *Ecological Economics*, 65(1). 13–23. DOI:10.1016/j.ecolecon.2007.10.014.

Petherick, A. (2013). Pipe dream. *Nature Climate Change*, 3(10). 859–60. DOI:10.1038/nclimate2011.

Pirog, R. (2013). *Oil and Natural Gas Industry Tax Issues in the FY2014 Budget Proposal*. R42374. Congressional Research Service, Washington, DC. https://www.fas.org/sgp/crs/misc/R42374.pdf.

Power, T. M. and Power, D. S. (2013). *The Impact of Powder River Basin Coal Exports on Global Greenhouse Gas Emissions*. Prepared for The Energy Foundation, Missoula, MT. http://www.powereconconsulting.com/WP/wp-content/uploads/2013/05/GHG-Impact-PRB-Coal-Export-Power-Consulting-May-2013_Final.pdf.

Pwc (2015). *Conscious Uncoupling? Low Carbon Economy Index 2015*. http://www.pwc.co.uk.

Rajagopal, D. and Plevin, R. J. (2013). Implications of market-mediated emissions and uncertainty for biofuel policies. *Energy Policy*, 56. 75–82. DOI:10.1016/j.enpol.2012.09.076.

Richter, P. M., Mendelevitch, R. and Jotzo, F. (2015). *Market Power Rents and Climate Change Mitigation: A Rationale for Coal Taxes?* Discussion Paper 1471. German Institute for Economic Research, Berlin. http://www.diw.de/sixcms/detail.php?id=diw_01.c.502680.de.

Schwanitz, V. J., Piontek, F., Bertram, C. and Luderer, G. (2014). Long-term climate policy implications of phasing out fossil fuel subsidies. *Energy Policy*, 67. 882–94. DOI:10.1016/j.enpol.2013.12.015.

Sinn, H.-W. (2008). Public policies against global warming: a supply side approach. *International Tax and Public Finance*, 15(4). 360–94. DOI:10.1007/s10797-008-9082-z.

Sinn, H.-W. (2012). *The Green Paradox: A Supply-Side Approach to Global Warming*. The MIT Press, Cambridge, MA, US. https://mitpress.mit.edu/books/green-paradox.

Sinn, H.-W. (2015). *The Green Paradox: A Supply-Side View of the Climate Problem*. CESifo Working Paper No. 5385. Ifo Institute, Center for Economic Studies, Munich, Germany. https://www.cesifo-group.de/ifoHome/publications/working-papers/CESifoWP/CESifoWPdetails?wp_id=19160937.

Skancke, M., Dimson, E., Hoel, M., Kettis, M., Nystuen, G. and Starks, L. (2014). *Fossil-Fuel Investments in the Norwegian Government Pension Fund Global: Addressing Climate Issues Through Exclusion and Active Ownership*. Report by the Expert Group appointed by the Norwegian Ministry of Finance. Oslo. https://www.regjeringen.no/contentassets/d1d5b995b88e4b3281b4cc027b80f64b/expertgroup_report.pdf.

Somanathan, E., Sterner, T., Sugiyama, T., Chimanikire, D., Dubash, N. K., et al. (2014). National and sub-national policies and institutions. In *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, E., S. Kadner, et al. (eds.). Cambridge University Press, Cambridge, UK and New York. https://www.ipcc.ch/report/ar5/wg3/.

The White House (2013). Remarks by the President on Climate Change, Georgetown University. 25 June. http://www.whitehouse.gov/the-press-office/2013/06/25/remarks-president-climate-change.

The White House (2014). *Draft Guidance to Federal Agencies on Considering GHG Effects Under NEPA*. Council and Environmental Quality. http://www.whitehouse.gov/sites/default/files/docs/nepa_revised_draft_ghg_guidance.pdf.

van Asselt, H. (2014). *Governing the Transition Away from Fossil Fuels: The Role of International Institutions*. SEI Working Paper No. 2014-07. Stockholm Environment Institute, Oxford, UK. http://www.sei-international.org/publications?pid=2583.

Williams, R. C., Gordon, H. G., Burtraw, D., Carbone, J. C. and Morgenstern, R. D. (2014). *The Initial Incidence of a Carbon Tax across Income Groups*. RFF Discussion Paper 14-24. Resources for the Future, Washington, DC. http://www.rff.org/research/publications/initial-incidence-carbon-tax-across-income-groups.

Wood Mackenzie (2013). *Impacts of Delaying IDC Deductibility (2014-2025)*. Prepared for the American Petroleum Institute. Washington, DC. http://www.api.org/~/media/files/policy/taxes/13-july/api-us-idc-delay-impacts-release-7-11-13.pdf.

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