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Just cuts for fossil fuels? Supply-side carbon constraints and energy transition

Philippe Le Billon
Department of Geography, University of British Columbia, Canada

Berit Kristoffersen
Department of Social Sciences, UiT Arctic University of Norway, Norway

Abstract
Reducing greenhouse gas emissions has generally been approached through demand-side initiatives, yet there are increasing calls for supply-side interventions to curtail fossil fuel production. Pursuing energy transition through supply-side constraints would have major geopolitical and economic consequences. Depending on the criteria and instruments applied, supply cuts for fossil fuels could drastically reduce and reorient major financial flows and reshape the spatiality of energy production and consumption. Building on debates about just transitions and supply constraints, we provide a survey of emerging interventions targeting the supply of, rather than the demand for, fossil fuels. We articulate four theories of justice and criteria to prioritize cuts among fossil fuel producers, including with regard to carbon intensity, production costs, affordability, developmental efficiency and support for climate change action. We then examine seven major supply constraint instruments, their effectiveness and possible pathways to supply cuts in the coal, oil and gas sectors. We suggest that supply cuts both reflect and offer purposeful political spaces of interventions towards a 'just' transition away from fossil fuel production.

Keywords
Fossil fuels, climate change, climate justice, divestments, blockades, energy transition

Corresponding author:
Philippe Le Billon, Department of Geography, University of British Columbia, 1984 West Mall, Vancouver, BC, V6T 1Z2, Canada.
Email: lebillon@geog.ubc.ca

Introduction

Keeping fossil fuels underground has become imperative to maintain global temperature rise under 2°C by 2050, the low bar set in the Paris Agreement on climate change. Most mitigation efforts have been so far directed at reducing fossil fuel consumption, with largely disappointing results. Global fossil fuel production continues to increase, reflecting in part the weight of political and economic interests supporting these sectors (BP, 2018; Lazarus and van Asselt, 2018). Despite clear indications that fossil fuel industries will exceed their carbon budget, most fossil fuel producers still push for increased extraction, including through emission-heavy fuels such as brown coal, bitumen and shale gas. In this context, calls to curtail fossil fuel production are growing (Green and Denniss, 2018; Verkuijl et al., 2018), and a number of instruments are becoming used, ranging from voluntary moratoriums to divestments and blockades. Supply constraints can represent strategic points of interventions for climate justice (Kartha et al., 2018; Lenferna, 2018), yet there remains much debate about their role in a just energy transition away from fossil fuels.

Bringing about an energy transition through supply constraints means articulating principles of justice with the profoundly *geographical* political economy of fossil fuel sectors. An energy transition would not only reflect and reshape the highly uneven geopolitical economy of fossil fuel energy sectors and their socio-environmental impacts (Bridge and Le Billon, 2017; Watts, 2005); it would also have major implications for global financial flows and international relations, as well as affect the emerging geopolitical economy of renewable energy (Scholten, 2018). So far, the spatialities of supply-driven energy transition, and specific instruments and pathways to achieve it, have not been much discussed. The international political economy of energy and resources literature, for example, has mostly stressed the spatial dimensions of access to resources, investment flows, price dynamics, and uneven power relations among multiple actors (Goldthau et al., 2018; Van de Graaf et al., 2016), while most geographical studies of energy transitions have generally focused on renewable energies (Bridge et al., 2013; Ellabban et al., 2014; Huber and McCarthy, 2017).

Taking a geographical political economy approach, we engage here with the socially contested and power-laden character of the fossil fuel sectors, the various principles of justice that can be called upon to advance supply constraint objectives, and the spatialities of supply-side energy transition. This involves not only examining the 'classical' geopolitics of energy transition processes (i.e. power relations between states around energy transition), but also the multi-scalar reworking of energy-related geopolitical and geoeconomic imaginaries and practices (Barnett, 2007; Dalby, 2013; Huber, 2013; Kristoffersen, 2014). As such, we advance a geographical political economy of supply-side constraints considering energy transition initiatives as both space-making processes of constraint, such as the blockading of pipeline routes, and as processes shaped by the spatial contexts of energy production networks, such as the relative accessibility of energy supply alternatives for consumers. Our first objective is thus to contribute to the envisioning of 'just' geopolitical and economic energy landscapes emerging out of climate-related supply constraints. A second objective is to inform debates about the spatialities of energy (Bridge, 2017; Calvert, 2016) and the difficulties of combining both 'energy justice' and 'climate justice' (Healy and Barry, 2017; Jenkins et al., 2016; Newell and Mulvaney, 2013; Weber and Cabras, 2017).

Following this introduction, we first discuss the definition and spatialization of supply cuts, as well debates around their justification. We then articulate theories of justice with supply cuts criteria to prioritize cuts among fossil fuel producers according to carbon intensity, production costs, affordability, developmental efficiency and willingness criteria. We then examine the operationalization of supply-side instruments, their spatialities and

their likely geopolitical economy impacts. Finally, we identify possible pathways to supply cuts, taking into account the specifics of the coal, oil and gas sectors and the relative effectiveness of various supply-side initiatives. We conclude with a discussion of challenges and opportunities associated with supply-side constraints.

Defining supply cuts

Supply cuts can be defined as measures and processes constraining the production, transportation or transformation of raw materials, either voluntarily or coercively, so that supply is reduced for consumers. Supply constraints have major spatial dimensions, both in terms of the space-making processes involved and of the influence of spatial contexts on constraint initiatives. The uneven geopolitical economy of fossil fuels reflects not only geological challenges and opportunities, but also patterns of past exploitation, as well as technological, commercial, regulatory and cultural processes influencing investments and production levels (Bridge et al., 2018). Such factors often mean that only part of the total fossil fuel resources is technologically and commercially *recoverable*, thereby lowering the upper-bound of estimated future CO_2 concentration and increase in global mean surface temperature (Wang et al., 2017). Inversely, new technologies, deregulation and higher prices in effect 'create' fossil fuel reserves through easier accessibility, growing investments and greater profit margins (see Kama, 2016). Importantly, supply-side constraints can thus have the effect of increasing supply in the medium term if they increase fossil fuel prices.

The spatial unevenness of fossil fuels and constraint measures also play out in terms of *revenues*, as differences in production costs, taxation rates, subsidies and fuel prices contribute to the unequal distribution of the massive revenues generated by fossil fuels – with only about 5% of the world's population collecting about 50% of fossil fuel rents generated between 1970 and 2010 (Kartha et al., 2016). Such uneven distribution is further exacerbated by highly unequal rent distribution *within* producing countries, thereby consolidating the rationale of a 'just transition' away from fossil fuels as a small minority directly accumulates revenues (Mazaheri, 2017). Unevenness is particularly significant in the oil sector, which accounted for about 75% of total fossil fuel rents in 2014 compared to 17% for coal and 8% for natural gas (World Bank, 2018).

The Paris Agreement and volatile fossil fuel prices constitutes a complex context for producers to consider cuts in the medium to long term. Companies such as Shell (2016) have integrated climate change into their strategies and communications, emphasizing the need and ability to decarbonize the power sector but also the challenges of doing so in transportation and heavy industries. Such scenarios, however, do not generally cast fossil fuel producers – either governments or companies – as promoters of supply constraints, but rather as facilitators of a smooth transition to 'zero emissions' through technological innovation and carbon capture and storage. Supply constraints mostly appear within these scenarios as 'risks' and 'threats', including through economic shocks and political instability in fossil fuel-producing countries (see Equinor, 2018), especially in relation to hydrocarbon 'stranded assets' as the geopolitical economy of fossil fuels recently shifted from public fears over shrinking reserves, or 'peak supply', to producers' concerns about having more fossil fuels than will be consumed, or 'peak demand' (see Van de Graaf, 2018).

Justifying supply cuts

Cutting supplies is increasingly deemed an effective complement to, and even have synergistic effects with, demand-side efforts (Erickson and Lazarus, 2018; Fæhn et al., 2017;

Lazarus and van Asselt, 2018). Recent econometric studies suggest that a cap on fossil fuel extraction could potentially have the same effects on global emissions as a cap on fossil fuel consumption (Fæhn et al., 2017; Verkuijl et al., 2018). Historically, many of the largest reductions in emissions resulted from actual or perceived supply crunch, such as the oil crises in the 1970s and the combination of record high prices and 'peak oil' concerns around 2006–2008. Fossil fuel producers have also demonstrated an ability to reduce supply, although mostly for political or financial motives, as seen after price slumps in the late 1990s and 2014–2016. With only 90 major industrial entities – mostly fossil fuel companies – accounting for about 50% of the rise in global mean surface temperature since 1980 (Ekwurzel et al., 2017), supply constraints offer the opportunity to target the main beneficiaries of fossil fuel revenues and more specifically to allocate responsibility for carbon emissions (Collier and Venables, 2014; Green and Denniss, 2018; Harrison, 2015). By reducing investments into future fossil fuel exploration and production, supply constraints should help to prevent longer-term carbon lock-in (i.e. 'persistent market and policy failures that can inhibit the diffusion of carbon-saving technologies despite their apparent environmental and economic advantages' Unruh, 2000: 817; Seto, 2016) through continued investment into capital-intensive fossil fuel projects, and to pre-empt the 'green paradox' of having producers rush to develop reserves before more stringent climate mitigation efforts shrink fossil fuel markets (Bauer et al., 2018; Sinn, 2012).

Supply constraint approaches to climate change mitigation are gaining ground and were included in the Talanoa Dialogues at COP 23; yet, they remain marginal within mainstream organizations and international climate change processes (Lahn, 2017: Lazarus et al., 2015). This marginality results from several challenges.

First, fossil fuel reserves are widely considered as sovereign assets under the control of national governments, even if in practice sovereign control over resources is largely reworked through contractual agreements and market mechanisms involving private and foreign entities. Second, the current international political economy paradigm considers market mechanisms as the most efficient, and though open to tax-based policies, it generally remains averse to 'hard' forms of market constraints such as production quotas and fixed prices. Third, supply leakages are to be expected between producers (Fæhn et al., 2017). Constraining supply from some countries increases economic incentives for others to increase exploration and production, as demonstrated to some extent by OPEC's history of attempts to control prices (Colgan, 2014).[1] Fourth, the fossil fuel industry – and especially the oil and gas sectors – remain powerful lobbyists for their own interests, while fossil fuel-producing governments are often insulated from both domestic and international pressure through major fossil fuel revenues (Princen et al., 2015; Ross, 2012). Fifth, within current international carbon accounting standards, curtailing supplies does not count as a full contribution to mitigation, since emissions are territorially accounted for at the location of consumption rather than production (Harrison, 2015). Sixth, supply revenues often constitute a major part of the economy and government revenues; supply cuts may thus translate into major disruptions and financial losses, especially if the economy has not transitioned away from fossil fuels and if cuts are not compensated for in producing countries. More generally, constraining production only works if demand is accordingly constrained, as the relatively low price elasticity of oil means that prices will increase. Since fossil fuel-exporting countries are generally most interested in revenues, those not affected by cuts will benefit from price increases, while those experiencing cuts may seek to compensate volume losses through price increases.[2]

These challenges do not foreclose a supply-side approach to climate change mitigation, but they do point to the challenges of a supply-driven transition and to the importance of

combining a 'just' approach to cuts with a geopolitical economy analysis of the diverse interests and incentives associated with fossil fuels.

Prioritizing just cuts

In an ideal world, all fossil fuel producers would urgently agree on a set of supply cuts criteria and begin implementation. A basic approach, for example, would be to determine a 'burnable fossil fuel allowance' for fossil fuel-producing companies and countries based on the current status quo. Yet, even this basic and questionable approach would raise the issue of deciding whether such allowance should be based on reserve or production levels (Rekker et al., 2018). The use of a reserve criteria would advantage state-owned entities and countries with the largest reserves, most of which are controlled by non-democratic governments, and likely lead to reserve inflation – as seen among many OPEC members. A production criteria would advantage investor-owned companies often publicly listed in Western democracies and countries having recently boosted unconventional production, such as the USA. More generally, few producers are likely to voluntarily curtail production without at least the hope of revenue compensation. Furthermore, even the most socially and environmentally 'progressive' countries may baulk at the idea of seeing their curtailed production leaking into producers with carbon-heavy fuel deposits, a dismal environmental record and poor governance.

Given the unlikeliness of a global consensus among all producers, one can turn to a discussion of prioritization criteria for considering which producers should first see cuts. Here, we articulate theories of justice with supply cuts criteria, and illustrate some geopolitical economic implications in terms of countries or reserves to be prioritized for a 'just' transition away from fossil fuels (see Table 1).

The first category of supply cuts criteria directly relates to the amounts and characteristics of fossil fuels, in terms of their relative *volume*, *greenhouse gas emission intensity*, and *cost of production* (Collier and Venables, 2014; McGlade and Ekins, 2015). In short, the countries producing the most fossil fuels, the most carbon-intensive fuels and/or the costliest fossil fuels should be the first to implement cuts.[3] These criteria rely on an *utilitarian* conception of justice whereby the reductions in emissions and economic benefits of a 'just' transition are maximized for all stakeholders. In their landmark paper on unburnable fossil fuels, McGlade and Ekins (2015: 187) conclude that 'globally, a third of oil reserves, half of gas reserves and over 80 per cent of current coal reserves should remain unused from 2010 to 2050 in order to meet the target of 2°C'. Accounting for the carbon intensity and production costs of reserves, McGlade and Ekins (2015) present a geographical distribution of unburnable reserves.[4] Within the oil sector, three main types of reserves should be prioritized for (future) cuts: Arctic oil deposits, deep-water oil reserves and unconventional oil resources. The regions, or countries, with the largest unburnable oil reserves would be the Middle East, followed by Canada and Central and South America, especially Venezuela. The average global percentage reduction for all three types of fossil fuels is 58% of total reserves, with the Middle East being the most severely affected in terms of foregone fossil fuel rents.

The second set of prioritization criteria relates to the economic context of producing countries, in terms of the *affordability* of production cuts and *developmental efficiency* of fossil fuel rents. The affordability criterion prioritizes cuts in wealthy countries with a low dependence on fossil fuel rents over poor countries with a high dependence. In contrast, the *developmental efficiency* criterion based on the resource curse paradigm prioritizes cuts in countries that mismanage their fossil fuel rents, notably as a result of corruption, ineffective

Table 1. Concepts of justice, supply cuts criteria and resulting prioritization.

Concepts of justice	Supply cuts criteria	Prioritization
Utilitarian	Greenhouse gas amount	Countries with the largest fossil fuel production (e.g. coal: China; oil: Saudi Arabia; gas: USA)
	Greenhouse gas emission intensity	Countries, or reserves, with the most greenhouse gas-heavy life cycle (e.g. coal: Germany's lignite mines; oil: Canada tar sands; gas: US shale gas)
	Production costs	Countries, or reserves, with the highest production costs (e.g. coal: Poland; oil: UK; gas: Canada)
Distributive	Affordability	Countries with high income and low fossil fuel revenue dependence (e.g. coal: USA; oil: Canada; gas: the Netherlands)
	Developmental efficiency	Countries with the poorest development record from fossil fuel wealth (e.g. coal: India; oil: Angola; gas: Venezuela)
Restorative	Past production	Countries with the largest historical cumulative per capita production (e.g. coal: Germany; oil: USA; gas: Qatar)
Rehabilitative	Willingness	Countries with the strongest public support and governmental willingness for cuts in (future) production (e.g. coal: Germany; oil: New Zealand; gas: the Netherlands).

Note: country examples for illustrative purposes only.

rent capture and wasteful allocation. Whereas the affordability criterion relies on a *distributive* concept of justice allocating to poorer countries the remaining rents within a 2°C 'carbon budget', the developmental criterion rests on a *retributive* concept of justice, seeking to prevent the future effects of poorly managed rents, based on previous performance. The developmental efficiency approach is in part based on path-dependence theory, asserting that past underperformance is likely to shape future performance. As such, a more radical interpretation of the 'resource curse' would suggest that some countries may be better off without fossil fuel revenues: even if cuts seem unaffordable, cutting fossil fuel production would be developmentally more efficient than remaining dependent on it.

The third criterion derives from *past production* and is associated with a *restorative* or reparative concept of justice, through which the proportion of past supply, either in absolute (e.g. percentage of global historical production per capita) or relative terms (i.e. percentage of total domestic reserves already produced per capita), prioritizes cuts among countries and determines compensation for previous harm, with, for example, compensation funding climate adaptation or fossil fuel cuts by other producers. Old major producers would thus be prioritized.

The fourth criterion relates to the *willingness* of fossil fuel producers to implement cuts. This criterion is based on a *rehabilitative* concept of justice, whereby governments (and citizens) recognize the harm associated with fossil fuels and commit to cuts, including in pre-emptive ways if they have not yet been producers. Political mobilization to act on climate change depends in large part on public support, at least in democracies. Policy shifts are thus more likely when more people are concerned with climate and environmental issues (Tvinnereim et al., 2017).[5] Citizens and governments are more inclined to see cuts occurring if they are strongly in favour of climate change action, and even more so if they will bear little or no costs from these cuts. Such contexts, however, are generally characteristic of

countries with little or no production. France, for example, banned further exploration and all production after 2040, but it is a negligible producer. Finding ways to increase willingness among significant fossil fuel producers is thus particularly important. These can include building awareness on climate change impacts, providing financial incentives to forego future fossil fuel production, demonstrating the value of economic diversification, as well as promoting viable economic alternatives and futures beyond fossil fuel dependence (Dale and Kristoffersen, 2018). In this respect, both Canada and Norway struggle with their 'cognitive dissonance' between their climate-friendly image and maintaining high levels of fossil fuel exports (Steentjes et al., 2017: 10). A comparative study including Canada and Norway shows that support for climate action also depends on expectations of reciprocity by other countries (Tvinnereim et al., 2017). Forming a coalition of 'first movers' thus seems a necessity for 'willingness' to happen.

Operationalizing just cuts

There are two main types of supply constraint instruments – financial and material – with some degree of overlap between them. Financial instruments seek to reduce supply by removing production subsidies, incorporating 'externalities' into the full cost of production, taxing production, reducing investments in production and compensating for revenue losses. Material instruments seek to reduce supply by creating legal or physical obstacles to production, transportation and transformation, and can include project-specific blockades and various forms of moratoriums, including voluntary cuts and export embargoes.

Subsidy removal

Subsidies play a major role in the political economy of fossil fuels, notably by reducing costs for producers and consumers (IEA, 2015). Broadly defined, fossil fuel subsidies would amount to an estimated $5.13 trillion in 2015, of which 81% results from the unaccounted costs of air pollution, climate change impacts and broader vehicle externalities (Coady et al., 2017). Global direct subsidies for *production* would amount to $50–100 billion and *consumption* subsidies at about $500 billion (GSI, n.d.; see also Bast et al., 2014). Production subsidies can play a significant role in the viability of individual fossil fuel projects, notably through support for non-conventional fossil fuels, foreign direct investment credit and insurances, as well as covering exploration and development expenses (Adeyeye et al., 2009).

Full accounting of externalities and emission-related production tax

First implemented in Finland in 1990, carbon taxes have generally been devised to constrain demand, with hydrocarbon production being often sheltered from carbon taxes through exemptions. Oil production in Norway and the Canadian province of Alberta are among the best-documented attempts to better account for fossil fuel externalities at the production stage. Norway first introduced a carbon tax in 1991, and doubled the applicable rate for the oil and gas industry to $72/tonne in 2012 – the highest among all of Norway's economic sectors. The Norwegian government also frequently imposes low-carbon options to field development – such as through on-shore hydroelectric supply – even if these options are pricier. Despite mature oil fields normally emitting more, Norway's per unit emission is about half the world average (Woodmac, 2017). In Alberta, a carbon tax was first imposed in 2007, and was increased to $20/tonne in 2012 and $30/tonne in 2018 (Alta. Reg. 139/2007). Although the effect of carbon pricing is generally considered to be minor compared to the impact of oil prices on levels of new production development, a recent

modelling of a production tax jointly levied by the main steam coal exporters suggests that it would significantly reduce steam coal emissions while being revenue-positive for the sector as a whole (Richter et al., 2018).

Finance swap

Finance swaps are based on the principle of monetary compensation for leaving fossil fuel underground.[6] This principle is itself based on the sovereign right of individual states to develop their resources, and the opportunity cost associated with renouncing this right (Armstrong, 2017). This 'right to exploit resources' is further legitimated by the idea of a 'right to development' (Grigorescu and Komp, 2017), which is all the more valid for poor countries having demonstrated an ability to turn fossil fuel rents into positive developmental outcomes for their population. By 2018, only one fossil fuel–finance swap had been attempted. Launched in 2007 by Ecuadorian president Rafael Correa, the Yasuní–ITT Initiative sought to obtain financial compensation for not exploiting the oil reserves of the Ishpingo–Tambococha–Tiputini (ITT) block, estimated at 846 million barrels and located within the Yasuní National Park in the Amazon (Vallejo et al., 2015). Rather than demonstrating the viability of swap schemes, the initiative served as a warning about the multiple and daunting challenges faced by supply-side efforts (Sovacool and Scarpaci, 2016). Key among these is the question of who is to compensate for fossil fuels left in the ground. This in turn implies an internationally agreed funding mechanism, including a redistribution of the rents potentially arising from price increases that would likely result from supply cuts in the absence of demand reduction (see Collier and Venables, 2014).

Divestment

Fossil fuel divestment campaigns first emerged in the early 1990s to further persuade insurance companies and financial institutions that investment in fossil fuels has negative knock-on effects on debts and equities through increased climate change-related risks (Leggett, 1996). The divestment movement has used a wide range of campaign strategies – including direct action, lobbying, knowledge construction and facilitation – to motivate investors to relinquish fossil fuel stock holdings (Ayling and Gunningham, 2017). Initially based on moral arguments mobilizing climate change science, the divestment movement found additional support as concerns over 'stranded assets' grew in the early 2010s and the commodity bust of the mid-2010s drove down fossil fuel company stocks (Le Billon and Good, 2016).[7] According to the main divestment coalition, 350.org, the number and market value of institutions committing to or having divested from fossil fuels grew from about 42 institutions valued at $50 billion in early 2013 to about 990 institutions valued at $7.2 trillion by October 2018. This rapid growth lends credence to the rise of an anti-fossil fuel norm among mostly ethically concerned financial institutions and international banks in Western countries, especially turning away from coal projects (Green, 2017). Although promising, norm diffusion towards a broader range of financial institutions and countries, as well as effective influence over fossil fuel state companies, remain to be seen. Many fossil fuel producers, especially those organized through large state-owned companies like national oil companies in the Middle East, are relatively insulated from external financial leverage, including from Western investment funds that constitute the vast majority of divesting organizations.

Tradeable production quota

Tradeable production quotas (TPQs) are based on principles of output rationing, efficiency and, to some extent, equity. TPQs are common in the agricultural and fisheries sectors (e.g. tradeable catch quota), and have also been used for environmental objectives (OECD, 2000), including tradeable energy quotas (TEQs) seeking to address both carbon emission concerns and oil scarcity concerns through the sharing out of access to fossil fuel energy among individuals and organizations (Fleming and Chamberlain, 2011). TPQs entice more expensive production to be traded over cheaper production, thus in effect preventing the growth of high-cost production opening up new (and often more carbon-intensive) reserves – which typically occurs during periods of high prices, and as expected if supply constraints occur in the absence of demand reduction. Unlike the OPEC production quota system based on official (mis)reported reserves, TPQs based on a 'right to produce' that reflect dimensions such as the carbon intensity of production, the income level and degree of fossil fuel dependence, as well as other considerations such as social development progress or decarbonization of the economy (Collier, 2015). Overall, TPQs offer a promising supply constraint option, but several major hurdles need to be overcome: agreement on overall production, quasi-universal participation, a fair system of quota trading, a potential queue system for new projects, and revenue allocation consistent with the overall objective of reducing emissions so that revenues are not reinvested in carbon-intensive projects and lifestyles.

Blocking extraction

Blockades are a form of direct action to prevent concrete 'on the ground' fossil fuel activities from taking place at any point of the supply chain. Frequently combined with other kinds of protests (such as rallies, strikes and boycotts), and often preceded or backed by online petitions (see McNeill and Thornton, 2017), blockades are used to prevent access to an area or to stop a physical operation from happening (Bradshaw, 2015). Both tactical and strategic approaches are used, taking into consideration the relative vulnerability, accessibility, significance and public visibility of specific infrastructure, equipment and places. Blockades are not only used as a 'last stand' in protracted campaigns, but also as preventative measures to signal the determination of local communities and their allies, as well as communication and mobilization tools drawing attention to specific projects or entire industries. As such, blockades are increasingly recognized as an effective tool for civil society groups and professionalized NGOs. Beyond 'blocking' fossil fuel projects, these forms of direct action can also (re)take control of fossil fuel spaces to give them an alternative non-extractive purpose, thereby 'opening' new spatialities for alternative energy futures as part of space-making processes (see Temper and Bliss, 2015). By early 2018, the Blockadia team at the Environmental Justice Atlas had documented 69 cases of sustained resistance and direct action against fossil fuel projects, part of a broader range of climate justice and socio-environmental energy struggles that rose from an estimated 50 in the late 1990s to about 350 by 2015 (Temper et al., 2015).[8] High-profile direct actions have targeted oil rigs in the Arctic and tar sands infrastructure in Canada (Le Billon and Vandecasteyen, 2013; McCreary and Milligan, 2014). Many producing countries and projects are largely immune to effective blockading campaigns as a result of repression against anti-fossil fuel groups, sophisticated corporate and governmental counterinsurgency against activist groups and communities, domestic redistributive policies funded through fossil fuel revenues and the relative insulation of their ruling

elites from public pressure (Brock and Dunlap, 2018; Le Billon and Carter, 2012). In this respect, blockades – and more generally supply-cut policies – may have more traction when associated with broader societal concerns about additional socio-environmental impacts, but also human rights abuses, corruption, inequalities or authoritarian rule associated with fossil fuels.

Production bans and moratoriums

Bans and moratoriums, understood as a permanent or temporary prohibition of on-going or future production, can have powerful effects when instituted by governments (Erickson et al., 2019; Princen et al., 2015). So far moratoriums tend to be project-, area- or time-specific, with place-based moratoriums often motivated by other considerations than carbon emissions, including the impacts of oil spills on biodiversity conservation, fisheries or tourism (Dale and Kristoffersen, 2018; Palen et al., 2014; Shavell, 2011). As such, they run the risk of increasing carbon leakages – as investments are redirected towards areas and projects not affected by moratoriums – and of overlooking the cumulative impacts of infrastructure development as companies seek alternative production projects (Palen et al., 2014). Moratoriums are also often imposed through discrete political decisions, rather than institutional or legal processes, thus increasing the risk of decision reversals, as seen in the USA between the Obama and Trump administrations (Erickson and Lazarus, 2018).[9] Overall, there is yet no emerging norm that could lead to a global moratorium on fossil fuel projects, even for new coal mines (Blondeel and Van de Graaf, 2018). As a result, moratoriums often result from a mix of climate and local impact concerns, mostly related to water pollution and oil spills, as seen in New Zealand. A first attempt at identifying all moratoriums and bans from press reports yielded a total of 108 cases, 101 dealing with the interdiction of shale gas projects by sub-national authorities and three national-level bans on fossil fuels, including by Costa Rica, Belize and France, with Ireland possibly joining this group.[10] None of these countries, however, are significant producers.

Pathways to just cuts

Just cuts can be justified through principles of justice, prioritized according to the characteristics of fossil fuel producers, and operationalized through various instruments. Based on the distributive justice principle of affordability, countries that can economically cope with the shutting down of their fossil fuel sectors and have the capacity to carry out an effective and fair transition for fossil fuel industry workers and energy consumers should be the first to implement supply cuts (Muttit and Kartha, 2018). This could notably include high-income countries with low fossil fuel rent dependence, diversified economies, capable governments and relatively few fossil fuel industry workers. Next could be middle- and high-income countries that are dependent on fossil fuel revenues or domestic energy input, and face difficulties to manage a transition. Last could be low-income countries that remain much in need of fossil fuel export revenues and have a very low ability to manage a transition, yet are still efficiently managing these revenues for developmental purposes. Compensation for supply cuts and international assistance mechanisms for effecting the transition should, in turn, reflect affordability and capacity criteria, with poorer and less capable countries receiving greater compensation and more assistance (Muttit and Kartha, 2018).

Yet, the question remains about the feasibility of *effectively* implementing cuts. Two main dimensions need to be taken into account: the first one is the relative effectiveness of the

various instruments proposed; the second is the relative likeliness of political processes that would result in the application of these instruments. However, no systematic assessment of supply constraint instruments has yet been conducted, and only a few studies provide either theoretical models or retrospective assessments of decision-making processes leading to supply cuts motivated by climate change concerns. Within these limitations, we discuss here some potential pathways towards supply cuts for each of the main fossil fuel sectors.

Coal

The coal sector is the most likely candidate for supply cuts. Not only has this fossil fuel been the longest in use – with coal cuts thus responding to restorative justice principles – but its higher carbon emission intensity compared to oil and gas also supports some aspects of utilitarian justice. Coal production is also highly concentrated and generates relatively low rents, which supports some distributive justice arguments (IEA, 2017; Lange et al., 2018).[11] The top 10 coal-producing countries account for 95% of global production, and three of them – China, the USA and Germany – have highly diversified and wealthy economies that could financially withstand a domestic production ban (see Table 2). Finally, there is generally stronger willingness among the public and governments to cut coal, as seen with the 'Powering Past Coal Alliance' pledging to phase out coal power, thereby supporting rehabilitative justice (UNFCCC, 2017). The phasing out of coal power plants is already well underway in the European Union, and China imposed restrictions on new plants in 2016 to reduce overcapacity and address emission concerns. In India, private capital is being redirected from coal to more profitable renewables, while the National Electricity Plan calls for more renewables. Supply constraints keeping coal prices up and above renewables could consolidate and even accelerate the transition away from coal.

Serious impediments to broad cuts remain, however. Coal's low production costs give it prominence on energy affordability criteria and it remains necessary in many countries to run power plants and thus many economic activities. Beyond existing plants, nearly one million megawatts in coal power was under construction or on hold, and nearly half a

Table 2. Major coal producers (2016).

Countries	Coal production (Mt)	Coal rent (% GDP)	Coal workers	Supply cut policies by government
China	3410	0.3	5,300,000	2016–2019, efficiency-driven
India	693	0.8	314,000	None
USA	661	0.1	100,000	2016, reversed, environment-driven
Australia	503	0.5	35,000	None
Indonesia	456	0.5	120,000	2016 announced but not implemented, environment- and economy-driven
Russian Federation	386	0.3	150,000	None
South Africa	251	1.6	81,000	None
Germany	176	0.01	40,000	2018 closure of hard coal mines, lignite mines under negotiation
Poland	131	0.2	82,000	None
Kazakhstan	103	0.6	180,000	None

Sources: BP, 2018; Lange et al., 2018; employment from industry sources for nearest year.

million megawatts was still being planned worldwide by early 2018 (Shearer et al., 2018). Coal also benefits from an iconic 'blue collar' image and offers significant employment in coal mining-dependent regions with limited prospect for diversification, thereby often benefiting from a higher level of public support than oil and gas. Even though coal mining in the USA directly employed only about 0.05% of the overall national workforce, US president Donald Trump actively played that card during his 2016 electoral campaign. Echoing the 2008 Republican slogan 'Drill, baby, drill', Trump seized upon the motto 'Trump digs coal' to advance a brash agenda of fossil-fuelled national revival towards 'greatness'. Reflecting popular sympathy for coal miners and concerns over energy dependence towards Russia, the Polish government is seeking to increase investment in new coal mines and projects to still have coal as 50% of its energy mix by 2050, despite unfavourable market conditions and possible EU fines (Mikulska and Kosinski, 2018).

Potential pathways to coal supply cuts could include: a mix of economic incentives resulting in the closure or abandonment of inefficient/subsidized coal mines, as recently seen in China (Blondeel and Van de Graaf, 2018); joint supply-side policies sustaining revenues through increased prices rather than increased volumes (Mendelevitch et al., 2017); and the morally motivated adoption of production moratoriums backed by domestic and international political mobilization (Green, 2018), including through the blockade of specific projects. Examining the case of the international steam coal market, Mendelevitch (2018) finds that reforms in production subsidies within major producing countries would only have a minor positive impact on emissions reduction, while a global moratorium on new coal mines would enable the achievement of 1.5–2°C reduction targets for this specific market. A global moratorium, however, would most likely require a compensation mechanism, at least for low-income countries, as discussed by Collier and Venables (2014), who propose that wealthier carbon producers compensate poorer ones.

Germany and the USA are the best placed to cut coal supplies, given their lower economic reliance on coal. Germany's federal government was set to close the last two hard coal mines by the end of 2018 and has established a 'coal exit commission' to find economic alternatives for lignite mining regions (Wehrmann, 2018). In contrast, the Trump administration undid most of the constraints placed on coal mining by the Obama administration and is seeking to revive the industry through easier licensing and lower standards for coal power plants (Popovich et al., 2018). China did impose a stricter moratorium on coal power plants in 2016, but as the world largest coal producer and consumer it is very unlikely to declare a major domestic production ban until it has implemented a sufficient transition in power generation to gas and renewables. As Blondeel and Van de Graaf (2018) conclude from a survey of the top five coal producers, coal mining moratoriums have been so far adopted for different reasons, limited in time and occasionally reversed. Despite unfavourable market conditions in recent years and more widespread public support for phasing out coal compared to other fossil fuels, there remain doubts about the possibility of a strong global norm promoting the end of coal production.

Oil

Oil is the second most likely candidate for supply cuts, as it tends to have higher production costs than coal and emits more carbon than natural gas, thus relating to some aspects of utilitarian justice. Oil production is also relatively concentrated, with the three largest producers accounting for about one-third of supplies. Many significant producers – with the exception of the USA and China – are also net exporters, thus reducing domestic energy security concerns. Yet, oil remains hard to replace within the current oil-fuelled

transportation system and its large production rents make it difficult for both consumers and producers to give up (Bridge and Le Billon, 2017). Unlike coal, oil rents represent more than 5% of GDP in many producing countries, most notably in the Middle East and North Africa, where it reaches an average of 15% of GDP, with up to 44% in Kuwait (Table 3). Supply cuts in such oil-dependent countries would entail a major shock, thus posing dilemmas in terms of distributive justice. In part because of the volatility of oil revenues and other 'oil curse' effects, many 'oil rich' countries are seeking to diversify their economies, although the political implications of such a shift is often seen by domestic ruling elites as a possible threat to their oil-fuelled regime (Le Billon, 2013; Ross, 2012). There is thus a possibility that governments in oil-producing countries may adopt some measures to curb their dependence through oil cuts, but these would be progressive and likely marginal in the medium term. While Saudi Arabia and Russia mutually agreed to curb production in 2017 and 2018 to increase prices, they rapidly advocated for production increases once the target of $80 per barrel was within reach and US sanctions against Iran were to be reinstated by the Trump administration (Wingfield et al., 2018).

The most likely pathways towards oil supply cuts combine market incentives in the face of depressed demand (e.g. accelerated by a progressive electrification of the transportation system), public pressure brought on by climate and other concerns (e.g. spills, air quality, traffic congestion), and a paradigm shift among government authorities to eschew an extractivist model of development in favour of alternative ones (e.g. by redirecting public subsidies from oil to renewables or non-oil transportation). While the first option had a long history associated with attempts to prop-up prices through quota systems, the second seems only viable in a very limited number of countries.

As Green (2018: 450) points out, 'understanding the interactions between states' social identities (affected by logics of appropriateness) and their incentives (the combination of social and economic costs and benefits) is crucial to explaining and predicting the diffusion of fossil fuel bans'. Yet, even Canada and Norway, two self-portrayed champions of climate change mitigation with some degree of public pressure for a decarbonization of the energy production mix, have not taken steps to reduce the prospects of oil production growth.

Table 3. Major oil producers (2016).

Countries	Oil production (Mbbl/d)	Oil rent (% GDP)	Supply cut policies by governments
Saudi Arabia	12.4	26.4	Supply cuts (2017–2018), economy-driven
USA	12.4	0.1	Moratoriums, reversed
Russian Federation	11.3	7.0	Subsidy removal and supply cuts (2017–2018), economy-driven
Iraq	4.4	42.4	None
Iran	4.6	13.6	None
China	4.0	0.3	None
Canada	4.5	0.3	Carbon tax hike, economy- and environment-driven
United Arab Emirates	4.0	14.5	None
Kuwait	3.1	44.0	None
Brazil	2.6	1.0	None

Sources: BP, 2018; Lange et al., 2018.

Instead, both have pursued a strategy of reducing consumption-based emissions to sustain or increase production-based emissions. Among large oil producers, such as Saudi Arabia, Russia and the USA, current governments are openly pro-oil and either battle for market-share or collude to sustain demand-inducing prices. Supply cuts are thus more likely to come from within the public, or governments that have little to lose or have concerns for other environmental aspects such as marine oil spills. Following the price slumps of 2014–2016, the oil sector did see some oil cuts, but these were largely financially motivated, and while some blockades against oil supply infrastructure are occurring, there seems to be little appetite in significant producer countries – among both the public and governments – to implement climate-related supply cuts.

Gas

Gas should be the least likely candidate for supply cuts. Its emissions are lower than the other two fossil fuels, and it is thus often presented as a 'transition fuel' helping to displace coal – notably by international oil companies that broadened their natural gas portfolio (but see Greiner et al., 2018) (Table 4). Like coal, natural gas also tends to generate lower levels of rents for producers than oil, even if more countries are gas revenue-dependent than coal-producing ones. Not all gas deposits are equal, however, and the growth in natural gas experienced over the past decade reflects in part the boom in hydraulic fracturing or 'fracking' techniques, which have more environmental impacts than conventional deposits and techniques (Howarth et al., 2011). Gas is thus seeing the largest number of blockades and bans among fossil fuels, thereby showing some support for rehabilitative justice. The structure of the natural gas market also influences the potential for supply cuts. It is traditionally more diffuse and regionalized than other fossil fuels, and backed by long-term bilateral sales contracts, but the spread of liquefied natural gas (LNG) and more malleable contractual terms have increased flexibility in the natural gas trade and contributed to making it more of a 'global market' (Bridge and Bradshaw, 2017).

Table 4. Major gas producers (2016).

Countries	Gas production (Bcf/day)	Gas rents (% GDP)	Supply cut policies by government
USA	70.4	0.1	Bans at state and municipal levels
Russian Federation	56.9	2.7	Moratorium on offshore Arctic licences, economy-driven
Iran	19.6	2.0	None
Qatar	17.1	4.8	None
Canada	16.6	0.1	Bans at provincial level, carbon tax, environment-driven
China	13.3	0.1	None
Norway	11.2	1.9	Carbon tax
Saudi Arabia	10.2	0.7	None
Australia	9.3	0.2	Bans at state level, environment-driven
Algeria	8.8	2.5	None

Sources: BP, 2018; Lange et al., 2018.

The most plausible pathway towards gas supply cuts at this point is a more global rejection of gas fracking. By mid-2018, such bans were in place within 19 countries at national level (although there were none in a top ten producing country), and 18 provincial/state jurisdictions, including within Australia, Canada and the USA. The uneven distribution of fracking bans in the USA, including at the municipality level, has highlighted some of the socioeconomic and micro-level politics factors that influence this, with notably higher education levels, poverty rates and percentage of Democrats increasing the likelihood of a fracking ban, while larger presence of veterans and existing wells reduces it (Hall et al., 2018). Similarly, the contrasting responses of different European countries point at the importance of political factors, with public concern being a sufficient condition for restrictions, while others like democratic tradition and energy security do not seem to matter (Van de Graaf et al., 2018). Public concerns for the local health and environmental impacts of shale gas deposits, rather than greenhouse gas emissions alone, thus appear to provide the best platform for gas supply cuts.

Conclusion

This paper has provided an overview of the geopolitical economy of fossil fuel supply-side constraints, with a discussion of justice principles, constraint criteria, supply-side instruments, and possible pathways to supply cuts. Here, we conclude by drawing major points about supply-side approaches.

First, very few fossil fuel producers are willing to cut their production for the purpose of reducing emissions, while instruments that respond to this unwillingness – such as blockades – have so far been largely ineffective at a systemic level, or inapplicable given the repressive context and revenue dependence prevailing in many fossil fuel-producing countries. Of all top 10 major producers across all three fossil fuel sectors, only Germany has taken steps at the national level to durably end production because of primarily climate concerns. All other initiatives taken by significant producer governments were largely economically driven, short-term or promptly reversed.

Second, the current unwillingness of fossil fuel producers requires that potential instruments be more policy refined so as to better identify their potentials, limits and impacts. It is important to distinguish fossil fuel-producing companies from the governments and diverse social groups of fossil fuel-producing countries, so as to better grasp and address their interests and incentives. This is challenging, however, given the tight links between companies and many ruling elites, the lobbying influence of actors linked to fossil fuel interests (including shareholders, managers and workers), the hold that 'petro-culture' has on many societies (including through cars and air travel) and the role of companies and governments in sustaining fossil fuel-based 'energy security'.

Third, supply-side initiatives must work in concert with demand-side policies, so as to bring out synergies and avoid counterproductive impacts. Many supply-side initiatives also need to connect with initiatives seeking to cut fossil fuel production for other motives than simply climate change. As such, not only do 'local spaces' of supply constraints need to be created, for example through blockades, but the 'non-carbon' values of places need to be (re) asserted, for example through indigenous values and territorialities.

Fourth, policy coalitions are required, especially among producers, as individual initiatives often have no significant impact due to production leakages between countries and companies. Effectiveness will come through the mobilization of geopolitical economic coalitions internalizing new norms of non-production. As such, energy transition through supply constraints will not only create new geopolitical economic spaces as energy transition

and emissions mitigation reshape the geography of fossil fuel production, but also reflect pre-existing networks of like-minded societies and organizations willing to take steps towards reducing fossil fuel production.

Fifth, energy transition through supply constraints offers possibilities for a 'negotiated' or 'managed' reshaping of energy spaces. Rather than facing only market-driven pressure associated with demand-side initiatives, supply constraint initiatives can offer more directed and intentional options for fossil fuel producers. As such, supply constraints offer a geopolitical economic space of purposeful *political* intervention that can help producers manage the economic (and political) fallouts of a transition away from fossil fuels. Again, this means that new spaces of political interactions are brought into being around supply constraint initiatives, such as blockading networks or coalitions of governments adopting moratoriums, while political processes around these initiatives are themselves shaped by existing socio-spatial forms such as territorial jurisdictions.

Finally, our brief evaluation of the supply-side 'toolkit' identified some of the opportunities and challenges of specific instruments that could help with the reshaping of energy spaces. Implementing these instruments involves discursive and material space-making processes that reflect both place-based politics and global geopolitical reconfigurations. Situating these processes within a broad range of micro-political practices and global discourses mobilizing a 'just transition' ethos should provide them with greater legitimacy. Yet, as discussed above, not only are energy and climate justice often difficult to reconcile, but different concepts of justice can be mobilized to shift between different prioritization criteria (Jenkins et al., 2016). Climate-driven energy transition thus constitutes a deeply geopolitical economic project, arguably more so than a market-driven demand-side approach. This further justifies the combining of demand- and supply-side approaches, and the use of diverse policy criteria for more effective mitigation of greenhouse gas emissions (Green and Denniss, 2018).

Further research is needed to better understand the various climate policy instruments and their geopolitical economies. To this end, we suggest three main complementary directions for further research. One is to build a comprehensive dataset of supply constraint initiatives and to track their outcomes. Such a dataset could use the categories identified in this paper, and include variables such as country; initiative promoters; start, end and duration; type, volume and production stage of fossil fuels targeted; outcomes; and motives for cancellation. The second is to more systematically document the characteristics of fossil fuel producers to better identify arguments for, and potential pathways towards supply cuts. The third is to delve deeper into specific cases to better understand the intricacies of power relations that have so far prevented more effective supply cuts, even in the presence of sound arguments and plausible pathways.

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Notes

1. Despite supposedly controlling 80% of oil reserves, OPEC still had relatively limited control over prices, as non-conforming and new producers could overcompensate for OPEC supply reductions. The organization has historically mostly been able to lower prices through extra supplies, rather than increasing prices through supply constraints, unless working in concert with other producers such as Russia (i.e. so-called 'OPEC+').
2. If both prices and volume decline, a producer may partially cushion some impacts on the domestic economy through a depressed exchange rate (e.g. Russia's rouble 60% fall in the wake of the 2014 oil price collapse).
3. There can be a trade-off between these two criteria. Some of the most carbon-intensive fuels are also among the cheapest to produce, such as coal, in which case carbon intensity should take precedence. In other cases, such as bitumen, both carbon intensity and production costs are high, thereby doubly justifying cuts.
4. The oil industry responded to the post-2014 price collapse and concerns about 'lower for longer' oil prices by greater efficiency and cost reductions, with the break-even price for deep-water offshore and for unconventional oil and gas in the USA going down. Some regions, such as the Arctic, still have high production costs and reputational risks as core concerns, but overall more oil and gas are being produced at lower prices, adding to low-cost Middle East reserves. On the impact of lower oil prices on production costs, see Toews and Naumov (2015).
5. The willingness criterion generally reflects the position of, and relations between, populations and governments, but also genuine concerns over negative socioeconomic impacts. The Dutch government, for example, reduced production from the Groningen gas field and committed to end production by 2030 out of concerns about gas extraction resulting in damaging earthquakes (van den Berg, 2018).
6. For formal modelling applied to coal, see Harstad (2012). For a critique of the concept of compensation of future generations through progress enabled via fossil fuel use, see Spash (1994).
7. More generally, divested portfolios do not significantly underperform compared to unconstrained ones; if divestment narrows opportunities for short-term gains, investment in fossil fuel increases exposure to systemic risks (Trinks et al., 2017). Yet, the rise of divestment may generate a premium for fossil fuel funding by increasing capital demand, and thus bring higher returns for the remaining investors.
8. See https://ejatlas.org/featured/blockadia.
9. Erickson and Lazarus (2018) estimate that the net effect on global emissions of reducing access to US federal land leases would have been 39 Mt CO_2 for oil and 240 Mt CO_2 for coal.
10. The search was conducted through a review of relevant academic studies and policy reports, as well as Lexis-Nexis and Google, with search terms including: ban, moratorium, oil, gas, fracking, coal. Languages used included English, French and Spanish. We thank Nicolas Gaulin for research assistance in this regard.
11. By 2016, only a few countries remained significantly dependent on coal production in terms of revenues: Mongolia at 4.3% of GDP, Mozambique at 2.2% and South Africa at 1.6% (Lange et al., 2018).

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