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Exporting Coal from the U.S. Pacific Northwest: Potential Impacts of Removing an Energy Transportation Constraint

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EXECUTIVE SUMMARY

This working paper provides a general review of how transportation constraints affect energy markets and then offers a framework for thinking more specifically about the greenhouse gas implications of building new coal ports in the U.S. Pacific Northwest.

Main Argument

The nature and extent of transportation constraints crucially shape energy markets of all kinds. Oil markets are largely integrated worldwide except where rapid changes in supply and demand have outpaced the process of bringing new pipelines online. Natural gas markets remain regionalized, an outcome that stems in part from the capital intensity of LNG and pipeline infrastructure. Coal prices at major trading hubs track each other, but rail constraints exist within many countries. Port constraints can also be an issue, such as in the U.S., where they have helped isolate Powder River Basin (PRB) coal from world markets.

Removing constraints on exports tends to increase the price of an energy commodity in the exporting country and decrease it in importing countries, but the precise effects can be complex. Removing barriers to export of an energy commodity like coal, whose use entails negative environmental externalities, will not necessarily have a net negative environmental impact—for example, if decreased use of the commodity in the exporting country predominates over increased use in importing countries. However, it is important to consider long-term environmental impacts as well as short-term ones.

Policy Implications

- Whether new coal ports are built in the U.S. Pacific Northwest will likely hinge on international coal-market conditions as well as on the cost, delay, and uncertainty added by local stakeholder processes.
- It is unlikely that removing the port constraint on PRB coal exports will substantially increase global emissions of greenhouse gases in the short term, but long-term effects are more uncertain and require a more sophisticated analysis.
- Coal markets face significant uncertainties on both the demand and supply sides. In addition to the relative availability of PRB coal, these include the size of demand from India, whether countries like Japan and Germany continue to use coal as their default baseload energy source, and whether Indonesia can maintain its role as the most significant coal exporter.

In the face of declining coal consumption in the United States—the result, more than anything else, of low natural gas prices—producers are seeking to export coal from the Powder River Basin (PRB) in Montana and Wyoming to Asia. No coal ports currently exist in the U.S. Pacific Northwest, but terminals are being contemplated along the Columbia River (in Boardman, Oregon, and Longview, Washington) and in Cherry Point in northwest Washington. These proposed ports have aroused concern on various grounds: the effects of increased rail traffic on local communities, possible local environmental hazards from coal dust released in transit or from stockpiles, and the implications for global greenhouse gas emissions of burning the coal in Asia. On the other hand, building coal ports in the Pacific Northwest would generate significant tax revenue and both temporary and permanent jobs.

The global environmental implications of eliminating a major barrier to the transportation of an energy commodity can be surprisingly difficult to assess. Coal emits more carbon dioxide (CO_2) per unit energy produced than any other major fuel, so at first glance it would seem obvious that hindering transport of PRB coal to countries with robust demand like China would be a win for climate change mitigation. However, on closer examination it becomes apparent that the net impact of Pacific Northwest coal exports on greenhouse gas emissions depends on a number of factors. These include the nature of the demand for coal and alternatives (both in the United States and in major importing countries like China, India, Japan, Korea, and Germany), whether and how decisions to build new power plants and associated infrastructure might be influenced by the availability of PRB coal resources, and whether it is even feasible to block exports of PRB coal.

This working paper provides a general review of how transportation constraints affect energy markets and then offers a framework for thinking more specifically about the greenhouse gas implications of building new coal ports on the West Coast. It is structured as follows. The first section following this introduction explains how transportation constraints have shaped the respective markets for coal, natural gas, and crude oil. The second section explores how transportation constraints arise and why they sometimes persist. The third section considers the conditions under which an economically valuable resource can be blocked from reaching a source of demand by policy and regulatory barriers. The fourth section identifies the factors determining the effect of PRB exports on global greenhouse gas emissions in the near term, and the fifth section considers harder-to-quantify effects that PRB exports might have on global greenhouse gas emissions over the longer term.

The Role of Transportation Constraints in Shaping Markets

An integrated energy market is one in which there are no significant transportation constraints, so that demand can be served with the lowest-cost supply sources available anywhere (taking into account the cost of transportation). By contrast, wherever transportation infrastructure is insufficient—or too costly—to bring supply from one region to demand in another, a larger market breaks into smaller ones with prices that may not track each other.[1] Key energy transportation links include electricity transmission lines, oil and natural gas pipelines, oil tankers, natural gas liquefaction and regasification plants, liquefied natural gas (LNG) tankers, railroads (critical for coal but also sometimes used for carrying oil), and barges and ocean bulk carriers for coal.

The markets for oil, natural gas, and coal all have distinct characteristics that are shaped by their transportation linkages. By the 1970s, transportation infrastructure for moving crude oil around the world and refining it was well developed.[2] As a result, oil in recent decades has behaved very much like an integrated global market, with price indices at different locations that differ only slightly as a function of crude grade and transportation cost (see **Figure 1**). From the beginning of 2011 through the middle of 2013, however, the surge of production from the Bakken shale in the United States and the oil sands in Canada created a disequilibrium in which more light crude was available in Cushing, Oklahoma—where the West Texas Intermediate (WTI) benchmark is priced—than could be shipped by pipeline to the U.S. Gulf Coast.[3] This shows up in Figure 1 as a delta between the WTI price and the price of Louisiana Light

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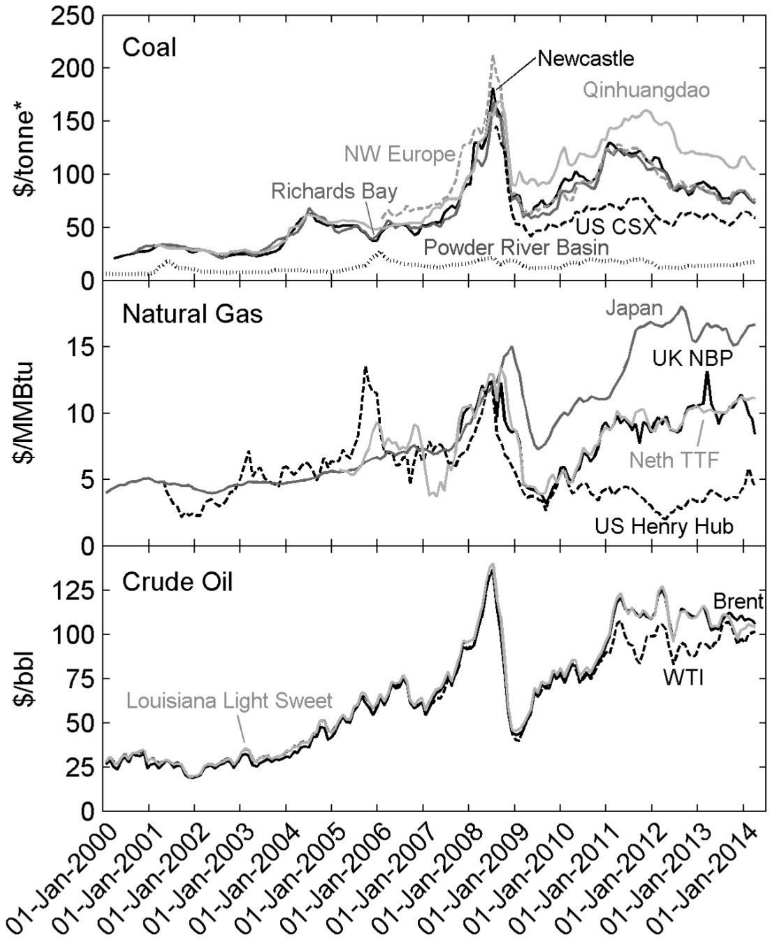
[1] In an intermediate case, capacity constraints on the most cost-effective form of transportation may force a shift to more costly modes (e.g., shipment of oil by rail rather than pipeline), increasing the price differential between regions. Price cointegration analysis is one means of statistically characterizing the degree of integration observed in a market. For a coal-market example, see Alexandar Zaklan, Astrid Cullmann, Anne Neumann, and Christian von Hirschhausen, "The Globalization of Steam Coal Markets and the Role of Logistics: An Empirical Analysis," *Energy Economics* 34 (2012): 104–16.

[2] Neil H. Jacoby, *Multinational Oil: A Study in Industry Dynamics* (New York: Macmillan, 1974).

[3] Crude prices in Alberta, which were even more transport-constrained, showed an even deeper discount to international prices.

Sweet (LLS) crude at the U.S. Gulf Coast. The WTI-LLS differential had narrowed by mid-2013 due to additional pipeline capacity that had come online to carry crude from Cushing to the Gulf Coast. In the second half of 2013, however, a gap opened up between the LLS price and the Brent benchmark in the North Sea, in part because of the ban on U.S. crude oil exports—another important transportation constraint.

Figure 1 *Monthly averaged benchmark prices for coal, natural gas, and crude oil*



* To allow approximate comparison on an energy basis, $/tonne figures for Qinhuangdao, U.S. CSX, and Powder River Basin coal are linearly adjusted by energy content to match the 6,000 kcal/kg standard used for Richards Bay, Newcastle, and Northwest Europe (Amsterdam/Rotterdam/Antwerp, or ARA) price indices.

Source: Bloomberg.

Note: All prices are spot except where otherwise noted. *Coal*: Qinhuangdao (FOB, 5,800 kcal/kg net as received, adjusted here to 6,000 kcal/kg, from IHS McCloskey); Richards Bay (FOB, 6000 kcal/kg net as received, from IHS McCloskey); Newcastle (FOB, 6,000 kcal/kg net as received, from IHS McCloskey); Northwest Europe (delivery into ARA hub, 6,000 kcal/kg net as received, from IHS McCloskey); Power River Basin (at mine mouth, 4,900 kcal/kg, adjusted here to 6,000 kcal/kg); U.S. CSX (one month ahead, FOB onto barges on the Ohio or Big Sandy River, 6,700 kcal/kg, adjusted here to 6,000 kcal/kg). *Natural gas*: Japan (average imports including freight); UK National Balancing Point; Netherlands TTF (one month ahead, ICE-ENDEX); U.S. Henry Hub. *Crude oil*: Brent; West Texas Intermediate (Cushing, Oklahoma); Light Louisiana Sweet

The importance of transportation constraints is illustrated vividly by natural gas markets. Unlike for oil, an integrated global market for natural gas does not yet exist. Infrastructure for natural gas transportation by pipeline or in the form of LNG is extremely capital-intensive and, as a result, has rarely been built in the absence of long-term contracts with customers that guarantee cost recovery over many years.[4] As late as 2008, it appeared that increased global movement of gas in the form of LNG was beginning to create a global gas market, with prices tracking each other ever more closely (see Figure 1). However, the explosion of U.S. shale gas production in the years that followed caused Asian, European, and North American prices to split apart in dramatic fashion. Prices at Henry Hub in Louisiana fell to rock-bottom levels in the face of an oversupply of gas, while Asian prices trended higher and Europe, with its wider array of cost-effective supply options, settled in the middle. (The use of oil-indexed contracts in Europe and Asia also caused prices in these regions to move up with the oil price, unlike Henry Hub prices, which respond more directly to natural gas supply and demand.) Time will tell if planned U.S. LNG export facilities will be able to narrow the price gap with Asia, although a significant transportation differential will persist due to the high cost of LNG, at least until Asia develops its own shale gas.

Transportation infrastructure is just as pivotal to coal markets, but the patterns are distinct from those in either oil or gas. Price indices at major international coal ports (Newcastle in Australia, Richards Bay in South Africa, and the Amsterdam/Rotterdam/Antwerp hub in northwest Europe) track each other, but coal at locations that are not international, liquid trading hubs can see significantly different prices due to rail and port costs and constraints (see Figure 1). In China, rail capacity constraints are one reason that the benchmark price of coal at the port of Qinhuangdao has surged above price indices at major international trading hubs. In the United States, the PRB price at mine mouth is largely isolated from, and far below, international market prices. BNSF and Union Pacific are the only real options for moving coal out of the PRB, and rail rates for shipping across the country are high, as reflected in the difference between the PRB mine-mouth price and the U.S. CSX price for thermal coal delivered onto river barges at the

[4] David G. Victor, Amy M. Jaffe, and Mark H. Hayes, eds., *Natural Gas and Geopolitics: From 1970 to 2040* (Cambridge: Cambridge University Press, 2006).

junction of Ohio, Kentucky, and West Virginia.[5] The less rail-intensive option of shipping PRB coal from the U.S. Pacific Northwest to Asia is ruled out at present by the lack of adequate port infrastructure.

Why Transportation Constraints Arise (and Persist)

Price differentials across locations create an economic incentive for developing new energy transportation links, but actually mobilizing investment, obtaining regulatory approval, and building capital-intensive infrastructure can be time-consuming. Transportation constraints arise when the location and quantity of supply and demand shift more quickly than new transportation links can be built. The WTI-LLS spread in 2011 and 2012 arose because new infrastructure projects between Cushing and the Gulf Coast, including the reversal of the Seaway pipeline and the completion of the southern segment of the Keystone XL pipeline, were playing catch-up with the rapid growth in crude oil supply from U.S. shale and Canadian oil sands.[6]

Regulatory processes for siting and approving needed infrastructure are characteristically contentious and can on occasion be intractable. The Keystone XL pipeline from Alberta to the U.S. Gulf Coast, whose cross-border segment awaits approval from the U.S. State Department and President Obama at the time of this writing, has become a political flashpoint over the question of whether it will significantly increase greenhouse gas emissions. Enbridge's Northern Gateway pipeline, which would take oil from Alberta to the coast of British Columbia for export, is facing stakeholder challenges from First Nations groups. Siting interstate (and even within-state) electricity transmission lines in the United States is notoriously difficult, which has led to persistent transmission limitations that constrain additions of renewable energy.

Approval processes can be particularly challenging when multiple jurisdictions have authority, many stakeholders are able to pursue challenges, and powerful stakeholders have divergent interests. For example, siting new interstate electricity transmission lines in the United

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[5] U.S. railways typically price to compete with the next best competitor fuel source at the destination point. See, for example, Meghan R. Busse and Nathaniel O. Keohane, "Market Effects of Environmental Regulation: Coal, Railroads, and the 1990 Clean Air Act," *RAND Journal of Economics* 38, no. 4 (2007): 1159–79.

[6] Severin Borenstein and Ryan Kellogg, "The Incidence of an Oil Glut: Who Benefits from Cheap Crude Oil in the Midwest?" Energy Institute at Haas, Working Paper, no. 231, 2012, http://ei.haas.berkeley.edu/pdf/working_papers/WP231.pdf.

States typically requires the involvement of the public utilities commissions (and sometimes other agencies) in each state as well as federal bodies like the Federal Energy Regulatory Commission and the Department of Energy. Transmission lines face many stakeholder challenges, especially by environmental groups and local communities that might be affected. Moreover, there are inherent difficulties in aligning incentives because ratepayers in states with more expensive electricity will tend to benefit from the transmission line, whereas those where electricity is cheaper are likely to see rates go up.

The fact that new energy transportation infrastructure creates not only winners but also significant losers is a common political economy problem that can hinder approval. For example, U.S. natural gas producers are pushing for permits to export LNG and access higher international gas prices, while industries that consume natural gas are fighting exports to keep their input prices low.[7] Such cases can produce odd political bedfellows, such as the alignment of anti–fossil fuel environmental groups with large chemical producers lobbying against LNG exports.[8]

Energy transportation infrastructure may also fail to be built simply because it presents too great a commercial risk. This is especially true before new kinds of infrastructure have been shown to be financially viable. Investors only pursued early LNG plants in Sumatra after guarantees from the Japanese government dramatically lowered the financial risk involved.[9] But even after a method of transporting energy is proved financially viable, investors need to be certain that market conditions will allow for cost recovery on the infrastructure over a long period of time. This requires a stable political and regulatory climate in the location where the energy is produced as well as a reliable source of demand at sufficiently high prices. In an effort to ensure the latter, LNG and gas pipeline developers have traditionally locked in long-term, "take or pay" contracts before proceeding with construction.

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7 Clifford Krauss and Nelson D. Schwartz, "Foreseeing Trouble in Exporting Natural Gas," *New York Times*, August 15, 2013, http://www.nytimes.com/2013/08/16/business/energy-environment/foreseeing-trouble-in-exporting-natural-gas.html.

8 Amy Harder, "Are Natural-Gas Exports the Next Keystone?" *Wall Street Journal*, March 18, 2014, http://blogs.wsj.com/washwire/2014/03/18/are-natural-gas-exports-next-keystone.

9 See, for example, Fred von der Mehden and Steven W. Lewis, "Liquefied Natural Gas from Indonesia: The Arun Project," in Victor, Jaffe, and Hayes, *Natural Gas and Geopolitics: From 1970 to 2040*; and Varun Rai, David G. Victor, and Mark C. Thurber, "Carbon Capture and Storage at Scale: Lessons from the Growth of Analogous Energy Technologies," *Energy Policy* 38 (2009): 4089–98.

Investments in U.S. coal and natural gas export infrastructure could become unprofitable if the price arbitrage opportunity that currently exists between U.S. and foreign markets does not persist over the long term and volumes dry up as a result. LNG regasification plants built in the early 2000s, when the United States foresaw a large supply gap, are a cautionary tale; their business models evaporated due to the shale gas boom.[10] At the time of this writing, Newcastle thermal coal prices were around $80 per tonne, significantly off of January 2011 highs of over $140 per tonne. While energy consultancy Wood Mackenzie forecasts long-term prices that would support exports of PRB coal, environmental groups have tried to play up the financial risks of port investments.[11] In the case of natural gas, the price spread between U.S. and foreign markets could narrow over time if a large number of export projects go forward and if other countries develop their own unconventional gas resources.

Is It Likely That Valuable Resources Would End Up Stranded?

Notwithstanding current transportation constraints, a commonly expressed view is that it is unrealistic in the long term to expect that abundant U.S. coal resources will not find their way to growing Asian markets in desperate need of energy. A similar line of reasoning was used in the U.S. State Department's environmental impact statement for the Keystone XL pipeline. The impact statement argued that the pipeline would have little ultimate effect on oil sands production, and thus greenhouse gas emissions, because the oil would find other routes to consumers even if Keystone XL approval were denied.[12]

Modest quantities of PRB coal are already exported to Asia from coal terminals in British Columbia, and the desire to export more has helped animate expansions of these ports.[13] There is

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[10] Frank A. Wolak, "Careful What You Wish For: The Shale Gas Revolution and Natural Gas Exports," Stanford Institute for Economic Policy Research (SIEPR), SIEPR Policy Brief, November 2012, http://siepr.stanford.edu/?q=/system/files/shared/pubs/papers/briefs/PolicyBrief11_2012.pdf.

[11] Hal Bernton, "2 Governors Wade into Coal-Export Controversy," *Seattle Times*, March 25, 2013, http://seattletimes.com/html/localnews/2020640596_coalexportsinsleexml.html.

[12] U.S. Department of State, "Final Supplemental Environmental Impact Statement for the Keystone XL Project," January 2014, chap. 1, http://keystonepipeline-xl.state.gov/finalseis.

[13] Lee Buchsbaum, "While Canadian Terminals Expand Export Capacities, Many U.S. Producers Are Still Going To Be Short of Space," *Coal Age*, March 20, 2012, http://www.coalage.com/features/1808-while-canadian-terminals-expand-export-capacities-many-us-producers-are-still-going-to-be-short-of-space.html#.U2Qg8PldWAg.

some resistance in British Columbia to new coal port development,[14] although as yet opposition does not seem to have risen to the level of that in Washington and Oregon. Ultimately, ports in British Columbia might indeed absorb significantly more U.S. coal, but for now the least capacity-constrained terminal, Ridley in Prince Rupert, is also the farthest away and thus most expensive to reach by rail.[15]

There are no significant examples to date of governments intentionally closing off export routes for their own fossil fuels on climate change grounds. More typical is for ostensibly climate-concerned governments to lobby against the burning of fossil fuels in other countries,[16] even while arguing that environmental restrictions affecting their own products abroad are unfair trade barriers.[17]

The climate-oriented policies that have been put in place thus far in fossil fuel exporting countries have regulated emissions inside the country. Such policies may lead to reductions in greenhouse gas emissions associated with domestic fossil fuel production, but they do not address the usually larger greenhouse gas emissions associated with burning the fuel that is exported. For example, Australia's carbon tax (which the Abbott government was seeking to repeal at the time of this writing) would tend to increase the costs of Australian coal production by increasing the price of the coal-fired electricity used by the industry. Norway, another major fossil fuel exporter, has had a stiff carbon tax on offshore oil and gas operations since 1991. This tax has lowered domestic emissions—for example, by encouraging national oil company Statoil to inject CO_2 separated from natural gas from the North Sea's Sleipner field into a saline

[14] Brent Jang, "B.C. Coal Export Plan Faces Resistance," *Globe and Mail*, February 9, 2014, http://www.theglobeandmail.com/report-on-business/industry-news/energy-and-resources/bc-coal-export-plan-faces-resistance/article16770342.

[15] Buchsbaum, "While Canadian Terminals Expand Export Capacities."

[16] Sophie Yeo, "Netherlands to Stop Funding Overseas Coal Power Plants," RTCC, March 24, 2014, http://www.rtcc.org/2014/03/24/netherlands-to-stop-funding-overseas-coal-power-plants.

[17] Tim Dickinson claimed that the U.S. trade representative lobbied against EU low-carbon fuel standards that would have put North American crude from oil sands at a disadvantage. See Tim Dickinson, "How the U.S. Exports Global Warming," *Rolling Stone*, February 3, 2014, http://www.rollingstone.com/politics/news/how-the-u-s-exports-global-warming-20140203. In another instructive case (albeit not one involving exports of energy commodities), U.S. politicians resisted proposed EU rules that would have levied carbon taxes on flights to Europe by U.S. airlines as well as those from other countries. See Keely Brazil and Tim Devaney, "EU Backs Down on Airline Carbon Tax," *Washington Times*, November 13, 2012, http://www.washingtontimes.com/news/2012/nov/13/eu-backs-down-airline-carbon-tax.

formation deep under the seafloor rather than release it into the atmosphere. However, the tax does not act directly on oil and gas exports. The increased cost of fossil fuel production associated with carbon pricing in a producing country is likely to have at most a slight effect on the international price of a fossil fuel by making that country's supply more expensive and perhaps discouraging new investment in marginally economic supply projects.

While explicitly climate-related prohibitions on fossil fuel exports appear unprecedented (though theoretically possible), it is common for policy and institutional roadblocks to cause plentiful resources to stay in the ground. The policy and institutional environment does not have to explicitly bar exports; it just has to make them expensive and risky enough that the large investments needed to develop transportation infrastructure do not take place. For example, international sanctions and a generally risky investment climate have dramatically slowed development of Iran's South Pars gas field even as Qatar has developed major LNG exports from its side of the same geological formation (known as North Dome). In many countries, policies favoring domestic use of gas (at reduced prices) over export applications have led to much slower overall resource extraction.[18]

In almost all global energy markets, institutional factors within producing countries play a significant role in shaping the aggregate supply curve and influencing international prices. (The policy and regulatory environment also has an important effect on the demand curve—for example, through energy consumption subsidies.) In the United States, too, it may turn out that non-climate-oriented policies and stakeholder processes will have the determining say as to whether and when PRB coal is exported. Local impacts like increased rail traffic or release of coal dust could prove more salient in building grassroots opposition to new ports than the more diffuse impacts of climate change. The structure of the rail market may help make exports of PRB coal from more distant ports on the East and Gulf Coasts uneconomic, while nearer port alternatives in British Columbia may prove too capacity-constrained to ship massive amounts of PRB coal.

[18] Mark C. Thurber and Joseph Chang, "The Policy Tightrope in Gas-Producing Countries: Stimulating Domestic Demand without Discouraging Supply" (paper presented at the Advance Summit of the 2011 Pacific Energy Summit, Jakarta, February 21–23, 2011).

The Short-Term Impact of Removing Constraints to Exports

Assuming that regulatory barriers are overcome and transportation constraints are alleviated in a particular energy market, the following effects might typically be expected in the near term.[19] Prices for the exported commodity go up in the country where it is produced as some supply is diverted to export. To the extent that demand is downward-sloping, less of the exported quantity is consumed in the exporting country and there may be a shift to substitutes. This can have a positive or negative environmental effect in the exporting country depending on the environmental attributes of the exported commodity relative to its substitutes.

Prices of the energy commodity in the international market tend to go down overall as additional supply becomes available. This decrease in international prices causes countries with more elastic demand to increase consumption of the commodity in question relative to alternatives. Consumption is not significantly affected in countries with inelastic demand. The net environmental impact of removing the transmission constraint is the sum of the impacts in the exporting country and those in all importing countries.

The net environmental impact of removing the transportation constraint thus depends in a complex way on the nature of demand in exporting and importing countries. Even for a product with negative environmental externalities like coal, it should not automatically be assumed that facilitating exports will increase global greenhouse gas emissions. In fact, preliminary modeling work by Frank Wolak and Michael Miller suggests that, in the short term, removal of the coal port constraint in the U.S. Pacific Northwest may not appreciably increase global greenhouse gas emissions and could even reduce them under certain assumptions.[20] Their econometric analysis found downward-sloping short-term demand for coal in the United States and Europe because these regions are able to switch between coal and natural gas in the power sector; it assumed less elastic short-term demand for coal in China and other major Asian consumers because of the present lack of affordable substitutes (and of infrastructure for transporting and consuming them at scale) in these countries.

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[19] As will be discussed later, there are a number of complexities that can cause actual effects to differ.

[20] Frank A. Wolak and Michael Miller, "Modeling the World Coal Market: The Impact of China's Behavior on World Coal Consumption" (draft paper, February 2014).

With the assumptions they used, Wolak and Miller found that PRB coal exports increase the price of coal in the United States, decrease it slightly in the Pacific Basin, and either decrease or increase the price in Europe depending on exact model assumptions.[21] The increased price of coal in the United States leads to reduced coal usage, cutting U.S. greenhouse gas emissions. Europe experiences a reduction in coal consumption if its coal price increases and an increase in consumption if its coal price decreases. The slightly decreased price of coal in the Pacific Basin does not significantly affect coal consumption in Asian markets because of the relatively inelastic demand from these countries. In net, the model predicts that the reduction in U.S. coal consumption due to PRB exports predominates over any increases elsewhere, resulting in a modest global reduction in coal usage and therefore in greenhouse gas emissions.

While this is a plausible short-term outcome, the predicted results depend significantly on model assumptions. If coal demand becomes more elastic in coal-importing countries—for example, due to the further development of their domestic gas resources or gas import capacity—this tends to reduce any favorable effect of U.S. coal exports on global greenhouse gas emissions. Additionally, if U.S. railways reduce their rates to keep shipped volumes high in the event of increased exports, there may be less fuel switching to natural gas in the United States than predicted with the model's current assumption of fixed transport costs.

The Long-Term Impact of Removing Constraints to Exports

Even if building Pacific Northwest coal ports is neutral or favorable for greenhouse gas emissions in the short term, it is possible that the increased access of PRB coal to world markets could have negative environmental impacts over the longer term. For example, the higher prices fetched by PRB coal as a result of new port capacity might stimulate investment in PRB production that would moderate coal price increases and dampen fuel switching to natural gas in the United States.

It is also possible that access to the enormous reserves of PRB coal would encourage consuming countries in Asia to build more coal power plants by providing confidence that they will have an affordable source of coal over the long term. This was one of the concerns cited by

[21] The reason that prices in Europe can increase under certain model scenarios is that some non-PRB coal that would have been exported to Europe from the East Coast stays at home as a result of the higher U.S. coal price.

Washington governor Jay Inslee and Oregon governor John Kitzhaber in a letter in which they urged the Obama administration to review the climate impacts of PRB coal exports from the West Coast.[22]

How realistic is the concern that planners in Asia might factor PRB coal availability into their decisions to invest in coal plants and coal infrastructure and perhaps forgo investments in cleaner alternatives like natural gas or nuclear power? On the one hand, coal planners in major importing countries like Japan and Korea (which already receive some PRB coal through the Westshore terminal in British Columbia) would certainly welcome more availability of PRB coal as a way of diversifying supply.[23] On the other hand, major investments in new coal power plants are already being made, and it is unclear if the enhanced availability of PRB coal would significantly increase such investment in the near term. China, with its significant domestic reserves, probably views coal as a secure long-term fuel irrespective of whether PRB supply is available—and in any case seems unlikely to trust its energy security to U.S. supplies. Japanese planners look to coal as an attractive option for meeting supply needs in the face of idled nuclear capacity and expensive natural gas; they already appear to perceive coal as being available at good prices from reliable suppliers.[24] Korea also values coal for its cost advantage over gas, although a planned tax on coal use in power generation could somewhat blunt this advantage.[25]

Whether plentiful coal will continue to be available at attractive prices on the international market over the longer term is less predictable. India's demand for imported coal is one of the major wildcards. Despite the country's ample reserves, India's coal production has not kept pace with demand due to a murky land-rights regime, insecurity in major coal-producing areas, and

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[22] Bernton, "2 Governors Wade into Coal-Export Controversy."

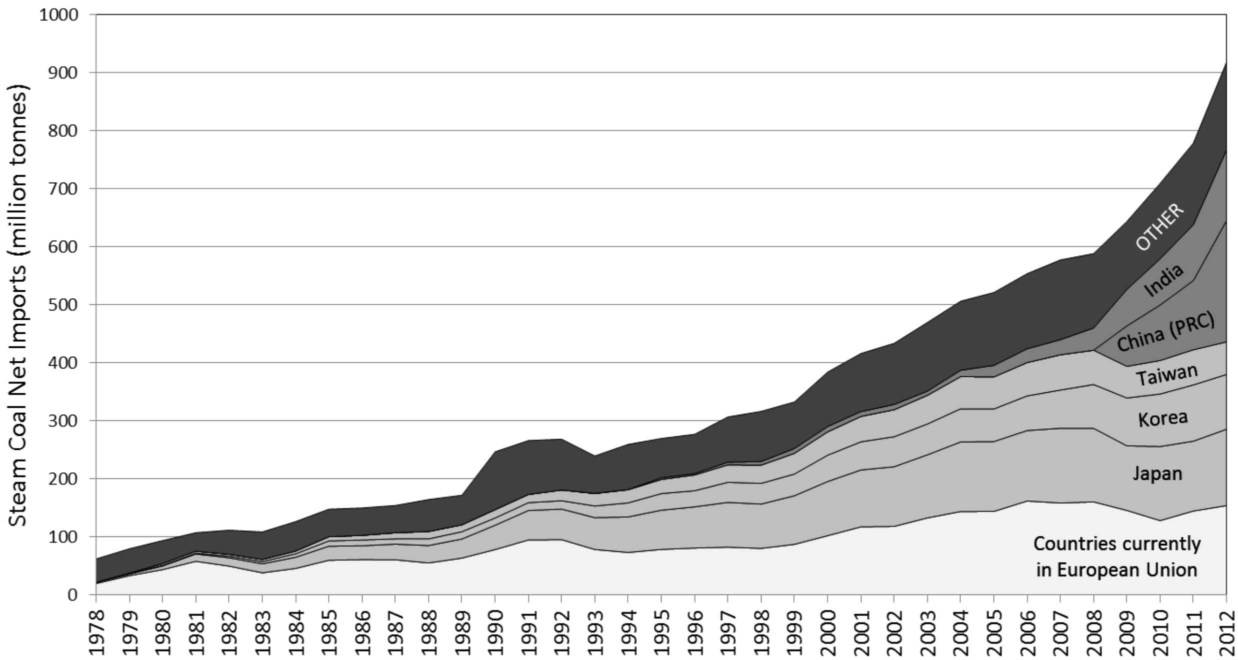
[23] Lee Kyungro, "Asia's Growing Coal Markets," United Press International, January 13, 2014, http://www.upi.com/Top_News/Analysis/Outside-View/2014/01/13/Asias-growing-coal-markets/UPI-28461389589380; and Rob Davis, "Viability of Oregon, Washington Coal Export Terminals Threatened by Falling Asian Prices," OregonLive, December 13, 2013, http://www.oregonlive.com/environment/index.ssf/2013/12/viability_of_oregon_washington.html.

[24] Mari Iwata, "Japan's Answer to Fukushima: Coal Power," *Wall Street Journal*, March 27, 2014.

[25] Sangim Han and Yuriy Humber, "Nuclear Halt in South Korea Seen Boosting Coal: Energy Markets," Bloomberg, April 13, 2012, http://www.bloomberg.com/news/print/2012-04-13/nuclear-halt-in-south-korea-seen-boosting-coal-energy-markets.html; and Meeyoung Cho, "S. Korea to Tax Coal for Power from July 1; Lower LNG, Fuel Oil Tax," Reuters, January 23, 2014, http://uk.reuters.com/article/2014/01/23/korea-power-tax-idUKL3N0KW1AB20140123.

the inefficiency of state producer Coal India Limited.[26] The country has increasingly turned to coal imports to fill the gap (see **Figure 2**). If India continues to grow its economy without resolving the issues that have held back coal production, it could absorb an increasing amount of internationally traded coal.

Figure 2 *Net imports of steam coal for the most significant importing countries*



Source: International Energy Agency, "IEA Coal Information Statistics," 2014.

China's demand for coal imports is of a significantly different character. While the increasing imports observed in Figure 2 might suggest that China's coal demand is outstripping its production capacity, the reality is different. In 2012, China consumed close to 3 billion tonnes of steam coal each year, far more than any other country.[27] (The United States was in a distant second place, consuming a bit under 800,000 tonnes.) China's imports, while large enough to significantly influence the international coal trade, are small relative to its own consumption. Rather than importing because of fundamental production-capacity limits, China's power

[26] Jeremy Carl, "The Struggle for Reform in India's Coal Sector" (draft chapter, unpublished manuscript, 2013).

[27] International Energy Agency, "IEA Coal Information Statistics," 2014, http://www.oecd-ilibrary.org/energy/data/iea-coal-information-statistics_coal-data-en.

producers import to arbitrage between international and domestic prices.[28] For this reason, the increase in imports shown from 2009 through 2012 does not necessarily presage ever-growing Chinese demand in the international market.

There are uncertainties on the supply side as well. Indonesia has become the world's leading coal exporter by a significant margin (see **Figure 3**), but in recent years the government has begun to intervene in more aspects of the coal market. There is some concern that this trend, if it continues, could turn the country into a less reliable exporter.[29] South Africa has been hampered by rail constraints and, at times, an uncoordinated approach to coal-sector policy on the part of the government.[30]

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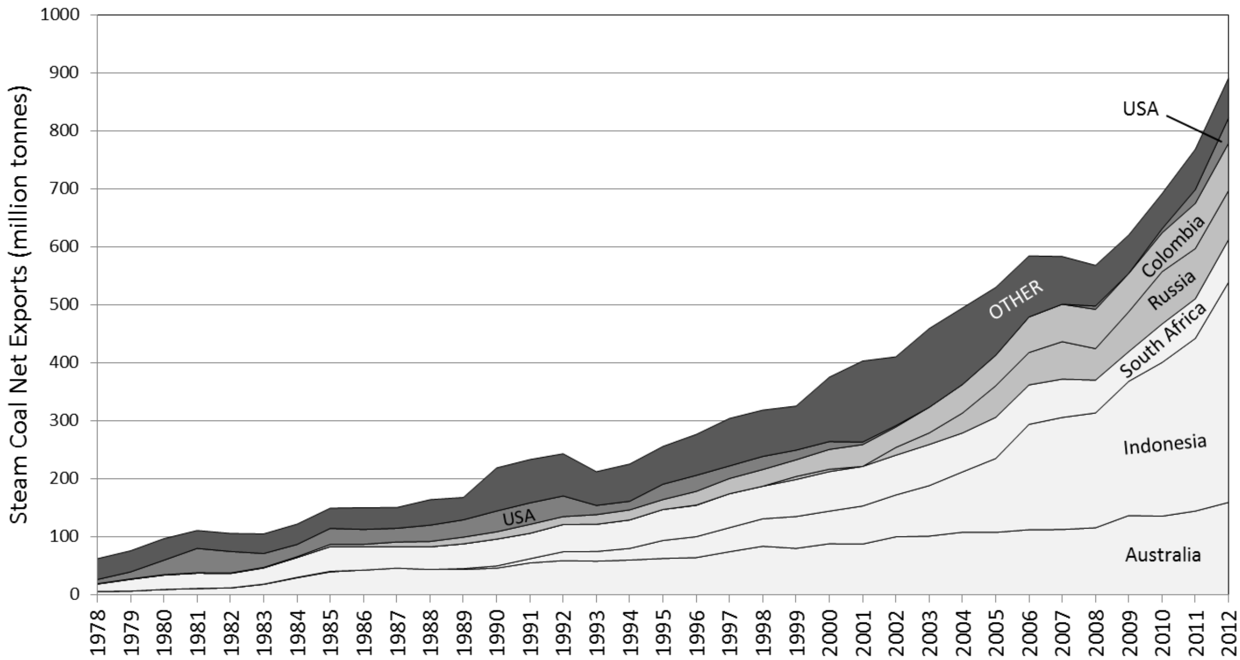
[28] Richard K. Morse and Gang He, "The World's Greatest Coal Arbitrage: China's Coal Import Behavior and Implications for the Global Coal Market," Stanford University, Program on Energy and Sustainable Development (PESD), Working Paper, no. 94, August 2010, http://iis-db.stanford.edu/pubs/22966/WP_94_Morse_He_Greatest_Coal_Arbitrage_5Aug2010.pdf.

[29] Bart Lucarelli, "The History and Future of Indonesia's Coal Industry: Impact of Politics and Regulatory Framework on Industry Structure and Performance," Stanford University, PESD, Working Paper, no. 93, July 2010, http://iis-db.stanford.edu/pubs/22953/WP_93_Lucarelli_revised_Oct_2010.pdf.

[30] Anton Eberhard, "The Future of South African Coal: Market, Investment, and Policy Challenges," Stanford University, PESD, Working Paper, no. 100, January 2011, http://iis-db.stanford.edu/pubs/23082/WP_100_Eberhard_Future_of_South_African_Coal.pdf.

Figure 3 *Net exports of steam coal for the most significant exporting countries*



Source: International Energy Agency, "IEA Coal Information Statistics," 2014.

Note: The total quantities do not exactly match those in Figure 2 because of acknowledged data gaps in accounting of coal flows.

If India's import demand continues to grow, developed countries like Japan and Germany continue to use coal as their default baseload power alternative,[31] and developing countries like Bangladesh turn to coal in the absence of other affordable choices,[32] the international coal market could become tighter over the long term. Market tightness will only intensify if suppliers like Indonesia have less to offer due to an adverse regulatory environment for coal production and export. If markets move in this direction in the future, the availability of 150 million tonnes a

[31] For all its renewable energy efforts, Germany is notable for its recent addition of power plants that burn dirty lignite, in part to fill the gap left by nuclear plant retirements. See, for example, "Green Revolution? German Brown Coal Power Output Hits New High," *Spiegel Online*, January 7, 2014, http://www.spiegel.de/international/germany/researchers-alarmed-at-rise-in-german-brown-coal-power-output-a-942216-druck.html; and Harry Wirth, "Recent Facts about Photovoltaics in Germany," Fraunhofer ISE, March 19, 2014, http://www.ise.fraunhofer.de/en/publications/veroeffentlichungen-pdf-dateien-en/studien-und-konzeptpapiere/recent-facts-about-photovoltaics-in-germany.pdf. Japan is also in effect using coal to plug a gap that was previously filled by nuclear energy. See Iwata, "Japan's Answer to Fukushima."

[32] Joseph Allchin, "Bangladesh's Coal Delusion," *New York Times*, March 4, 2014, http://www.nytimes.com/2014/03/05/opinion/bangladeshs-coal-delusion.html.

year of PRB coal (and perhaps much more[33]) and the knowledge that the "Saudi Arabia of coal" is open for business might indeed play some role in reassuring project developers in Asian countries with limited domestic coal reserves that coal plants are a safe investment.[34]

Beyond the direct effect of PRB coal availability (or lack thereof) on coal-plant investments, might there be an indirect, psychological effect on world markets if the United States were to deliberately strand a massive energy resource on climate grounds? There is a new strain of climate activism that seeks to build moral opprobrium against the use of fossil fuels. A centerpiece of this movement has been a campaign exhorting universities to divest their endowments from fossil fuel companies.[35] Arguably there would be few stronger statements than the United States making a conscious choice not to export coal. However, such a move to deliberately "shut in" resources because of the climate impacts of consuming them abroad would seem to be unprecedented. Even if the United States were to pursue such a policy, its effectiveness as a statement could well be undermined by international skepticism about the true motivations behind it.[36]

Conclusions

It is this author's view that the federal government is unlikely to block coal export terminals in Oregon and Washington on climate change grounds. Rather, their fate is likely to hinge on how much cost, delay, and uncertainty are added by stakeholder processes at various

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[33] The three West Coast export terminals currently being considered would have a combined capacity of approximately 100 million tonnes per year. See Scott Learn, "Another Northwest Coal Export Project Falls by the Wayside; Kinder Morgan Drops Oregon Terminal Plan," OregonLive, May 8, 2013. But there is certainly the possibility of adding additional port capacity beyond this. Forecasts from consultant Wood Mackenzie suggest that as much as 420 million tonnes of PRB coal could be exported by 2035. See Hal Bernton and Brian M. Rosenthal, "Demand Cools as Fight Rages over Coal-Export Terminals," *Seattle Times*, September 3, 2013.

[34] The United States has the largest coal reserves in the world and is therefore sometimes referred to as the "Saudi Arabia of coal." The analogy is dubious because, unlike Saudi Arabia for oil, the United States remains for the time being a relatively small exporter of coal.

[35] Andrew C. Revkin, "A Closer Look at Harvard's Choice on Fossil Fuels," *New York Times*, October 4, 2013, http://dotearth.blogs.nytimes.com/2013/10/04/a-closer-look-at-harvards-choice-on-fossil-fuel-divestment.

[36] While it is hard to see how keeping coal resources in the country would provide a significant boost to U.S. industries, there could certainly be questions, for example, about whether any effort to block LNG exports on environmental grounds was in fact an attempt to help gas-consuming industries in the United States gain an advantage over international competitors.

levels of government, and how these interact with the global coal market to influence decisions on whether to go ahead with investment. Environmental groups have increasingly learned that they can be just as effective in blocking a given project by adding cost, delay, and uncertainty as by having the project expressly prohibited. Indeed, if there is a larger lesson about new transportation infrastructure projects in energy markets, it is that, because of the huge investments and market risks involved in building out a global supply chain, they are exquisitely sensitive to the regulatory and investment environment.

Determining the net environmental impacts of Pacific Northwest coal ports requires a more comprehensive and sophisticated analysis than has been performed to date. Such an analysis will need to incorporate models of demand for coal and its alternatives both in the United States and abroad, such as are being developed by Wolak and Miller.[37] (As mentioned above, one counterintuitive finding of initial modeling work is that there could be scenarios in which coal exports could actually reduce global greenhouse gas emissions, at least in the short term.) Critically, the analysis will also need to be informed by detailed insight into the planning process for new power plants and transport infrastructure in key consuming countries—and especially into how planners develop and incorporate long-term energy supply and demand forecasts when deciding on their choices of fuel and generation technology.

In theory, technologies that improve the efficiency of coal power plants, reduce local pollution, and capture and store CO_2 have the potential to make coal use more compatible with environmental objectives, thereby removing a potential objection to U.S. exports. The biggest challenge is cost. The most attractive feature of coal is its low cost, and "clean coal" technologies that substantially increase upfront and operating costs risk erasing the economic edge of coal relative to alternatives like natural gas and nuclear. High-efficiency coal plants using "ultrasupercritical" technology are starting to be deployed in some locations, with the attraction that the efficiency improvement not only reduces emissions but also may help pay for itself over the long term through fuel savings. Technologies to reduce local pollution, such as flue gas desulfurization for sulfur dioxide (SO_2) and selective catalytic reduction for nitrogen oxides (NO_x), are well established and can be implemented relatively cost-effectively. (In fact, wider use of the PRB's low-sulfur coal around the world could itself reduce SO_2 emissions problems.)

[37] Wolak and Miller, "Modeling the World Coal Market."

But carbon capture and storage (CCS) remains extremely expensive in power plant applications and yields no significant benefits apart from reducing greenhouse gas emissions.[38] Due to the absence of sufficiently compelling carbon prices or other incentives, there have as yet been no demonstrations at scale of CCS on coal power plants. Until demonstrations and development programs validate the technology at scale and reduce its costs, and carbon pricing provides a genuine spur to implementation, CCS will not be able to assuage concerns about the climate change impacts of U.S. coal exports.

[38] The main exception to this is niche cases where enhanced oil recovery applications create demand for CO_2.