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# Why Taxing Carbon May Not Make the World More Green

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# Why Taxing Carbon May Not Make the World More Green

## Summary

Although taxing carbon is an idea that enjoys significant support among policymakers and business leaders, new research indicates that carbon taxation can actually cause energy investments to gravitate away from the cleanest energy technologies. This counterintuitive finding reflects two key characteristics of energy markets: the worldwide increase in renewable energy sources whose output is intermittent and variable; and greater market liberalization, which has made the spot driving of electricity more volatile. The intermittency of renewable energy sources requires backup generation, typically from generators using fossil fuels. The dynamics of market liberalization amplify this negative effect of intermittency. Policymakers need to take steps to reduce intermittency by supporting storage technologies or setting monetary incentives to increase renewable generation capacity investment.

## Disciplines

Business Law, Public Responsibility, and Ethics | Economic Policy | Environmental Policy | Taxation

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# Why Taxing Carbon May Not Make the World More Green

Serguei Netessine, PhD and Sam Aflaki, PhD

ISSUE BRIEF

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There is an important yet largely overlooked link between the intermittent accessibility of renewable energy sources and the effectiveness of renewable-promoting policies such as carbon pricing.

Putting a price on carbon is sometimes discussed in terms of a “tax,” but a carbon tax is not necessarily the same as a traditional tax, as the primary purpose is not to raise revenue but rather to reduce emissions. A variety of proposals exist that would introduce a revenue-neutral carbon tax in the U.S., with disparities, of course, in the price itself and on how the revenue generated from the tax should be spent.<sup>1</sup> But as a general topic of public policy, taxing carbon enjoys the support of some strange political bedfellows, from most Democrats and economists to nearly half of all Republicans and over 1,200 multinational corporations, including the United States’ own Exxon Mobil.<sup>2</sup> Over 140 global companies, including Microsoft and Cummins, already embed a carbon price deep within their business strategies and operations without any legal mandate to do so.<sup>3</sup> While the Trump Administration has repeatedly denied that it will consider a carbon tax as part of its tax reform agenda, there is an important, new consideration about which policymakers should be aware, should the topic arise.

We have discovered through our research a surprising, non-intuitive result concerning the effects of a carbon tax.<sup>4</sup> When the price of carbon rises, investment in (greenhouse gas-free) renewable energy technology does become comparatively cheaper, but most

## SUMMARY

- Although taxing carbon is an idea that enjoys significant support among policymakers and business leaders, new research indicates that carbon taxation can actually cause energy investments to gravitate away from the cleanest energy technologies.
- This counterintuitive finding reflects two key characteristics about energy markets: the worldwide increase in renewable energy sources whose output is intermittent and variable; and greater market liberalization, which has made the spot pricing of electricity more volatile. The intermittency of renewable energy sources requires backup generation, typically from generators using fossil fuels. The dynamics of market liberalization amplify this negative effect of intermittency.
- Long-term fixed price contracts with electricity suppliers can help address the risk of volatile spot prices and encourage investment in renewables, but the intermittency problem will still force suppliers to employ emission-intensive generators for backup, and thus will fail to significantly abate emissions.
- Policymakers therefore also need to take steps to reduce intermittency by supporting the development of electricity storage technologies or setting monetary incentives to increase renewable generation capacity investment.
- The price effects of market liberalization and the problem of intermittency must be addressed in concert, in order for carbon taxation to more effectively promote investment in renewables and reduce overall emissions.

new capacity investment actually goes toward newer, more efficient (yet still GHG-emitting) gas-fired turbines. The reason is that, under the status quo, renewables remain chained to the heaviest GHG-emitting generators (see Figure 1). These fossil fuel sources—comprised predominantly of old, inefficient gas-fired turbines—are often the only generators that can quickly be brought online by electricity suppliers to provide the necessary supply of energy when renewables are unable to meet energy demand. This dependence on emission-heavy reserves is a practical consequence of the intermittency of green energy sources and of renewable generators' inability to store excess power. When carbon prices go up, the combination of renewables and emission-heavy reserves becomes too expensive relative to efficient gas-fired technologies. Ultimately, this leads the majority of uncoordinated investments made in the liberalized energy marketplace to gravitate away from the cleanest technology.

Before delving into potential policy responses to the problem of GHG emissions in light of this new finding, a clear understanding of energy markets is essential. To begin with, not one but two monumental developments

have recently reshaped electricity generation, transmission, distribution, and retailing: the introduction of renewables and market liberalization.

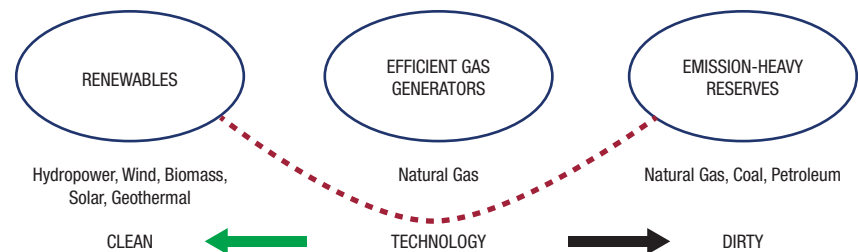
### THE INTRODUCTION OF RENEWABLES

The worldwide increase in capacity installations for renewable sources of energy, such as wind and solar power, has been accelerating. In the last decade, wind capacity installations have increased tenfold. China has the greatest installed capacity in the world, followed by the United States,

and electricity generation from solar panels is volatile because of their sensitivity to weather conditions, air pollution, and other determinants of solar radiation intensity. Although some of this variability in supply is natural and can be planned for (e.g., the lack of generation from solar panels at night), there is still significant uncertainty associated with the outputs of renewable technologies.

Investment in the capacity to generate renewable energy is hampered not only by intermittency but also by the high costs involved. A variety of strategies have been adopted to incen-

FIGURE 1 GENERATION TECHNOLOGY



Germany, Spain, and India.<sup>5</sup> But a critical aspect of renewable technologies is their *intermittency*—that is, the supply of electricity from these sources is typically uncertain. For instance, wind blows neither continuously nor in concert with demand,

tivize investment in renewables. These strategies include establishing renewable portfolio standards, minimum prices for renewable energy injected into the grid (i.e., renewable feed-in tariffs), and multiyear subsidies and investment credits in some jurisdictions

### NOTES

- 1 Kotchen M, Turk Z, and Leiserowitz A (2017), "Public willingness to pay for a US carbon tax and preferences for spending the revenue," *Environmental Research Letters*, 12:9. Available at: <http://iopscience.iop.org/article/10.1088/1748-9326/aa822a>.
- 2 CDP, *Global Carbon Price Report 2016*, available at: <https://www.cdp.net/en/research>; and Alexander Kaufman, "Americans Are Willing to Pay a Carbon Tax, But Trump Won't Even Consider It," *Huffington Post*, October 12, 2017.
- 3 CDP, *supra note 2*; and Light S (2015), "Not the Only Game

- in Town: The Complementary Roles of Public and Private Environmental Governance," *Penn Wharton Public Policy Initiative*, Issue Brief: Volume 3, No. 8.
- 4 The research in this Issue Brief is based on Aflaki S and Nettekine S (2017), "Strategic Investment in Renewable Energy Sources: The Effect of Supply Intermittency," *Manufacturing & Service Operations Management* 19(3):489-507. Available at: <https://doi.org/10.1287/msom.2017.0621>.
- 5 Ren21 (2014), *Renewables 2014 Global Status Report*, REN21 Secretariat, Paris.
- 6 For a critical review of various incentives for renewable en-

- ergy investments, see Bushnell J (2010), "Building blocks: Investment in renewable and non-renewable technologies," Moselle B, Padilla J, Schmalensee R, eds., *Harnessing Renewable Energy in Electric Power Systems: Theory, Practice, Policy* (Earthscan, Washington, DC), pp. 159-180.
- 7 Proposals for pricing the carbon emissions from fossil-fuel electricity plants include a carbon tax or a "cap and trade" system of credits. For a discussion of the various forms of carbon pricing in the context of technology planning, see Drake DF, Kleindorfer PR, Van Wassenhove LN (2016), "Technology choice and capacity portfolios under emis-



as direct incentives for new renewable capacity.<sup>6</sup> In addition to these direct incentives for renewable investment, there can be indirect incentives in the form of increased prices on fossil-fuel electricity generation (gas-fired, coal, etc.) through the penalizing of firms for technology-induced environmental damage. The most significant of these penalties is referred to generically as carbon pricing.<sup>7</sup>

We find that increasing the carbon price has two counteracting effects on investments in renewables. On the one hand, it improves the cost competitiveness of renewables relative to nonrenewable technologies—a result of the former’s lower greenhouse gas (GHG) emissions. On the other hand, renewables require backup generation, which typically comes from generators using fossil fuels; thus, an increase in the carbon price leads to an increase in the cost of reserves to cover intermittency. How these countervailing forces affect the technology share of renewables in the overall generation portfolio depends on the carbon price and also on the emission intensity of backup generation technologies. Often it is the older, more emission-intensive technologies that are used for backup. So in stark contrast to intuition, increasing the carbon price

may actually *reduce* the overall proportion of renewable generation.<sup>8</sup>

## MARKET LIBERALIZATION

Besides the introduction of renewable sources, electricity markets have undergone another important change in the last two decades: market liberalization. For almost a century, the electricity sector resembled a natural monopoly. All four primary elements of electricity supply—generation, transmission, distribution, and retailing—were organized as a vertically integrated firm that was owned either privately or by the state and with price and entry regulations identical to natural monopolies. The logic of this approach was based on operational constraints associated with balancing the generation, transmission, and distribution of electricity. That balancing also contributed to the economics of electricity generation because it reduced retailing costs.<sup>9</sup> The first step toward the liberalization of electricity markets was the “vertical unbundling” of the industry’s generators and retailers. Such restructuring was motivated by the desire to create competition among generators, thereby reducing retail prices, and to prevent incumbent utilities from exploiting the market

power stemming from their historically dominant position. The result is that market liberalization has rendered electricity a commodity that can be traded in wholesale electricity markets.

In a competitive electricity market, power generators typically submit their *supply offers* to the market (grid or pool) administrator while retailers (representing their end-use electricity customers) submit their *demand bids*. The independent system operator, responsible to meet all the demand, then sorts the supply offers from the lowest to the highest before scheduling dispatch based on the merit order—subject to transmission (and other physical) constraints. The efficient dispatch algorithms used in this process, in combination with the bidding rules, imply that the spot price of electricity under typical conditions and in a perfectly competitive market is determined by the marginal cost of the last unit of energy dispatched.<sup>10</sup> Hence, the spot price, which is extremely volatile, is determined by supply and the realized random demand.<sup>11</sup>

The problem is that wind generators suffer more under competition than under vertical integration. The intuitive explanation for this outcome is that the incentive of each genera-

## NOTES

- sions regulation,” *Production Oper. Management* 25(6): 1006–1025.
- <sup>8</sup> I focus on generation capacity rather than the total monetary investment, which may or may not be higher than that for the conventional generation source.
- <sup>9</sup> Michaels RJ (2007), “Vertical integration and the restructuring of the U.S. electricity industry,” Working paper, *Cato Institute Policy Analysis Series*, California State University, Fullerton.
- <sup>10</sup> Joskow PL (2006), “Competitive electricity markets and investment in new generating capacity,” Working paper,

- Center for Energy and Environmental Policy Research*, Massachusetts Institute of Technology, Cambridge, MA.
- <sup>11</sup> In practice, not only zero but also negative electricity prices are possible. That possibility reflects the costliness of supply adjustment even for renewable generators. See, e.g., [https://www.epexspot.com/en/company-info/basics\\_of\\_the\\_power\\_market/negative\\_prices](https://www.epexspot.com/en/company-info/basics_of_the_power_market/negative_prices).
- <sup>12</sup> Joskow, *supra* note 10.
- <sup>13</sup> Borenstein S (2002), “The trouble with electricity markets: Understanding California’s restructuring disaster,” *J. Econom. Perspect.* 16(1):191–211.

- <sup>14</sup> Such a bilateral arrangement takes one of two possible forms (see Borenstein). In an electricity pool, or market-based bilateral contracts, all generators sell to a pool run by an independent system operator and all suppliers buy from that pool. In this case, the ISO manages the physical feasibility of electricity flow within the network. An alternative is for buyers and sellers to make their own arrangements for the purchase of electricity and then to inform the system operator about those arrangements. Here the system operator steps in only if some physical infeasibility might otherwise occur—as when a part of the transmis-



tor to underinvest in the competition scenario depends not only on its unit total cost but also on the market price. A higher carbon price increases the unit cost of gas-generated electricity, which under competition creates a disincentive for the gas generator to invest. Similarly, the intermittency of wind generation creates a disincentive for the wind generator to invest under competition. The reason is that the spot price of electricity is decreasing in the availability of wind capacity; this puts wind at a significant competitive disadvantage because the price is lowest when wind is available and is highest when wind is not available. In short, the spot-price disadvantage of wind dominates. As the carbon price rises, this disadvantage is balanced by the emission disadvantage of the gas technology, which decreases the gas generator's incentive to invest, because higher investment pushes the spot price down and results in less revenue.

A principal takeaway from the development of liberalized markets, therefore, is that the negative effect of intermittency is amplified by the marginal-cost pricing that is typical of such markets. This finding offers novel support for the hypothesis that market liberalization—over and above intermittency—leads to underinvest-

ment in renewable electric generation capacity.<sup>12</sup>

## **POLICY RESPONSES**

To counter the disincentives to invest in renewables in a liberalized market, public policy experts suggest long-term fixed-price contracts with generators so that investment in new generating capacity will be protected from the risk of volatile spot prices.<sup>13</sup> For instance, long-term contracts involving wind developers, electricity suppliers, and large customers are used in the United States and Europe to promote investment in renewable capacity. Such fixed-price contracts with renewable generators are typically benchmarked on feed-in tariffs, often with regulatory guarantees, that specify long-term prices based on generation costs rather than spot prices. Using numerical experiments with real-world data, we find that fixed-price contracts are effective at stimulating investment in renewables in a liberalized market. However, overreliance on carbon-intensive backup generation may significantly lessen the environmental benefits of using renewables relative to the hypothetical case in which firms are vertically integrated.

## **FIXED-PRICE CONTRACTS**

Given the volatility of spot prices, bilateral forward contracts between suppliers and generators play a significant role in almost all electricity markets today.<sup>14</sup> The time horizon of the forward contracts can range from a single day to 15-20 years. In the United States, long-term forward contracts have been advocated as a means to promote investment in renewable generation capacity and to “spur the growth of renewable generation.”<sup>15</sup> In a number of states (including Massachusetts, Rhode Island, New Jersey, and Delaware), the legal instruments are already in place to sign long-term power purchase agreements with fixed prices and with contracting horizons of 10-25 years. Germany and Spain, the two European countries with highest installed capacity for renewable energy, have used long-term fixed-price contracts to promote renewable energy investments.

In the case of unbridled market competition, fixed-price contracts increase the installed wind capacity and decrease the gas capacity. This is because the wind generator now has the clear advantage of no uncertainty in prices. Somewhat surprisingly, however, there is little difference in gas capacity investment between the fixed-

## **NOTES**

sion grid is overloaded. In that case, the ISO sets grid usage charges to balance the network.

<sup>15</sup> Wilson NE, Newell RG, Burtraw D (2005), *The Effect of Long-Term Generation Contracts on Valuation of Electricity Generating Assets Under the Regional Greenhouse Gas Initiative* (Resources for the Future, Washington, DC).

<sup>16</sup> Of course, these statements hold only for relatively high shares of renewable electricity generation capacity, for which emission-free backup generation (such as hydro-power) does not exist.

<sup>17</sup> See, e.g., Wu QQ, Kapuscinski R (2013), “Curtailling inter-

mittent generation in electrical systems,” *Manufacturing & Service Oper. Management* 15(4):578–595.



price contracting and market competition scenarios.

These contracts are a viable means of compensating for the disadvantages of market liberalization from the standpoints of total cost and greenness. Yet they could also lead to dramatic overinvestment in renewables and underinvestment in gas generation (relative to vertical integration) for high enough carbon prices. The likely result would be an overreliance on the emission-heavy backup (coal-fired) generators, given the total absence of workable and scalable solutions for storing unutilized renewable energy. Besides degrading the environment, that outcome could also lead to grid-balancing issues—should the need arise for significant backup generation.

To put this another way, although the overall increase in wind capacity under a regime of fixed-price contracts is good news, there is no free lunch: the increase in wind and total capacity is such that emissions in this setting remain higher than under vertical integration. The installed gas capacity in this case is insufficient to provide backup for the intermittent wind capacity, forcing the supplier to employ the emission-intensive backup option. In short, fixed-price contracts are successful at promoting renewables but fail to significantly abate emissions.<sup>16</sup>

### REDUCING INTERMITTENCY ITSELF

The intermittency of renewable energy sources is a problematic feature that handicaps investment decisions in these technologies. It then follows that a more effective approach to increasing capacity investment in renewables would be to reduce the effect of intermittency itself. Reduc-

ing intermittency would increase the effectiveness of carbon pricing as a green-promoting strategy because not only would it eliminate that pricing's burden on renewables (since there would then be less need for a backup technology), but it would also ameliorate renewables' spot-price disadvantage in electricity markets.

There are various options for reducing the intermittency of renewables. The first of these is electricity storage, for which various (relatively new) technologies are available, albeit in prototype form mostly. These technologies include pumped-storage hydropower, which stores electricity in the form of potential energy, and pumped-heat electricity storage, which uses argon gas to store power in the form of heat. And Tesla has developed the first potentially scalable form of renewable energy storage in the form of a battery that retains excess solar power for use in individual homes. But these technologies have a long way to go and will require significant investment before they can begin to noticeably reduce the intermittency prevalent in the status quo.

Other options besides storage include the "curtailing" of intermittent generation<sup>17</sup> and the pooling of multiple generation units (possibly with different technologies) whose supply is not perfectly correlated. This latter approach may be possible only for large generators with enough resources to invest in multiple wind farms in different (strategically located) geographical regions. So even though there are no economies of scale in wind electricity generation, there are clear statistical economies of scale in terms of reduced intermit-

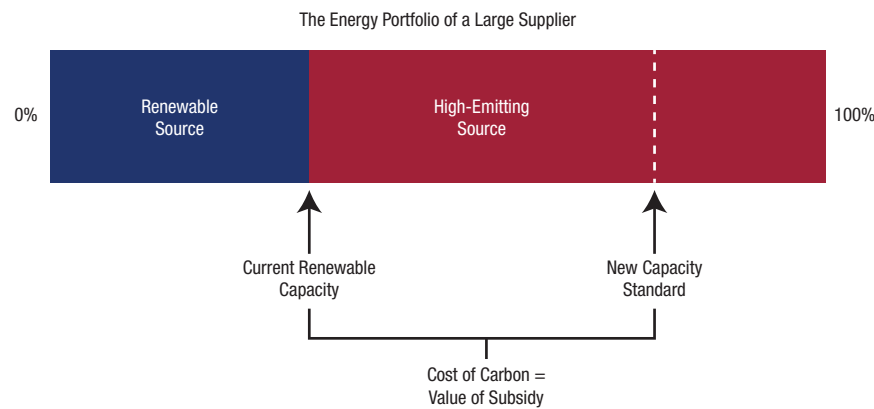
tency. As of yet, however, there has been no concerted effort to pool technologies to reduce intermittency.

Policymakers can aid the curtailing of intermittency by offering additional monetary incentives to generators who make investments to improve capacity and effectively reduce suppliers' reliance on emission-heavy backup forms of energy. Rather simply, policymakers can set new capacity standards. The hypothetical (or real) cost of carbon between a generator's current capacity and a new capacity standard could be offered as a subsidy alongside current feed-in tariffs to reward a generator for ensuring renewable energy supply (see Figure 2). If the feed-in tariffs currently in practice incent increased renewable investment, then an additional subsidy could reward (primarily large) generators for better management and mitigation of intermittency. Such an incentive could induce generators to invest in multiple renewable sources (instead of only one, as most currently do), as well as to invest in scalable storage technology, and it could place an emphasis for the first time on strategically designing and implementing new plants, with an eye towards counter-balancing renewable energy sources.

### CONCLUSION

Although increasing the price of carbon emissions does lead to lower total emissions, this policy is not a universally good way to promote investment in renewables. Moreover, market liberalization may not promote efficient investment in generation capacity. Liberalization leads to an increase in total emissions from the generation

**FIGURE 2 MONETARY INCENTIVE FOR REDUCING INTERMITTENCY**



portfolio, and for a reasonable range of carbon prices it leads to a lower share of renewables than in a scenario

where all electricity generators are vertically integrated. The root cause of these effects is the interaction between

intermittency and market pricing. Long-term electricity contracts do ameliorate some disadvantages of the liberalized markets. Namely, they lead to a significant increase in renewable capacity investment while not appreciably affecting nonrenewable capacities. In this way, long-term contracts with renewable generators increase the total installed capacity and reduce emissions relative to the case of unrestricted market competition. But since firms likely will not reintegrate, additional monetary incentives may be required to reduce renewable energy intermittency and spur greater investment in new renewable capacity.





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