CARROT AND STICK:
USING BOTH CARBON PRICES & REVENUES TO DRIVE EMISSION REDUCTIONS

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Climate Law & Policy Project

About Climate Law & Policy Project

Climate Law & Policy Project is a 501(c)(3) non-profit organization. CLPP's mission is to use its legal and policy expertise to help formulate and advocate environmentally, socially, and scientifically sound policies to reduce emissions and protect communities around the world from the impacts of climate change.

CLPP operates like a think tank – seeking practical and politically viable strategies – while simultaneously advocating for strong responses to avert the increasingly urgent problem of climate change.

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INTRODUCTION

Climate science continues to paint a dire picture. Every month seems to break temperature records. Scientists are now able with increasing accuracy to tie heat waves, floods, and other extreme weather events to climate change – and that is with only about 1ºC of warming. To have even a decent chance of avoiding the worst impacts of climate change, the countries of the world agreed in Paris in December 2015 to aim to keep warming well below 2ºC while taking measures to limit warming to 1.5ºC – but the world is nowhere near a trajectory to achieve those goals.[1]

To have a two-thirds chance of limiting warming to 2°C at the end of the century, studies suggest that global greenhouse gas emissions must be net zero by the latter half of the century – and significant amounts of negative emissions will probably be needed thereafter.[2] Humanity is not even close to being on pace to achieve that. While global energy-related carbon dioxide (CO_2) emissions remained flat in 2016 for the third year in a row (which is progress), massive reductions are required.[3] The United States and other countries must significantly strengthen their efforts in order to avoid the worst impacts of climate change.

Many types of policies have been developed to promote climate mitigation, including mandates and subsidies for clean energy and transportation, limits on and early retirement of coal-fired electricity generation, and international agreements to promote collective action and drive ambition on reducing greenhouse gas emissions. While these all can play useful roles in advancing greenhouse gas reductions, there is generally a consensus that carbon pricing is also needed. It is already being implemented or discussed in a number of U.S. states and various places around the world.

Putting a price on CO_2 emissions, whether via a carbon tax or a cap-and-trade mechanism, sends a price signal that the atmosphere is no longer a free dumping ground for greenhouse gas pollution, spurring emission reductions and clean energy deployment. Political constraints, however, create a significant hurdle to implementing carbon pricing policies at levels sufficient to achieve the reductions necessary.[4] There are also some needed reductions that a carbon price signal will be unable to reach. Carbon pricing, alone, will not get humanity to zero.

There is a way, though, to make carbon pricing policies much more powerful drivers of reductions. **How carbon price revenues are used can matter just as much as the carbon**

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[1] *See, e.g.*, UNEP, *The Emissions Gap Report 2016*, 2016, http://web.unep.org/emissionsgap/
[2] IPCC, *Climate Change 2014: Synthesis Report*, 2015, p.21, https://www.ipcc.ch/report/ar5/syr/; *See also*, Pete Smith et al, *Biophysical and economic limits to negative CO2 emissions*, Nature Climate Change, Vol. 6, Dec. 2015, http://www.nature.com/nclimate/journal/v6/n1/full/nclimate2870.html (text also at: https://www.researchgate.net/publication/285742474_Biophysical_and_economic_limits_to_negative_CO2_emissions).
[3] *See* International Energy Agency, *IEA finds CO2 emissions flat for third straight year even as global economy grew in 2016*, Press release, Mar. 17, 2017, https://www.iea.org/newsroom/news/2017/march/iea-finds-co2-emissions-flat-for-third-straight-year-even-as-global-economy-grew.html
[4] *See* Jesse D. Jenkins and Valerie J. Karplus, *Carbon pricing under binding political constraints*, United Nations University – WIDER Working Paper 2016/44, Apr. 2016, https://www.wider.unu.edu/sites/default/files/wp2016-44.pdf

price itself. Using carbon price revenues as a "carrot" to cost-effectively subsidize reductions *additional* to those that would be driven by the carbon price "stick" can get humanity on a significantly faster emission reduction trajectory – one more commensurate with the scale of the challenge.

One way to increase the effectiveness of carbon prices is to use the revenues to subsidize reductions of emissions that are not covered by the tax or cap. This approach raises a host of issues, such as the methodology for determining whether such reductions can be adequately monitored, quantified, and verified to ensure they are real and additional. This issue has given rise to a vast amount of literature and is beyond the scope of this paper. Instead, this paper describes a method for using carbon price revenues to cost-effectively subsidize achievement of additional reductions of emissions subject to the tax or cap – beyond the level that would be achieved by the carbon price alone.

In its most basic form, a cost-effective "price-and-subsidy" system would identify the marginal abatement cost of available reductions and subsidize the difference (the delta) between the abatement cost and the carbon price. This could be done, for example, by establishing a carbon price, putting the revenues into a fund, and holding a reverse auction that offers subsidies equal to the delta to any emitter or project developer that wants to submit a bid for achieving reductions, until the funds are fully committed. The subsidies would go first to the cheapest reductions beyond the price signal, working up the abatement cost curve until the carbon price revenues have been spent. This approach can work with either a carbon tax or a cap-and-trade system, though there are some additional steps required with the latter to ensure the subsidized reductions are additional to what the cap alone would achieve.

In the real world, of course, all of the carbon price revenues would not and probably should not go only towards achieving the next cheapest reductions. There are other important climate-related needs as well, such as enhancing infrastructure resilience and adapting to unavoidable impacts of climate change, supporting research and development related to technologies that may be needed to achieve deep decarbonization, cushioning economic dislocation resulting from climate policies (e.g., assisting workers transitioning out of the old energy economy), and offsetting potentially regressive effects of such policies on lower-income communities. In addition, the types of reductions eligible for subsidies under a price-and subsidy approach will likely have to be constrained to ensure the subsidized reductions do not lock in current technologies or infrastructure incompatible with deep decarbonization pathways.

Much more serious action to ward off the worst impacts of climate change has to start immediately. Humanity is starting to make good (if long-belated) progress in reducing emissions, but far more is needed, and the pace must be accelerated. Particularly at a time when it appears that the U.S. government will be inactive or hostile with regard to progress in the fight against climate change, states will need to further take on the mantle of leadership. Combining the "carrot" of cost-effective subsidies with the "stick" of carbon prices can dramatically accelerate their efforts to drive towards a zero-carbon future.

I. OPTIONS FOR USING CARBON PRICE REVENUE

The economic rationale for a pollution price, whether imposed directly by an emissions tax or indirectly by cap-and-trade, is to address the problem of environmental externalities — costs resulting from the pursuit of private economic activities that are borne, not by the private entity engaged in those activities, but by society. Putatively, the purpose of the pollution price is to "internalize" this externality, shifting the cost from society to polluter.[5] Its practical effect is to create a financial disincentive, encouraging the polluter to find ways to reduce its emissions. It also creates a potentially vast stream of revenue, which can be used to serve a range of purposes.

There are generally three broad categories of uses of carbon price revenue that have been discussed or implemented:

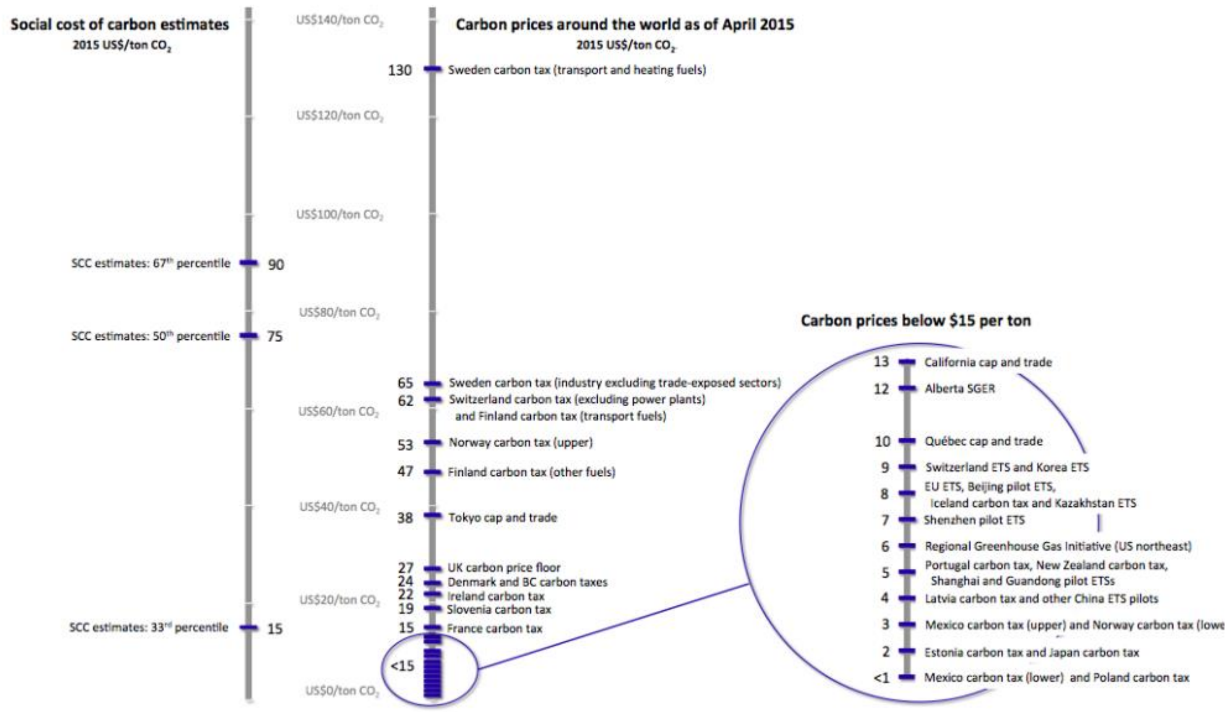
1) To support activities that bear some relation to climate change (e.g., emission reductions, adaptation to climate impacts) or that mitigate negative effects of the climate policy (e.g., offsetting the regressive effects of a carbon price on the poor);
2) To promote economy-wide economic efficiency (i.e., a revenue-neutral tax swap that would replace economically undesirable taxes, such as business or payroll taxes, with the more desirable carbon price mechanism); or
3) To provide a "dividend" to all citizens, whether based on the premise that the atmosphere belongs equally to every individual or based on the political calculus of building support.

Using carbon price revenues for the second or third categories implicitly presumes that the carbon price (or cap) alone would be sufficient to remedy the problem. There is good reason, however, to be skeptical of how realistic that assumption is.

First, as shown in Figure 1, an analysis of carbon prices around the world finds that most are far below estimates of the social costs of carbon. There are real political constraints on carbon pricing policies, and an adequate price or cap may well be politically unachievable. Second, there are some needed reductions that a carbon price will be unable to reach (e.g., some energy efficiency measures), requiring other types of solutions that carbon price revenue could help fund. Third, the reduction trajectory has to be so steep to achieve the global targets of keeping warming well below 2ºC (and below 1.5ºC if possible) that it seems imprudent to give away resources that could be used to help. Finally, the world has already warmed about 1°C and is already experiencing impacts from climate change, so the 1.5°C and 2°C targets do not necessarily represent what is "safe" – just what would provide a reasonable chance of avoiding the worst impacts of climate change. Even if a cap or tax could somehow get enacted that could achieve the 1.5°C and 2°C targets, there is a strong argument that some revenues should still go towards achieving even greater reductions.

[5] This presupposes that the external cost can be monetized. Since unabated greenhouse gas emissions are predicted to lead to global catastrophe, it could be argued that at some point, the social cost (externality) must be extremely high. It has also been argued that, because of the extremely long residency time of carbon dioxide in the atmosphere, the social cost of current emissions is higher than future emissions. This is equivalent to saying that early reductions are worth more than later ones.

Figure 1. CO_2 prices in markets around the world, compared to the social cost of carbon



Source: Jenkins & Karplus, 2016

Public polling shows that most people prefer to see carbon price revenue used to further the core purpose of the carbon price, such as by investing the revenue in clean energy technology. A 2016 Yale poll found that 81% of registered voters support using carbon tax revenue to support the development of clean energy, more than for any other use; the least popular uses of tax revenue were reducing corporate taxes (26%), reducing payroll taxes (46%), and returning the money as dividends to households (48%).[6] Similarly, a 2014 poll (National Surveys on Energy and Environment) found that a carbon tax with revenues used to fund research and development for renewable energy programs received 60% support, including support from majorities of Democrats, Republicans, and Independents – and greater support than rebate checks or deficit reduction.[7] Another 2014 poll found 75% support for enacting a carbon tax and using the revenues to pay for new, cleaner technologies for the future.[8]

Based on the climate policy programs that have already been adopted by states, using carbon price revenue to invest in reduction strategies and other activities related to climate change clearly seems to be the most popular approach. The two main U.S. carbon pricing jurisdictions –

[6] Yale, Nov 2016, http://climatecommunication.yale.edu/publications/politics-global-warming-november-2016/2/, http://climatecommunication.yale.edu/wp-content/uploads/2016/12/Global-Warming-Policy-Politics-November-2016.pdf
[7] National Surveys on Energy and Environment (NSEE), Spring 2014, Center for Local, State, and Urban Policy at the University of Michigan and the Muhlenberg College Institute of Public Opinion, http://closup.umich.edu/files/ieep-nsee-2014-spring-carbon-tax.pdf
[8] Beyond the Beltway report, Dec. 2014, Benenson Strategy Group and SKD Knickerbocker, https://www.scribd.com/doc/250250238/Beyond-the-Beltway-Report

California and the nine states in the Regional Greenhouse Gas Initiative (RGGI)[9] – have adopted cap-and-trade systems that auction allowances and invest much of the auction proceeds in reducing emissions through a variety of strategies, as well as in moderating the economic effects of the carbon price on their citizens. Many of the investments, though, support reductions already covered by the cap – potentially making the cap cheaper to achieve but not driving reductions beyond the cap.

The price-and-subsidy approach proposed in this paper generally follows the RGGI and California approach of investing revenue in climate-related activities – but with an explicit focus on using the revenue to drive reductions at greater scale and speed.

II. BASICS OF A PRICE-AND-SUBSIDY APPROACH

A price-and-subsidy approach can help accelerate reductions by putting a price on CO_2 and possibly other greenhouse gas emissions (the "stick") to create a financial disincentive to emit those gases, while also offering a subsidy (the "carrot") to encourage investment in additional reductions of emissions subject to the carbon price.[10] This is a market-based approach – the type that economists have long favored. Properly executed, it is both efficient and cost-effective. Like a traditional carbon price, a price-and-subsidy approach internalizes the externality associated with emissions by placing the social cost squarely on emitters. The key elements of this approach are:

1. Emitters pay for their emissions (e.g., via a carbon tax or allowances in a cap-and-trade system);
2. Proceeds from the carbon price are pooled and used to subsidize achievement of *additional* reductions (i.e., reductions beyond those that would have been achieved by the carbon price or cap itself); and
3. The additional reductions are achieved *cost-effectively* by:
   a. utilizing mechanisms, such as reverse auctions, that "buy" additional reductions, starting with the cheapest reductions beyond what the carbon price signal or cap alone would achieve;
   b. limiting subsidies to the difference (the delta) between the carbon price and the abatement cost of the reduction; and
   c. paying for reductions only as they occur.

The cost-effective features of a price-and-subsidy approach are designed to maximize the amount of additional reductions that can be achieved with the pooled revenues. For instance, paying for reductions only as they occur instead of offering upfront, multi-year payments to projects not only provides insurance against projects that fail to deliver, but also means that more revenues can be devoted to spurring earlier reductions from more projects.

Reverse auctions or other similar mechanisms can drive costs down and identify the cheapest opportunities to achieve additional reductions. Such mechanisms are already used in a range of

[9] Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont
[10] The issue of subsidizing reductions of emissions not subject to a tax or cap is complex and has given rise to a large body of literature. While the idea almost certainly has merit, it is beyond the scope of this paper.

jurisdictions to purchase renewable energy, energy efficiency, and emission reductions – though their funds do not appear to be linked to carbon price revenues, as in a price-and-subsidy approach. The Australian government, for example, instituted a reverse auction to purchase emission reductions, with the first auction occurring in April 2015.[11] Reverse auctions have also been used to achieve savings in purchasing renewable energy and energy efficiency in the United States, India, and elsewhere,[12] and the World Bank used reverse auctions for its Pilot Auction Facility for Methane and Climate Change Mitigation, which held its first auction in July 2015.[13]

Having subsidies cover only the difference between the cost of a reduction and the carbon price ensures that subsidies enhance instead of duplicate some or all of the effects of the carbon price. The carbon price creates an incentive to abate emissions, and the subsidies increase that incentive so higher-cost reductions can be achieved. The subsidies work in tandem with the carbon price, so that together they provide an abatement incentive that is greater than either by itself. The financial incentive to abate should equal their sum:

$$\text{abatement incentive} = \text{carbon price} + \text{subsidy}$$

Together, the carbon price "stick" and the subsidy "carrot" create a more powerful incentive that can drive higher levels of reductions more quickly. This price-and-subsidy approach can work with either a carbon tax (described in Section III below) or a cap-and-trade system (described in Section IV below), though there are some additional steps required with cap-and-trade to ensure the subsidized reductions are additional to what the cap alone would achieve.

III. PRICE-AND-SUBSIDY APPROACH: CARBON TAX

A simple way to implement a price-and-subsidy system is to adopt a carbon tax to incentivize reductions and use the revenue from the tax to provide subsidies for additional reductions.

Imagine a jurisdiction enacts a carbon tax of $20 per ton of carbon dioxide. Any entity that can reduce emissions for less than $20 per ton will do so, to avoid having to pay the tax. That is the

[11] Australian Government (2015), *About the Emissions Reduction Fund* website, https://www.environment.gov.au/climate-change/emissions-reduction-fund/about

[12] After the introduction of reverse auctions, prices in the UK dropped to about half that of the prices in Germany's feed-in tariff. In China, the average price for a reverse auction concession project was 0.47 Renminbi (RMb)/kWh, whereas the average for a non-concession project was 0.71 RMb/kWh. In Brazil, reverse auction prices for wind decreased from 148 R$/MWh in 2009 to 123 R$/MWh in 2011. Cozzi, P. (2012). *Assessing Reverse Auctions as a Policy Tool for Renewable Energy Deployment*. The Center for International Environment & Resource Policy. http://fletcher.tufts.edu/~/media/Fletcher/Microsites/CIERP/Publications/2012/May12CozziReverseAuctions.pdf. *See also* AEP Ohio. (2014). *Bid4efficiency* website. https://www.aepohio.com/save/business/programs/EnergyEfficiencyAuction/; Zahodiakin, P. (2012). *Connecticut Auction Cuts Clean Energy Costs While Providing a Template for Other States*. Breaking Energy. http://breakingenergy.com/2012/12/07/connecticut-auction-cuts-clean-energy-costs-while-providing-a-te/?icid=mostPopular2; Pearson, N. (2011). *India's 'Astonishing Auction' Pushes Down Global Solar Price*. Bloomberg Business. http://www.bloomberg.com/news/articles/2011-12-02/india-s-solar-power-bid-prices-sink-to-record-consultant-says

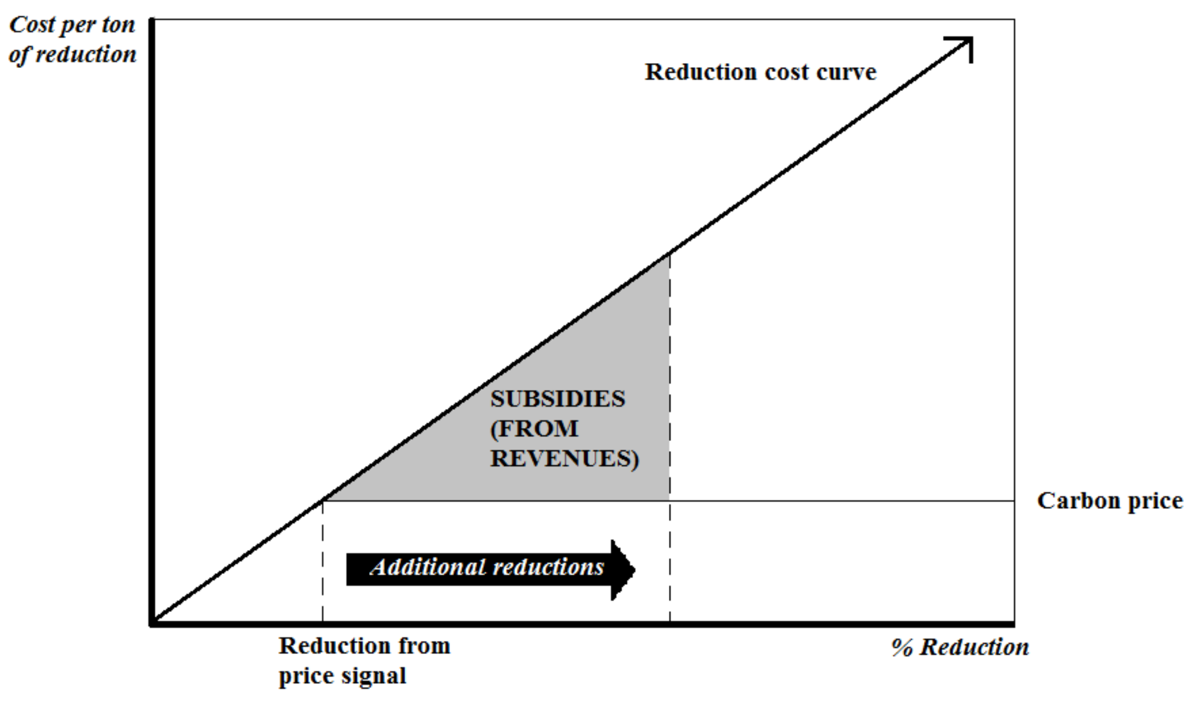
[13] Pilot Auction Facility for Methane and Climate Change Mitigation website, http://www.pilotauctionfacility.org/; The World Bank, *First Pilot Auction to Capture Methane a Success*, Press Release, July 17, 2015, http://www.worldbank.org/en/news/press-release/2015/07/17/first-pilot-auction-to-capture-methane-a-success

effect of the price signal sent by the carbon tax. If a reduction costs $21 a ton, however, the emitter's incentive is just to pay the tax. If, instead, that emitter is given a subsidy of $1/ton, and emitters with $22/ton reductions are given subsidies of $2/ton, then those reductions also would get made. Scaling this up, the carbon tax revenues could be collected and put into a fund, and then a reverse auction could be held, offering subsidies (equal to the delta between the carbon tax level and the per-ton cost of a reduction) to any emitter or project developer that wants to submit a bid for a way of achieving reductions.[14] The subsidies would go first to the cheapest reductions beyond the price signal, working up the reduction cost curve until all of the carbon price revenues have been spent.

Over time, as the carbon tax rises, some abatement activities that had received subsidies would no longer qualify. For instance, the emitters with the $22/ton reductions would no longer receive delta subsidies once the tax rises any higher than $22/ton, as the price signal alone should drive those reductions. (In other words, there is no longer a delta between the abatement cost and the carbon price that has to be filled in.) The risk of smaller or eliminated subsidies in later years as the tax level rises – and therefore having to bear more of the reduction costs themselves – should give emitters greater incentive to use the subsidies to make their reductions early.

Combined with the tax, the subsidies should massively increase the incentive to abate and, thus, the scale and rate of emission reductions, as illustrated in Figure 2 below.

Figure 2. A simplified price-and-subsidy approach



[14] If the project developer is not an emitter, it would not have to pay the carbon price. The subsidy therefore may not be sufficient to spur the project. Accordingly, for bids into the reverse auction, it may be desirable for project developers to partner with emitters whose emissions and carbon costs would be reduced by the subsidized project.

How much would reductions increase? If you take a very simplified case like the one in Figure 2 above – which, for instance, assumes that the reduction cost curve is linear – some quick math (detailed in the Appendix) suggests that the answer is: quite a lot. A carbon tax that would achieve a 10% reduction in emissions could, if all revenues were used to provide delta subsidies, instead theoretically achieve reductions of more than 40%, at the same cost to emitters and consumers. A carbon tax that would achieve a 20% reduction could instead theoretically achieve 60%. Table 1 below shows the range of enhanced reductions that could theoretically be achieved if all revenues from a carbon price mechanism, such as a carbon tax, were used to cost-effectively subsidize additional reductions.

Table 1. Additional reductions from using a price-and-subsidy approach

Reduction with Carbon Price Alone	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%
Reduction with Price-and-Subsidy	31%	44%	53%	60%	71%	80%	87%	92%	95%	98%	99%

A price-and-subsidy approach could achieve these higher levels of reductions at much lower cost to emitters and consumers than achieving them with a conventional carbon tax. Again, some quick math (detailed in the Appendix) suggests that a 40% reduction could, in theory, be achieved with a price-and-subsidy approach for a quarter of the cost of achieving a 40% reduction with a conventional carbon price mechanism, as shown in Table 2 below.

Table 2. Cost savings for achieving reductions using a price-and-subsidy approach

Reduction Level	40%	60%	80%
Cost with Price-and-Subsidy versus Carbon Price Alone	1/4	3/7	2/3

In the real world, it is unlikely that all of the carbon price revenues would go into a reverse auction to achieve reductions beyond those resulting from the carbon price alone. For one thing, technology, reliability, or other constraints beyond cost may limit the number of additional reductions that are achievable during a given period. Moreover, there are political and social realities to confront. Some percentage of the revenues probably should go to offset the regressive effects of the carbon price on the poor.[15] Some could go to help coal communities transition.[16] Some may have to go to tax relief or other areas needed to garner political support.

[15] Chad Stone, Center on Budget and Policy Priorities, *The Design and Implementation of Policies to Protect Low-Income Households under a Carbon Tax*, Sept. 2015, http://www.cbpp.org/research/climate-change/the-design-and-implementation-of-policies-to-protect-low-income-households

[16] Adele Morris, Brookings (2016). *Coal economy workers need help – and a carbon tax could provide it.* https://www.brookings.edu/blog/planetpolicy/2016/04/26/coal-economy-workers-need-help-and-a-carbon-tax-could-provide-it/

There are also other climate realities to confront. Some revenues probably should be used to promote adaptation and resilience to climate impacts. Polling suggests a sizable majority of registered voters support federal preparations for climate impacts, prioritizing impacts on public water supplies, agriculture, public health, and the electricity system.[17]

Another constraint on the use of carbon price revenues is the risk that subsidizing the cheapest available reductions could lock in technologies or infrastructure incompatible with deep decarbonization pathways. In some cases, it may be necessary to support longer-term carbon reduction investments that are not the cheapest near-term options but that may be needed to achieve long-term deep decarbonization (e.g., advanced nuclear, carbon capture and storage).

Nevertheless, a meaningful portion of the carbon price revenues should go towards cost-effectively achieving additional near-term reductions. Even a relatively small percentage of the revenues could give a significant boost to reductions, as some quick math (detailed in the Appendix) makes clear and as shown in Table 3 below. For example, given a carbon tax that would achieve a 20% reduction alone, it is theoretically possible to boost reductions to 27% using only 10% of the revenues, to 35% using a quarter of the revenues, or to 45% using half of the revenues.

Table 3. Additional reductions from using a percentage of revenues in a price-and-subsidy approach

Reduction with Carbon Price Alone	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%	90%
Reduction using 10% of Revenues	11%	17%	22%	27%	36%	46%	55%	64%	73%	82%	91%
Reduction using 25% of Revenues	16%	23%	29%	35%	44%	53%	61%	69%	77%	85%	92%
Reduction using 50% of Revenues	22%	32%	39%	45%	55%	63%	71%	77%	84%	89%	95%

While these numbers are just theoretical and are based on a simplified model, they highlight the potential power of a price-and-subsidy approach. By using carbon tax revenues to cost-effectively subsidize additional reductions, governments that are willing to adopt robust carbon taxes can achieve even higher levels of reductions, without increasing costs to emitters or consumers – or, looking at it differently, can achieve high levels of reductions far more cheaply than with a conventional carbon price alone. Governments not yet fully committed to ambitious climate action could still make tremendous progress by cost-effectively utilizing all or part of the revenues from a very modest carbon price. Revenue use matters.

[17] *See, e.g.*, Yale, Nov 2016, *supra* note 6.

Several governments that have instituted carbon taxes already invest the proceeds in emission reduction measures. Some have made investment of proceeds in reductions the central feature of the policy, while for others it is more peripheral. For example, the U.S. City of Boulder, Colorado, has a carbon tax based on electricity consumption that has funded most of the city's greenhouse gas reduction efforts since 2007, including transportation initiatives, energy efficiency, and renewable energy programs.[18] In Switzerland, one-third of carbon tax revenue is used to reduce emissions from buildings.[19] In Japan, a tax on fossil fuels known as the Tax for Climate Change Mitigation (or Global Warming Countermeasures Tax) directs its revenues toward various emission reduction measures, including energy conservation and renewable energy. In rolling out the tax, the Japanese government clearly distinguished between the 'price effect' on reductions and what it called the 'budget effect' (i.e., investing tax revenues for more reductions), projecting that by 2020 the budget effect will produce two to twelve times more reductions than the price effect.[20]

It is not apparent that any of these systems utilize a reverse auction or similar measures to spend the revenues cost-effectively. Nor is it clear that any of these systems limit subsidies to cover only the delta between the carbon price and the abatement cost or pay for reductions only as they occur. While these jurisdictions are rightly directing revenues toward achieving more reductions than they would achieve if they relied solely on the carbon price, it is unlikely that they will achieve the levels of reduction that could be reached with a true price-and subsidy approach.

IV. Price-and-Subsidy Approach: Cap-and-Trade

Virtually the same price-and-subsidy approach can be used with a cap-and-trade system, with the revenues for the reverse auction coming from allowance auctions or sales rather than from a carbon tax. In its most basic form, a cost-effective allowance-based price-and-subsidy system would involve establishing a cap, selling the allowances, putting the revenue into a fund, and holding a reverse auction that offers subsidies (equal to the delta between the allowance price and the per-ton cost of the reduction) to any emitter or project developer that wants to submit a bid for achieving reductions that cost more than the allowance price.[21] The subsidies would go first to the cheapest reductions beyond the price signal, working up the reduction cost curve, until the funds are fully committed. A price-and-subsidy cap-and-trade approach could achieve the same theoretical increases in reductions per dollar spent by emitters as shown in Tables 1 and 3, with the same cost savings, compared to a carbon price alone, as shown in Table 2.

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[18] City of Boulder. (2014). *Climate Action Home Page* website. https://bouldercolorado.gov/climate; City of Boulder. (2013). *Your CAP Tax Dollars at Work*. https://www-static.bouldercolorado.gov/docs/Tax_At-a-Glance_v05-1-201307081503.pdf

[19] Swiss Office fédéral de l'environnement (OFEV). (2013). *Objectif de réduction 2012 non tenu: hausse de la taxe CO2 sur les combustibles dès 2014*. Press release. http://www.bafu.admin.ch/dokumentation/medieninformation/00962/index.html?lang=fr&msg-id=49576; Chuffart, S. (2013) Switzerland raises its CO_2 tax by almost 70% in order to fulfill its Kyoto obligations. *Climate Law Blog, Columbia Law School Center for Climate Change Law*. http://blogs.law.columbia.edu/climatechange/2013/07/09/switzerland-raises-its-co2-tax-by-almost-70-in-order-to-fulfill-its-kyoto-obligations/

[20] Japan Ministry of the Environment. (2012). *Details on the Carbon Tax (Tax for Climate Change Mitigation)*. https://www.env.go.jp/en/policy/tax/env-tax/20121001a_dct.pdf

[21] As noted earlier, this section only discusses the use of subsidies to reduce emissions covered by the cap.

However, to ensure the reductions subsidized by the reverse auction are additional to the cap, an allowance must be retired or otherwise removed from the system for each subsidized ton of reduction.[22] Otherwise, excess allowances could be banked, or other emitters could use them instead of making reductions, which means the subsidized reductions would end up displacing reductions required by the cap instead of being additional.[23]

Another way to pull allowances tied to additional reductions out of the system is never to sell them in the first place. This would involve collecting up-front information about abatement opportunities (e.g., by issuing a request for proposals), contracting with emitters or project developers to make subsidized reductions, and selling only the amount of allowances needed to cover the remaining anticipated emissions.[24] A variant of this approach would involve having the allowance auction and the reverse auction rely on the same bids (assuming the universe of bidders for allowances is the same as the universe of bidders for reduction subsidies).

Alternatively, and more simply, it probably would be sufficient to reduce the number of allowances sold in subsequent auctions to reflect the number of reductions that, to date, have been achieved by means of subsidies. Subsidizing additional reductions means that the actual level of emissions at the start of successive compliance periods may already be below the cap levels set for those periods, even assuming the cap declines over time. Reducing allowance sales to account for prior subsidized reductions would allow a jurisdiction to ratchet its cap down further – and then continue to use allowance revenues to drive even more reductions. As with a price-and-subsidy carbon tax, the risk of rising allowance prices over time – and thus reduced or eliminated subsidies – should give emitters greater incentive to use the subsidies to make their reductions early.

Several existing cap-and-trade programs already use revenues to achieve reductions. In the United States, both the California economy-wide cap-and-trade program and the RGGI cap-and-trade program for the electric power sector use revenues from allowance auctions to pay for measures to reduce emissions. In California, auction proceeds go into a Greenhouse Gas Reduction Fund to support programs on sustainable communities, clean transportation, energy efficiency, and clean energy.[25] The California Legislative Analyst's Office, though, has questioned the cost-effectiveness of the program and whether additional reductions (beyond those required by the cap) are actually being achieved, given that subsidies were larger than needed and the allowances freed up by the reductions remained in the system for others to use

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[22] Allowances removed from the system could also be added into the cost containment reserve, if there is one.

[23] The Emissions Containment Reserve proposed as part of the RGGI program review process is a somewhat similar idea. *See* Resources for the Future, *An Emissions Containment Reserve for RGGI: How Might It Work?*, webinar, Feb. 7, 2017, http://www.rff.org/events/event/2017-02/emissions-containment-reserve-rggi-how-might-it-work

[24] For more on this idea, *see* CLPP, *Using "Action Caps" to Boost Ambition and Lower Costs for Clean Power Plan Compliance*, April 2016, http://www.clpproject.org/CPP Action Caps Apr 2016.pdf

[25] California Legislative Analyst's Office. (2014). *The 2014-15 Budget: California Spending Plan*. http://www.lao.ca.gov/reports/2014/budget/spending-plan/california-spending-plan-080414.pdf; State of California. (2013). *Cap-and-Trade Auction Proceeds Investment Plan: Fiscal Years 2013-14 through 2015-16*. http://www.arb.ca.gov/cc/capandtrade/auctionproceeds/final_investment_plan.pdf

rather than make reductions themselves.[26] The price-and-subsidy approach addresses both of those issues.

RGGI states decided from the outset to use some or all of the revenues from auction sales to achieve reductions. From 2009-2014, the RGGI states invested more than $1 billion from allowance auction revenues into state programs to advance energy efficiency, clean and renewable energy, and greenhouse gas abatement in multiple sectors. These programs have avoided about 1.7 million short tons of CO_2 emissions to date and are projected to avoid more than 15 million short tons over their lifetime (in addition to returning nearly $4.7 billion in lifetime energy bill savings to 4.6 million households and 21,400 businesses in the region).[27] It is difficult to tell, however, how many of those reductions are additional to the cap. Some (e.g., in transportation and forestry) are clearly additional, as these sectors are not under the cap, but the investments in energy efficiency and renewables are responsible for the bulk of the RGGI-attributed emission reductions, and at least some of those reductions are occurring within the cap.

Thus, while California and the RGGI states are rightly directing revenues toward addressing climate change, it is unclear how much of the spending is achieving reductions beyond the caps. These states also do not appear to be using reverse auctions or other mechanisms to cost-effectively subsidize reductions, nor do they seem to be limiting subsidies to the delta between the carbon price and the per-ton abatement cost. Using a price-and-subsidy approach could boost and accelerate the reductions made under their caps.

CONCLUSION

With the steep emission reduction trajectory needed to avoid the worst impacts of climate change – and the urgent need for state leadership, given the climate views of the current U.S. administration – states and other jurisdictions should explore how they can use a price-and-subsidy approach to spur greater action.

Using a price-and-subsidy approach would allow ambitious governments to implement strong carbon price mechanisms that are acceptable to their citizens and still aim for much higher levels of reductions than would be achieved by carbon prices alone – without increasing costs for emitters or consumers. Governments that only want to test the waters can set a low carbon price and still make good progress by using a price-and subsidy approach to direct the revenues toward additional reductions. Polling suggests the public would support these kinds of policies.

A price-and-subsidy approach, even if it utilizes only a portion of revenues, can help move jurisdictions onto an emissions trajectory more commensurate with the urgency of the climate challenge. Combining the “carrot” of cost-effective subsidies with the “stick” of carbon prices can dramatically accelerate the drive towards a zero-carbon future.

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[26] California Legislative Analyst’s Office. (2016). *Cap-and-Trade Revenues: Strategies to Promote Legislative Priorities*. http://www.lao.ca.gov/Publications/Report/3328

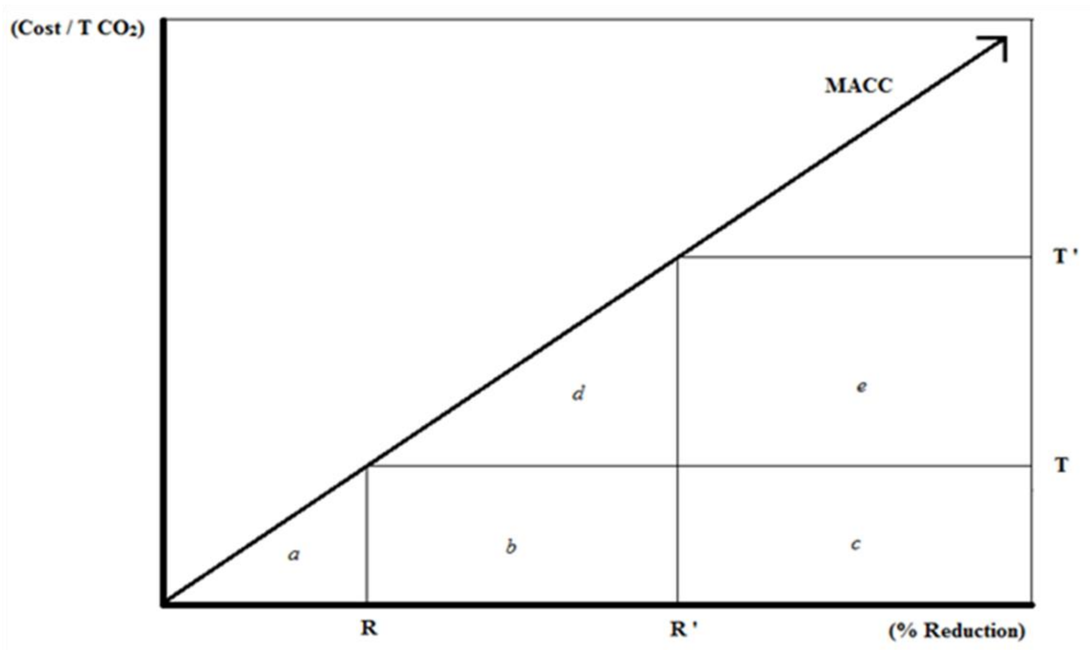
[27] RGGI (Regional Greenhouse Gas Initiative). (2016). *The Investment of RGGI Proceeds Through 2014.* https://www.rggi.org/docs/ProceedsReport/RGGI_Proceeds_Report_2014.pdf

APPENDIX: DERIVATIONS OF EQUATIONS

Derivation of R' Using All Revenues for Subsidies (Table 1)

Figure A.1

Price-and-Subsidy Approach: All Revenues Used for Subsidies



Diagonal arrow: marginal abatement cost curve (MACC)
T: Carbon tax or allowance price level
R: Reduction achieved by the price signal of a carbon tax set at T or by a cap set at R
R': Reduction achieved by investing all carbon price revenues in additional reductions
T': Conventional carbon tax that would have been needed to achieve R', or allowance price of cap set at R'
a: Cost to emitters of achieving reduction R
b: Investment by emitters in achieving additional reductions under a price-and-subsidy approach
c: Amount paid by emitters in carbon taxes or for allowances under a price-and-subsidy approach
d: Subsidies from the reverse auction fund to achieve additional reductions
a + *b* + *c*: Expenditures by emitters to achieve reduction R under conventional tax set at T or conventional cap set at R, or to achieve reduction R' under a price-and-subsidy approach
a + *b* + *c* + *d* + *e*: Expenditures by emitters to achieve reduction R' under a conventional tax set at T' or conventional cap set at R'

The simplified model in Figure A.1 captures the whole process, from initial levying of a carbon price through achievement of the subsidized additional reductions; there is no time element in the graphic. If no revenue is used to subsidize additional reductions, then carbon price revenue is T(1 – R), which equals *b* + *c*. Once additional reductions start occurring, the expenditure of *b* by emitters is redirected from paying the tax or allowance price to being invested directly in achieving the additional reductions. The subsidies for additional reductions are *d*. If all revenues go to subsidies, then the amount by which state revenue goes down (the foregone revenue *b* plus the collected revenue *c* spent for subsidies) will equal the cost of additional reductions (the spending *b* by emitters to achieve reductions plus the spending *d* by the state in the form of subsidies). So, $b + c = b + d$, which means $c = d$.

$c = T(1 - R')$
$d = (R' - R)(T' - T)/2$
So $T(1 - R') = (R' - R)(T' - T)/2$

Because the MACC is linear, the ratio of R' to R is the same as the ratio of T' to T, so:
$T'/T = R'/R$
$T' = TR'/R$

Substituting TR'/R for T' above:
$T(1 - R') = (R' - R)(TR'/R - T)/2$
$T - TR' = (TR'^2/R - TR' - TR'R/R + TR)/2$
$1 - R' = (R'^2/R - R' - R'R/R + R)/2$
$1 - R' = (R'^2/R - 2R' + R)/2$
$2 - 2R' = R'^2/R - 2R' + R$
$2 = R'^2/R + R$
$2R = R'^2 + R^2$
$2R - R^2 = R'^2$
$\sqrt{(2R - R^2)} = R'$

Cost of Price-and-Subsidy Approach versus Carbon Price Alone (Table 2)

Again, because the MACC is linear, the ratio of R' to R is the same as the ratio of T' to T, so:
$T' = TR'/R$

C_A = cost to emitters to get to R' under a price-and-subsidy approach = $a + b + c$, which, if all revenues go to subsidies (and thus *c* equals *d*), also equals $a + b + d$.
$C_A = a + b + d = T'R'/2$
$= TR'/R \times R'/2$
$= TR'^2/2R$

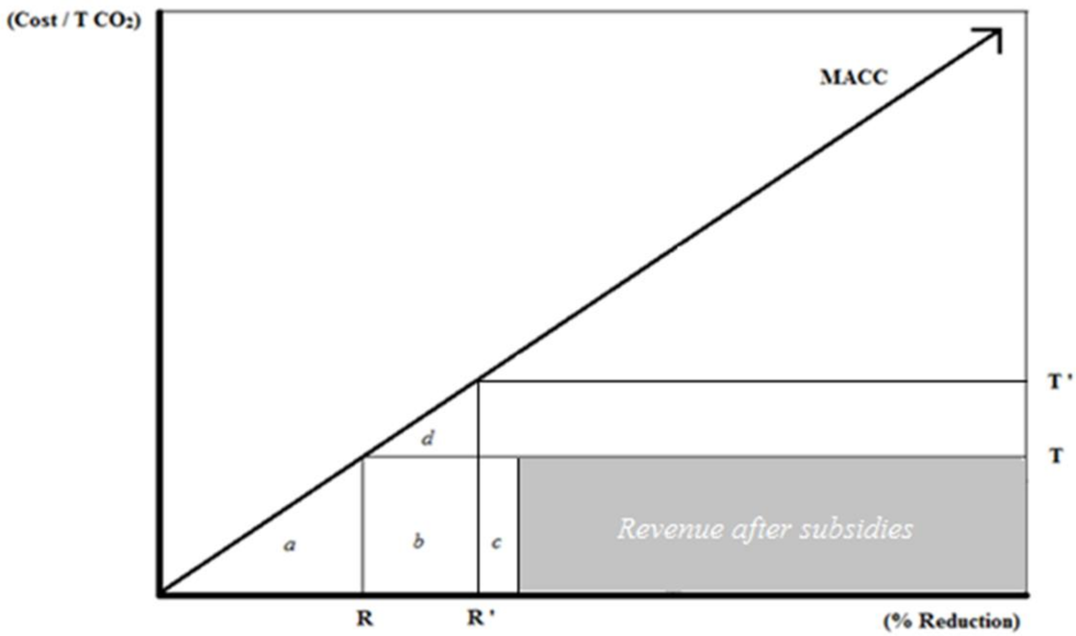
C_C = cost to emitters to get to R' under a carbon price alone = $a + b + c + d + e$ = triangle $a + b + d$ plus rectangle $c + e$
$c + e = T'(1 - R') = TR'/R \times (1 - R') = TR'/R - TR'^2/R$
So $a + b + c + d + e = TR'^2/2R + TR'/R - TR'^2/R$
$= TR'^2/2R + 2TR'/2R - 2TR'^2/2R$
$= 2TR'/2R - TR'^2/2R$
$= (2TR' - TR'^2)/2R$

$C_A / C_C = (TR'^2/2R)/[(2TR' - TR'^2)/2R]$
$= TR'^2/(2TR' - TR'^2)$
$= R'^2/(2R' - R'^2)$
$= R'/(2 - R')$

Derivation of R' Using a Percentage of Revenues for Subsidies (Table 3)

Figure A.2

Price-and-Subsidy Approach: Percentage of Revenues Used for Subsidies



Diagonal arrow: marginal abatement cost curve (MACC)
T: Carbon tax or allowance price level
R: Reduction achieved by the price signal of a carbon tax set at T or by a cap set at R
R': Reduction achieved by investing a portion of carbon price revenues in additional reductions
T': Conventional carbon tax that would have been needed to achieve R', or allowance price of cap set at R'
a: Cost to emitters of achieving reduction R
b: Investment by emitters in achieving additional reductions under a price-and-subsidy approach
c: Portion of the amount paid by emitters in carbon taxes or for allowances that is used to provide subsidies under a price-and-subsidy approach
d: Subsidies from the reverse auction fund to achieve additional reductions

In Figure A.2, if no revenue is used to subsidize additional reductions, then, as in Figure A.1, carbon price revenue is T(1 – R). If, however, a percentage (P) of that revenue is used to subsidize additional reductions, then the amount by which state revenue goes down (the foregone revenue *b* plus the portion *c* of collected revenue spent for subsidies) will equal the cost of additional reductions (the spending *b* by emitters to achieve reductions plus the spending *d* by the state in the form of subsidies). So, $b + c = b + d$, which means $c = d$. (Of course, if P = 100%, meaning all revenues are spent on subsidies, then Figure A.2 and its associated equation for R' would be identical to Figure A.1 and its equation for R'.)

$b + c = PT(1 – R)$
$b = T(R' – R)$

$d = (R' - R)(T' - T)/2$
So $PT(1 - R) = T(R' - R) + (R' - R)(T' - T)/2$

Again, because the MACC is linear, the ratio of R' to R is the same as the ratio of T' to T, so:
$T' = TR'/R$

Substituting TR'/R for T' above:
$PT(1 - R) = T(R' - R) + (R' - R)(TR'/R - T)/2$
$PT - PTR = TR' - TR + (TR'^2/R - TR' - TR'R/R + TR)/2$
$P - PR = R' - R + (R'^2/R - R' - R'R/R + R)/2$
$P - PR = R' - R + (R'^2/R - 2R' + R)/2$
$2P - 2PR = 2R' - 2R + R'^2/R - 2R' + R$
$2P - 2PR = R'^2/R - R$
$2P = R'^2/R - R + 2PR$
$2P = R'^2/R - (1 - 2P)R$
$2PR = R'^2 - (1 - 2P)R^2$
$2PR + (1 - 2P)R^2 = R'^2$
$2PR - (2P - 1)R^2 = R'^2$
$\sqrt{[2PR - (2P - 1)R^2]} = R'$