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Synthesis Articles

Underwriting 1.5°C: competitive approaches to financing accelerated climate change mitigation

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ABSTRACT

Delivering emission reductions consistent with a 1.5°C trajectory will require innovative public financial instruments designed to mobilize trillions of dollars of low-carbon private investment. Traditional public subsidy instruments such as grants and concessional loans, while critical to supporting nascent technologies or high-capital-cost projects, do not provide the price signals required to shift private investments towards low-carbon alternatives at a scale. Programmes that underwrite the value of emission reductions using auctioned price floors provide price certainty over long time horizons, thus improving the cost-effectiveness of limited public funds while also catalysing private investment.

Taking lessons from the World Bank's Pilot Auction Facility, which supports methane and nitrous oxide mitigation projects, and the United Kingdom's Contracts for Difference programme, which supports renewable energy deployment, we show that auctioned price floors can be applied to a variety of sectors with greater efficiency and scalability than traditional subsidy instruments. We explore how this new class of instrument can enhance the cost-effectiveness of carbon pricing and complementary policies needed to achieve a 1.5°C outcome, including through large-scale adoption by the Green Climate Fund and other international and domestic climate finance vehicles.

Key policy insights

- Traditional public climate finance interventions such as grants and concessional loans have not mobilized private capital at the scale needed to decarbonize the world economy consistent with the 2°C target, much less 1.5°C, and will likely face ongoing constraints in the future.
- Auctioned price floors – subsidies that offer a guaranteed price for future emission reductions – maximize climate impact per public dollar while incentivizing private investment in low-carbon technologies.
- This new subsidy instrument, if applied at scale via the Green Climate Fund and other domestic and international climate finance vehicles, can promote private sector competition to bring down technology costs and drive innovation, thereby supporting a longer term transition to regulation and sector- or economy-wide carbon markets.
- To facilitate the transition from public subsidy to the market-based support of climate mitigation, auctioned price floors should work in tandem with carbon pricing and complementary policies, using the same accounting and monitoring, reporting and verification toolkits.

KEYWORDS:

Auctions capital investment carbon finance market mechanisms financial incentives economic efficiency

I. Introduction

Limiting global temperature rise to 1.5°C requires an all-out effort to shift the global economy onto a high-efficiency, low-carbon pathway. The 2015 Paris Agreement recognizes the role of both climate finance and carbon market approaches in meeting this challenge (UNFCCC, 2015). However, with current and projected volumes of climate finance inadequate for meeting even a 2°C scenario, the toolkit of existing public finance instruments such as grants, loans and loan guarantees will fall far short of mobilizing the private investment required to achieve a 1.5°C target.

The OECD foresees only incremental growth in climate finance, estimating that public, North–South flows will increase from $45 billion in 2014 to $67 billion in 2020, while mobilized private investment will grow from $17 to $24 billion over the same period (OECD & Climate Policy Initiative, 2015; Bodnar, Brown, & Nakhooda, 2015). Total climate finance flows (including private, North–North and South–South investments) averaged $364 billion in 2011–2014 (CPI, 2015). These figures – both current and projected – pale in comparison to the scale of required investment, with the IEA estimating that a 2°C scenario will require $16.5 trillion in global low-carbon and energy-efficient investment over the next 15 years – an annual average of $1.1 trillion (IEA, 2017).

Limiting warming to 1.5°C is more difficult still, with Rogelj et al. (2015) finding that a 1.5°C scenario will cost roughly '1.5–2.1 times' more than a 2°C scenario between 2010 and 2100 (Rogelj et al., 2015, p. 525). Hof et al. (2017) corroborate these estimates in their models for 2030 emission levels and abatement costs, finding that the global abatement costs of achieving 1.5°C are 'twice as high' as those for 2°C, and 'even five to six times as high' as those for all actions proposed in current nationally determined contributions (NDCs) under the Paris Agreement; the aggregate incremental cost of achieving 1.5°C against current NDCs has been estimated at $600 billion annually (Hof et al., 2017, p. 35). Notably, these models are among the few that solve for a 1.5°C scenario, with Clarke et al. (2009) and IPCC (2014) pointing to the difficulty of achieving even the 2°C target. In short, limiting global warming to 1.5°C requires transformative, not incremental, growth in climate finance flows. Given the inherent limits of public finance tools, the innovation in financial instruments must be correspondingly transformative.

In response to this challenge, this article analyses a promising new financial tool at the intersection of climate finance and carbon markets: auctioned price floors for emission reductions.[1] Our research argues that auctioned price floors outperform grants and loans in terms of efficiency and scalability. Denominating climate finance in the currency of emission reductions – tons of CO_2 equivalent – and allocating scarce public subsidies via a transparent and competitive process to private sector actors can bring down technology costs and foster the innovation required to help achieve the 1.5°C target.

We first survey the current state of climate finance and carbon markets in the context of the Paris Agreement's objectives, describing the context in which auctioned price floors have emerged. We then introduce the theory of auctioned price floors, including the potential for this instrument to mobilize private climate finance and build on carbon market infrastructure (Betz, Seifert, Cramton, & Kerr, 2010; Milgrom, 2004; Pizer, 2011). We then describe the experience with pilot applications to date, principally in the context of the World Bank's Pilot Auction Facility for Methane and Climate Change Mitigation (PAF) and the UK's Contracts for Difference (CfD) programme for renewable energy. Building on the analysis of these programmes, we discuss lessons learned and considerations for policy makers. Finally, we explore the potential for replicating and scaling the model, including applications to the Green Climate Fund (GCF) under the UN Framework Convention on Climate Change (UNFCCC).

II. Delivering climate finance in the context of the Paris agreement

i. Subsidies and effective climate policy

Subsidies, together with carbon markets, taxes and other climate policy instruments, form an important part of the overall climate policy portfolio (Aldy, Barrett, & Stavins, 2003; Keohane & Victor, 2011). Similar to the negative global warming externality demanding a price on GHGs, the positive learning-by-doing externality calls for a direct subsidy on low-carbon technologies well beyond merely substituting for the inadequacy of carbon pricing systems (Acemoglu, Aghion, Bursztyn, & Hemous, 2012). Subsidizing low-carbon technologies also lowers the cost of climate policy, thus smoothing the political passage of first-best carbon pricing policies (Meckling, 2011; Wagner et al., 2015).

Effectively allocating limited public subsidies poses a challenge under any circumstances. For one, it necessitates 'picking winners'. It also comes with the difficulty of setting subsidies at appropriate levels to motivate the desired activity without generating excess rents. Moreover, raising public funds itself causes distortions in the form of deadweight losses associated with taxation (Kay, 1980).

Subsidies have been an integral part of the global climate regime for decades, enshrined in the 1992 UNFCCC via the concept of 'agreed incremental cost' to be paid by developed countries for mitigation actions in developing countries (UNFCCC, 1992). The Paris Agreement explicitly maintains the financial obligations of developed countries as set out in the UNFCCC. Although the Paris Agreement establishes the general objective of 'making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development' (UNFCCC, 2015), it does not offer a roadmap for achieving the requisite transformation of current financial investment patterns.

ii. The state of climate finance

The Paris Agreement's emphasis on continuity – including carrying forward the $100 billion North–South mobilization goal articulated under the 2009 Copenhagen Accord and the 2010 Cancun Agreements – raises the question of whether an incremental evolution of the current climate finance toolkit is likely to deliver investments needed to keep 1.5°C within reach. To be sure, the last 10 years have seen an explosion of climate funds and finance initiatives at the global, regional and national levels. The GCF has been capitalized with an initial $10.2 billion (Peake & Ekins, 2017). The Climate Investment Funds have allocated $8.3 billion (Climate Investment Funds, 2017) and development finance institutions have substantially increased climate finance; for example, the US Overseas Private Investment Corporation (OPIC) increased clean energy investment from $155 million in 2010 to an average of over $1.2 billion in 2013–2015 (OPIC, 2010, 2011, 2012, 2013, 2014,2015). Multilateral development banks have similarly rebalanced their portfolios, with the Asian Development Bank pledging to double annual climate finance from $3 billion in 2015 to $6 billion in 2020, while the African Development Bank has proposed to triple its climate funding to 40% of its overall portfolio by the same year (Multilateral Development Banks, 2015).

Despite this progress, public finance has not managed to mobilize significant private unlocking institutional investor capital (OECD & Climate Policy Initiative, 2015). The reasons for this poor performance are complex but include the relatively higher capital costs of some low-carbon energy technologies, the presence of markets dominated by incumbent fossil fuel technologies (which still receive significant subsidies) and the risks of doing business in many emerging markets (Wilkinson, 2017). Another contributing factor is the insufficient level of innovation, coordination and efficiency on the part of public sector actors. While traditional development finance tools such as grants and loans may develop enabling conditions for private investment, they have not adequately addressed these challenges. Furthermore, grants and loans offer no systematic way to ensure public funds are being allocated efficiently and can be highly time-intensive and costly to administer and monitor (Ciplet, Mueller, & Roberts, 2010; World Bank Group, 2013). New climate finance instruments that work in tandem with market forces while making more efficient use of public resources are needed.

iii. The evolving role of carbon markets in mobilizing capital

Carbon finance – the monetization of emission reductions to finance mitigation actions – has demonstrated its potential to mobilize climate finance. By delegating part of national emission reduction targets to private firms via market mechanisms, governments create a private source of capital for the same subsidies they seek to deliver via policy instruments such as grants and feed-in tariffs. The Kyoto Protocol's Clean Development Mechanism (CDM) has become the largest mitigation policy instrument under the UNFCCC, mobilizing over $400 billion (UNEP, 2017a, 2017b; UNFCCC, 1997). CDM activities have generated more than 1.7 billion issued certified emission reductions (CERs), and offer a theoretical mitigation potential of up to 10.7 billion CERs by 2020 and 18.7 billion CERs through 2030 (UNEP, 2017a, 2017b). Voluntary carbon standards such as the Gold Standard, VCS and Climate Action Reserve have also generated substantial mitigation pipelines.

However, carbon markets have suffered from low prices partly as a result of weak global mitigation ambition, and have therefore not lived up to their full potential as a major driver of low-carbon investment and substitute for public subsidies. The World Bank estimates that 'an international (carbon) market could reduce the cost of delivering the emission reductions identified in the current INDCs by about a third by 2030' (World Bank Group, 2016), while the integrated assessment models cited above estimate even higher cost reductions (Hof et al., 2017, p. 39). Yet, many ongoing on investment because carbon prices have not provided a meaningful signal for shifting investment decisions.

Despite these challenges, the CDM in particular has evolved significantly from its original purpose as an offset mechanism to a potentially powerful tool for climate finance (Michaelowa et al., 2015). The CDM has generated more than 200 internationally recognized baseline and monitoring methodologies for measuring mitigation results in a large variety of sectors (UNFCCC, 2017b). As a result, the CDM offers a readily available, UNFCCC-approved monitoring, reporting and verification (MRV) toolkit for generating GHG-denominated result units (Mikolajczyk et al., 2016). Because CERs are issued outside the host country by a third party (the UNFCCC), the CDM provides a novel way for investors to support low-carbon investment in developing countries while minimizing delivery and currency risk. Moreover, CDM programmatic approaches have allowed for the efficient aggregation of projects and lower transaction costs (e.g. for distributed energy access models) (Figueres, 2006; Figueres & Streck, 2009). This experience offers a foundation upon which results-based climate finance tools can build to deliver mitigation impacts at scale.

iv. Linking climate finance and carbon finance

Deepening the integration of climate finance and carbon finance enhances the effectiveness and transparency of delivering mitigation results while also encouraging private investment (Michaelowa, 2012). Specifically, public climate finance and private carbon finance can mutually reinforce their respective strengths through competitive auctions for emission reductions units to be purchased and retired. Carbon market methodologies offer an internationally accepted set of tools to quantify emission reductions and a means to monitor, report and verify results. Using tons of CO_2e reductions as the currency of climate finance creates a single, transparent benchmark for measuring results. Two decades of experience with the CDM and other carbon market standards has increased familiarity within the private sector, including banks, with the notion of using carbon purchase contracts to underwrite project finance.

The World Bank’s Carbon Initiative for Development, the PAF and the Forest Carbon Partnership Facility have all tested models whereby carbon credits are procured and then cancelled as a means of delivering results-based finance, thereby generating net climate benefits compared to an offsetting approach. Recently, the CDM registry has accounting of cancelled CERs (UNFCCC, 2017a). Article 5 of the Paris Agreement has a strong commitment to results-based finance for forests, while Article 6 establishes a potentially important role for a new generation of carbon market approaches and results-based finance in the Paris Agreement architecture. In addition, from its earliest days, the GCF explored purchasing sustainable energy CERs through reverse auctions under its Private Sector Facility (GCF, 2013). The following section provides the theoretical underpinnings of these emerging ‘quantity-performance’ instruments.

III. The theory of auctioned price floors

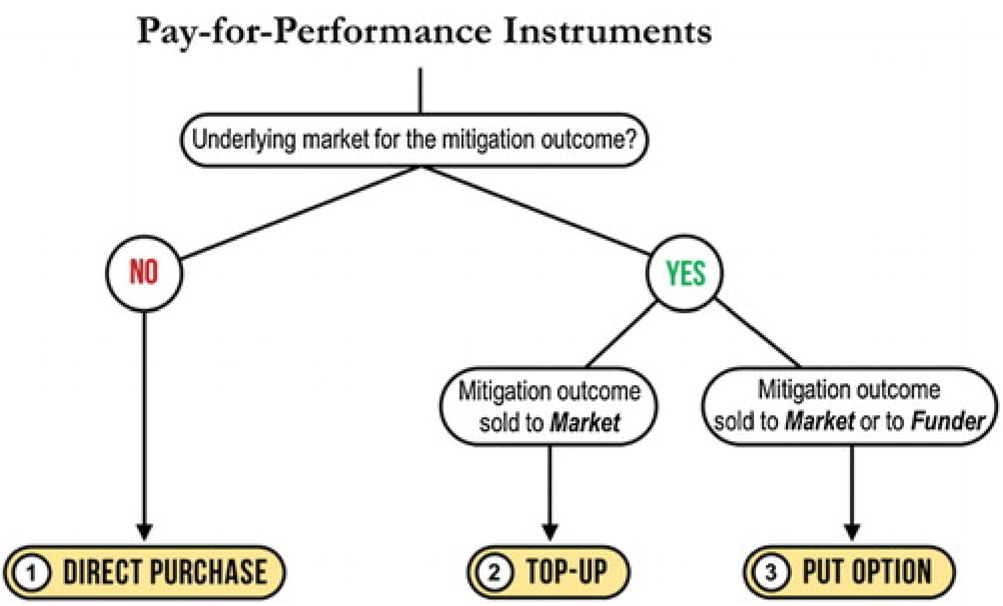
i. Pay-for-performance and quantity-performance instruments

‘Pay-for-performance’ mechanisms, also known as results-based finance, offer perhaps the most effective way of spending limited public funds to mobilize private capital for climate change mitigation (Ausubel, Cramton, Aperjis, & Hauser, 2014; Climate Focus & Ecofys, 2016; Pizer, 2011). Unlike input- or activity-based approaches, pay-for-performance mechanisms deliver funding only upon achievement of pre-defined and verified results, thus transferring risk from public donors to private service providers. Pay-for-performance instruments rely on clear and verifiable yardsticks for measuring results, which may be either quantitative (e.g. tons of carbon dioxide equivalent) or qualitative (e.g. successful completion of a mitigation project).

‘Quantity-performance’ instruments are a subset of pay-for-performance mechanisms that disburse finance for performance assessed in terms of quantities (Ghosh, Muller, Pizer, & Wagner, 2012). To date, public funders have adopted several variations on quantity-performance instruments. In the case of direct purchase agreements, a public funder contracts emission reductions at a fixed price directly from the project implementer. The public funder thus pays the incremental cost necessary to achieve a particular emission reduction. Perhaps the most advanced example of the direct purchase model is Australia’s Emission Reduction Fund, an AUD 2.55 billion concessional financing vehicle that supports domestic climate mitigation projects across a variety of sectors. The Fund purchases and cancels domestic Australian Carbon Credit Units (ACCUs) via fixed price spot and forward contracts (Government of Australia Department of Energy and the Environment, 2017). Sellers have a legal responsibility to deliver the contracted volumes and do not have the option to sell

By contrast, put options and top-up instruments offer price floors while allowing holders to sell to the market, thus ensuring that the private sector developer receives at least a minimum price for emission reductions. In the case of put options, the funder offers a floor price and the project implementer may sell emission reductions to either the funder or to the market (e.g. World Bank Pilot Auction Facility). With top-up instruments, the funder pays the difference between the guaranteed price and the market price, with the project implementer always selling to the market (e.g. UK Contracts for Difference). The three mechanisms – direct purchase, put options and top-ups – can be understood as stages in the evolution of the role of the public subsidy, with concessional finance playing varying roles depending on the level of market development and private sector participation (Figure 1).

Figure 1. Typology of pay-for-performance instruments. Source: Climate Focus & Ecofys (2016).



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ii. Auctioned put option

The auctioned put option for emission reductions offers perhaps the most advanced – and flexible – pay-for-performance subsidy instrument (Ghosh et al., 2012). This instrument provides option holders with the right, but not the obligation, to sell future emission reductions to the funder at a predetermined price (the 'strike price'). The options must be purchased at the 'premium price', meaning that the price per emission reduction equals the strike price minus the premium price. Unlike direct purchase ownership to projects most likely to deliver results. The public funder only pays the strike price for emission reductions verified through existing market infrastructure.

Auctions provide a competitive and transparent means for determining both the price per emission reduction and the allocation of options, promoting effective price discovery and ensuring that the public sector pays as little as possible for emission reductions. Through online auctions, private sector participants bid in multiple rounds by submitting a quantity of options demanded at a series of prices.[2] Auctions can be structured as either reverse auctions, in which the premium price is fixed and bidders bid down the strike price, or as forward auctions, in which the strike price is fixed and bidders bid up the premium price. In both cases, bidders drop out as the price per emission reduction (the strike price minus the premium) decreases, forcing private sector participants to underbid each other and thus maximizing the impact of funds. Other public auctions have produced similar results, e.g. at least 44 countries have held auctions in the electricity sector (Ecofys, 2016; IRENA, 2013; Milgrom, 2004).

Together, the put option as pay-for-performance instrument plus the auction as allocation tool address several barriers to climate finance (Table 1). The primary benefit to the private sector is reduced market risk, as the public fund guarantees a minimum price for future emission reductions. Furthermore, while carbon price instability has historically posed a major barrier for project developers seeking to raise capital, price floor contracts can be used as collateral by the private sector to raise up-front project finance, much as a wind developer can use a power purchase agreement from a creditworthy utility to raise debt. While paying an option premium itself requires capital resources unavailable to some developers, an auction open to all market participants enables the subsidy to be delivered in other ways. For example, commercial banks can purchase the options and package their subsidy value into the pricing of debt products, while technology suppliers can do the same via vendor financing.

Table 1. Advantages of the auctioned put option.

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For the public funder, the auctions guarantee the minimum subsidy per ton of carbon dioxide equivalent, thus maximizing progress towards 1.5°C, while also eliminating how much). This approach therefore minimizes overhead costs, also relying on existing carbon market systems for project monitoring and verification. This approach also mitigates public sector risk by disbursing payments only for results in the form of actual emission reductions achieved. Finally, auctioned put options support emerging markets for climate assets, ensuring that public funding takes advantage of, and does not crowd out, private sector financing.

While the put option offers several desirable features, there are clear trade-offs compared to the other quantity-performance instruments. First, if the carbon market does not deliver carbon prices that motivate investments, the put option relies on the ongoing availability of public funds; conversely, top-ups require an underlying private market. Second, both the put option and top-up approaches tend to favour mature technologies, whereas direct purchase contracts may be more applicable for early-stage technologies. Third, while the tradability of the options maximizes the probability of achieving results, it also creates the opportunity for speculative financial gain. Finally, as with any pay-for-performance instrument, all three instruments require project implementers to have sufficient access to other forms of finance, as well as the capacity to monitor, report and verify results. The following section explores how these theoretical advantages and barriers have played out in practice.

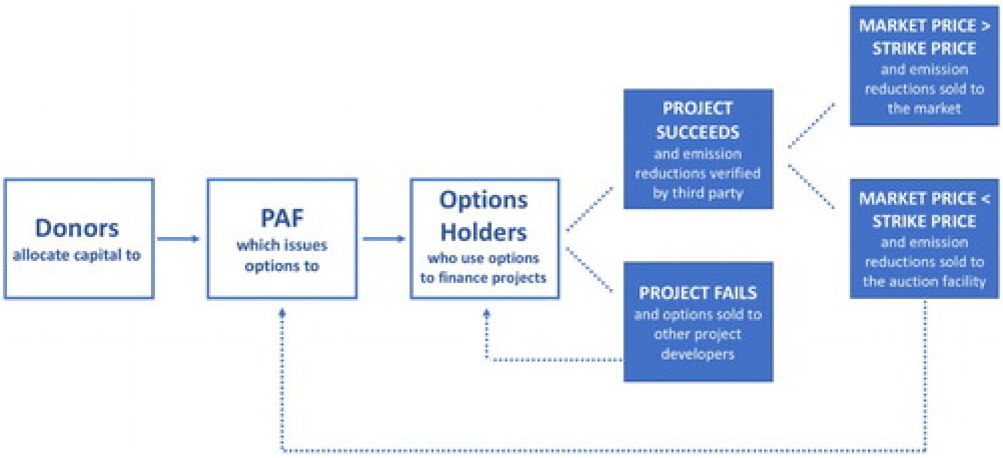
IV. Implementation and results of auctioned price floors

Initial evidence from the World Bank's Pilot Auction Facility for Methane and Climate Mitigation (PAF) and the United Kingdom's Contracts for Difference programme (CfD) indicates that auctioned put options and auctioned top-ups, respectively, offer effective models for maximizing the impact of public climate funds while also mitigating private sector risk and supporting market development.

i. Pilot auction facility

Developed by the World Bank Group and supported by funding from Germany, Sweden, Switzerland and the US, the PAF is a $53 million pilot programme designed to stimulate private investment in projects that reduce greenhouse gas emissions in developing countries. Through the issuance of tradable put options, technically structured as zero-coupon World Bank bonds called Pilot Auction Facility Emission Reduction Notes carbon market prices rise above this floor, option holders may sell their emission reductions to the market rather than the PAF. Conversely, if prices fall below the floor, the option holder has the right to sell emission reductions to the PAF at the strike price; in this case, credits are cancelled and not used as offsets. The PAF determines the price floor through online auctions, which reveal the minimum price required by the private sector to invest in emission reductions, therefore achieving the highest volume of climate benefit per dollar (World Bank Group, 2015) (Figure 2).

Figure 2. Pilot auction facility model.



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Between 2015 and 2017, the PAF conducted three pilot auctions. The first, hosted in July 2015, allocated \$20.9 million in put options at a net price of \$2.10/tCO2e.[4] This auction focused on emission reductions from the solid waste, wastewater and agricultural waste sectors. To receive payment, option holders must present CERs under certain CDM methodologies. In its second auction of May 2016, the PAF allocated an additional \$20 million for emission reductions at a net price of \$2.09/tCO2e from these same sectors, while also expanding eligibility to the Gold Standard and Verified Carbon Standard (VCS). Finally, the third auction, hosted in January 2017, allocated \$13 million at a net price of \$1.80/tCO2e to projects that reduce nitrous oxide emissions from chemical and fertilizer plants (World Bank Group, 2015).

ii. Contracts for difference

In 2011, the UK embarked on a strategy to increase security of power supply, support swift decarbonization in the electricity sector and increase efficiency of their renewable

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reduce the market risk faced by low-carbon generators by paying a variable top-up between the market electricity price and a 'strike price' determined through reverse auction (a 'competitive allocation process') (Fitch-Roy & Woodman, 2016;). The CfD programme supports 15 different renewable and low-carbon energy technologies across three 'pots': established technologies (e.g. PV solar, onshore wind, hydro), less established technologies (e.g. offshore wind, wave, tidal, geothermal) and coal-to-biomass conversions.

For each CfD 'allocation round' (auction), a budget is set for each pot and only technologies within the same pot will compete, which ensures that less mature technologies receive a certain level of support and are given the opportunity to come down the cost curve (Duke, 2002; Duke & Kammen, 1999; Lacerda & van den Bergh, 2014; Ueno, 2007). Unlike the PAF auctions, CfD relies on both administrative pricing and auctions to determine the strike price. Prior to an allocation round, the UK government establishes a ceiling price for each eligible technology and commissioning period. Applicants then submit bids, specifying the technology, capacity and desired strike price, and an auction is triggered if the value of contracts demanded exceeds the available budget (Onifade, 2016; UK BEIS, 2017a).

In total, the CfD and related programmes have signed 42 contracts for renewable energy production and have issued GBP 98 million as of the end of June 2017 for over 1000 MW of operating renewable projects (Low Carbon Contracts Company, 2017a, 2017b). The UK government announced in September 2017 that 11 new energy projects worth up to £176 million per year were successful in the latest auction (UK BEIS, 2017b). The competitive approach is generating savings for taxpayers and consumers with the cost of offshore wind projects now 50% lower than the first auction held in 2015 (UK BEIS, 2017c).

iii. Comparing the PAF and CfD

The CfD programme differs from the PAF in several ways. First, the CfD demonstrates the ability to apply top-up instruments for both established and less established technologies, while noting that the latter requires a higher level of price support. Second, the contracts under CfD are specific to individual projects and not tradable like put options. This increases the government's risk of exposure to project failure. By contrast, because PAF options are tradeable, owners of failed projects can sell their over the course of several months, as compared to the PAF's online, single-day, multiple round auctions. This longer process is required for vetting complex, large-scale power projects and requires appropriate staff expertise at the relevant government agency to minimize project failure risk. Finally, in cases where the wholesale power price exceeds the strike price, CfD contracts require generators to pay this difference back to the public funder; holders of PAFERNs would simply opt not to exercise their options if they could sell to the market at a higher price.

V. Lessons learned and considerations for policy makers

Building on PAF and CfD implementation, auctioned price floors have the potential to maximize the impact of public resources by revealing the minimum subsidy required for mitigation activities (IRENA, 2013; Klemperer, 2004). However, they also pose implementation challenges and risks. To complement the literature on renewable energy auctions (Cramton, 2009; IRENA, 2013; Klemperer, 2004; Lesser & Su, 2008; Maurer and Barroso 2011), this section provides a set of lessons learned and recommendations for governments and public finance institutions to appropriately target and design auctioned price floors. These considerations fall into three categories: (1) enabling emerging technologies and capital-intensive projects, (2) ensuring competitive auctions and (3) managing public and market risk.

i. Enabling emerging technologies and capital-intensive projects

The subsidy delivered by auctioned price floors will vary by technology and project development stage, with emerging technologies and capital-intensive projects likely demanding higher subsidies. While price floor mechanisms reduce revenue and market risk for projects, technologies in early stages of development often face technology, execution and other risks that may stymie deployment even with price floor support. Furthermore, auctions for early-stage technologies may not attract sufficient participation due to a potentially low number of active projects.

While the PAF focused on existing projects, targeting subsidies towards operating expenditures only, the CfD programme offers several lessons on how to overcome potential barriers when targeting emerging technologies or capital-intensive projects:

- Longer timelines for project and bid development: Policy makers should provide lengthy lead times before hosting auctions for new projects, and should provide clear guidance on the level of project readiness required for auction participation.

- Revenue certainty over an extended period of time: Large-scale, capital-intensive projects often require long payback periods to meet investment goals (Granoff, Hogarth, & Miller, 2016). The CfD programme recognizes this fact, providing price floors for renewable energy facilities for up to 15 years. To minimize budgetary risk for projects that receive auctioned puts or price floor contracts, the length of the contract should not be dependent on future appropriations, but rather on budget availability in the year of contract award.

- Larger auction budgets: As a result of supporting larger capital costs and longer contractual periods, auctions for new and high-capital expenditure projects require substantially higher budgets than those supporting existing projects. For example, the CfD budget for just one year (600 million GBP) dwarfs that of the PAF's multi-year budget ($53 million). When defining auction budgets and scope, policy makers should look to balance goals of achieving immediate, low-cost emission reduction opportunities with longer term gains from large-scale technologies.

Finally, while not demonstrated by the CfD programme, policy makers targeting early-stage technologies may seek to blend results-based incentives with more traditional grants and loans, as demonstrated in a number of results-based climate finance programs in the energy and forestry sectors (World Bank Group, 2017a). Once technologies reach commercial readiness, they may then graduate to pure pay-for-performance support schemes.

ii. Managing public and market risk

From the perspective of the public sector, auctioned puts reduce delivery risk by ensuring that taxpayer monies are only disbursed for verified results. However, auctioned price floors pose challenges for public budgeting. In the case of auctioned put options, the public funder is uncertain about the share of options that will be exercised and therefore not sold to the market. This uncertainty creates an opportunity cost because these funds cannot be utilized elsewhere. In cases like the CfD, where the total liability of the public funder is uncertain because the commitment to top up varies with market conditions, policy makers may need to take the most pessimistic view of reduce the opportunity cost of reserving public funds, public entities could size the price floor programme budget based on probabilistic estimates, as is done with loan guarantee programmes.

Using auctioned price floors, like many subsidy formats, has the potential to distort markets. While individual projects with price floor support may be competitive compared to those of other auction participants, they may not be competitive with the market at large. In the near term, selectively supporting emerging technologies allows for learning-by-doing and concomitant cost reductions that can justify small amounts of near-term market distortion. Technologies supported primarily by a carbon revenue may demand higher levels of public subsidy. However, in the long run, mature emissions-reducing technologies and projects should graduate to either regulation or market-determined pricing to ensure achievement of mitigation goals at the lowest possible cost.

iii. Ensuring competitive auctions

Strategic auction design is one of the most important factors for increasing subsidy efficiency (Kreiss, Ehrhart, & Haufe, 2017). Key principles for effective auctions include the following:

- Setting the budget: The optimal auction budget will vary according to a funder's objectives. For example, the PAF targeted existing, and therefore relatively low-cost, methane and nitrous oxide reductions in an effort to capture maximum emission reductions in the near term. The CfD programme created distinct categories for less mature and more mature technologies, with separate budgets for each pool, thereby serving a diversification objective. Based on the auction objectives and scope, policy makers should set the auction budget based on the likely number of participants as well as technology costs, using market data (e.g. CDM data on abatement costs) and stakeholder interviews to gauge demand (UNEP, 2017a; World Bank, 2015).

- Maximizing participation: Perhaps the most critical factor to ensuring successful auctions is attracting sufficient participation, indicated by both the number of bidders as well as their aggregate demand. Each of the PAF auctions attracted a diverse set of bidders, ranging from large multinationals to small local businesses, and including both project developers and aggregators (World Bank Group, 2015;

https://www.pilotauctionfacility.org/content/third-auction-results World Bank Group, 2017b). According to experienced auction managers, auctions should aim to attract several times the demand that the auction budget can support. Lower demand may lead to collusion and potential subsidy inflation, with the potential for uncompetitive and higher risk projects receiving public funds (Ausubel et al., 2014).

- Avoiding collusion and gaming: Competitive auctions should be designed to avoid both collusion and speculation (i.e. financial institutions or intermediaries securing a relatively high strike price and then profiting by sourcing and delivering much cheaper credits). Sufficient auction participation, and even a requirement around the minimum number of bidders, can again mitigate this risk. Programmes can also require that options, though tradeable, be exercisable only by the owners of underlying projects. Policy makers should carefully consider auction, trading and ownership rules during programme design to ensure programmatic efficiency is not hampered.

VI. Potential future applications

Initial real-world experiments with auctioned price floors indicate broad applicability for a large range of existing and early-stage technologies. In this section, we identify some promising opportunities in both international and domestic climate finance that could support efforts to achieve a 1.5°C warming limit.

i. International climate finance

The GCF is the largest source of concessional finance for mitigation and adaptation in the developing world. It faces both a challenge and an opportunity to allocate its initial $10.2 billion pledged resource base efficiently, not least to help countries move towards a 1.5°C warming limit. The GCF’s initial funding activities have predominantly relied on grants and loans, which require time- and labour-intensive application processes and accreditation systems, and a lack of comparability in subsidy requests and provision, and an elaborate accreditation system for managing GCF resources. The GCF’s ‘Private Sector Facility’ (PSF) – touted as one of the fund’s innovative features – has not yet been implemented. It is not clear that this approach is scalable or efficient, and the GCF Board has been criticized for moving money too slowly (Darby, 2017;

The demand for faster, more efficient and more transparent funding by the GCF presents an opportunity to apply the auctioned price floor model. The GCF could directly build on the PAF experience and method by running a series of auctions targeting emission reductions tailored to key technologies, sectors and countries. A recent paper has highlighted the opportunity for the GCF PSF to engage directly with private actors rather than via intermediary National Accredited Entities by using quantity-performance instruments (Mueller, 2015). Such a programme could maximize private sector participation while retaining national sovereignty over countries' low-carbon development strategies through the use of the GCF's established procedure for letters of no objection issued by the respective National Designated Authority (NDA). While this programme could start with project-level support, as market mechanisms emerge under Article 6 of the Paris Agreement, the GCF could scale to back-stopping auctioned price floors for entire sectors. At that stage, the GCF could provide technical assistance to help countries put auctions in place, and provide a guarantee against countries exceeding their price floor support budgets.

Of the sectoral climate policy tools developed at the international level, 'jurisdictional' REDD+ has focused most closely on results-based financing.[5] Bilateral funding committed from Norway, Germany and others to support national or sub-national verified emission reductions from REDD+ represents an important opportunity to extend the auctioned price floor model. Put options issued by the GCF could also allow jurisdictions the opportunity to monetize REDD+ credits into compliance carbon markets, if and when they emerge. Stimulating the development of a supply of cost-effective REDD+ credits could have the added benefit of encouraging more ambitious compliance targets in industries that have the option to use offsets. In response to a recent GCF request for public inputs on results-based payments for REDD+, 6 of 14 inputs from GCF Board members suggested reverse auctioning as a possible tool (GCF, 2017).

Finally, auctioned price floors can harness market forces to reveal untapped mitigation opportunities across a variety of sectors, thus supporting the decarbonization that will need to happen throughout the global economy to meet a 1.5° target. By identifying projects with low costs, auctioned price floors can also help policy makers identify sectors and technologies that can transition to regulation. For example, the German Nitric Acid Climate Action Group (NACAG) incentivizes emission reduction projects in developing countries via a CDM methodology while also supporting the transition to national restrictions on nitrous oxide emissions as a part of countries' efforts to meet their NDCs from 2020 onwards (Carbon Pulse, 2015; NACAG, 2017).

ii. Domestic climate finance

The long-running struggle of European policy makers to find the right structure and level for renewable energy feed-in tariffs illustrates the difficulty of allocating limited public subsidies efficiently and transparently in a national context (IRENA, 2013; Pyrgou, Kylili, & Fokaides, 2016). Auctioned price floors can be applied within the context of dedicated domestic funds or programmes aimed at promoting climate action. The use of auctioned price floors to deliver national or sub-national subsidies may be particularly appropriate for established technologies or if the availability of concessional finance has a high impact on achievable emission reductions; where private sector actors are able to finance capital costs given more certainty about revenues; and where established MRV methodologies are available to enable quantification and verification of emission reductions.

In California, an auctioned put or price floor mechanism is being considered to support investments under the Low Carbon Fuel Standard (LCFS), in an effort to make the value of LCFS credits (denominated in tons of CO_2e) more predictable. Investment in low-carbon fuels has declined substantially in recent years due to low global oil prices, making it difficult for oil-substituting transportation fuels to compete. To create greater certainty and support new investment, California is looking at a number of options for increasing low-carbon fuel incentives. Pavlenko, Searle, Malins, and El Takriti (2016) estimate a reverse auction-price floor programme applied to the California LCFS could motivate greater market entry of low-carbon fuels than a constant per-gallon price. Based on this analysis, the California Air Resources Board has identified price floor auctions as a leading option for a pilot financial mechanism to support renewable biogas projects (CARB, 2017).

In Brazil, price floor auctions have been proposed as a mechanism to avoid forest loss, the country's largest source of emissions. Brazil's Forest Code allows landowners the flexibility to comply by purchasing a 'CRA' (Environmental Reserve Quota). The potential oversupply in the CRA market is large – the Forest Code's targets could be achieved while still leaving a theoretical potential for legal clearing of 85 million hectares of forests (Soares-Filho et al., 2014). There is an opportunity for a range of government efforts to reach more ambitious targets for avoided deforestation. Soares-Filho et al. (2016) suggest an investment of US$ 8.4 ± 2.0 billion to purchase low-cost CRAs could cut legal deforestation (19 million ha) in half by 2030 and would reduce CO_2 emissions by as much as 3.8 ± 0.8 billion tons. With the potential for the market to be oversupplied, there should be opportunities for using reverse auctions (Edwards, 2016).

In addition to these specific examples, as all countries prepare for implementing their NDCs, dedicated concessional financing vehicles could utilize the auctioned price floor approach, including Australia’s aforementioned Emission Reduction Fund and China’s CDM Fund, established in 2005 with the proceeds of CER taxation on HFC-23 and N2O credits (Irawan, Xie, Li, Meng, & Heikens, 2012).

VII. Conclusion

Achieving the 1.5°C target will require a rapid surge in both the volume and efficiency of climate finance. The traditional toolkit of public finance instruments has enabled some progress, but it is becoming clear from the early years of the GCF and other vehicles that grants and loans do not mobilize sufficient private investment, therefore failing to drive down mitigation costs. Such tools can enhance capacity in developing countries, support early-stage technologies and help overcome financing barriers, but are difficult to scale and face fundamental challenges in terms of allocating public funding in a fair and transparent manner. At the same time, a new generation of quantity-performance instruments is emerging with early results from pilots like the World Bank PAF and the UK's CfD programme, as well as Australia’s ERF.

Quantity-performance instruments put a direct value on GHG mitigation outcomes while harnessing the benefits of competition among private sector actors to lower the incremental costs of transitioning to low-carbon economies and leveraging private finance. As the PAF demonstrates, auctioned price floors can be particularly effective at capturing and encouraging immediate mitigation opportunities at risk due to low-carbon prices. At the same time, the ability to tailor auctions enables policy makers to provide direction on which low-cost technologies and geographies may transition towards regulatory approaches under NDCs (as proposed by NACAG), and which ones continue to play a role in crediting mechanisms as the new generation of Paris Agreement market mechanisms emerges.

To be clear, the mechanism described in this paper is not intended exclusively or even mainly to support offsetting activities, nor does it obviate the need for carbon pricing, regulation or technology innovation funding. In the short- to medium-term, auctioned price floors can underpin the evolution of carbon market mechanisms by providing certainty for the minimum value of units, while contributing to overall global mitigation effects through the cancellation of units in support of NDCs in developing countries. During this transition, carbon tax or allowance auction revenues can be used to fund quantity-performance instruments encouraging abatement in other sectors. In the long term, limiting warming below 1.5°C will require a rapid transition to net-zero emissions across all sectors, potentially resulting in a small role for cross-sectoral or cross-jurisdictional offsets. Even then, linking price floor support to carbon pricing policies decreases direct costs for taxpayers (World Bank Group, 2015) and for consumers in the case of sectoral schemes like the International Civil Aviation Organization's Global Market-Based Measure. It also deepens competition for mitigation capital across technologies. If implemented carefully and in concert with other policies, auctioned price floors can evolve into a central mechanism by which limited public funds are allocated to attract the scale and speed of private investment required to keep the 1.5°C goal within reach.

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Notes

1. By emission reductions, we refer to verified mitigation outcomes such as carbon credits issued under the 1997 Kyoto Protocol's Clean Development Mechanism, voluntary carbon standards, national and regional carbon markets or future Paris Agreement market mechanisms.

2. The auctions can be designed either a reverse auction, in which the premium price is fixed and bidders submit their demand at decreasing strike prices, or a forward auction, in which the strike price is fixed and bidders submit their demand at ascending premium prices. In both scenarios, the net price per emission reduction decreases over the course of the auction.

3. PAFERNs are a special type of World Bank bond. They do not pay interest, nor do they pay holders a traditional principal at maturity. Rather, PAFERN holders, upon delivering qualifying emission reductions, receive a redemption payment equal to the auction strike price multiplied by the quantity of emission reductions. The PAF selected this instrument because it is built on existing market infrastructure for issuing and trading World Bank bonds.

4. 'Net' here refers to the net benefit to the option holder, or the strike price minus the premium price.

5. 'Jurisdictional' approaches to REDD+ are designed to overcome the shortcomings of project-based approaches (including the potential for deforestation to 'leak' to other areas) by working across landscapes with multiple stakeholders for national and sub-national implementation. Support from Norway for Brazil's Amazon Fund is an example of donor funding for a jurisdictional REDD+ outcome at the national level.

Carbon Markets or Climate Finance

Source: Unknown Repository

Carbon Coalitions

Source: Unknown Repository

The Evolution of the CDM in a Post-2012 Climate Agreement

Source: The Journal of Environment & Development

Cracking Brazil's Forest Code

Source: Science

Exploring the financial and investment implications of the Paris Agreement

Source: Climate Policy

International climate policy architectures: Overview of the EMF 22 International Scenarios

Source: Energy Economics

The deadweight loss from a tax system

References

1. Acemoglu, D., Aghion, P., Bursztyn, L., & Hemous, D. (2012). The environment and directed technical change. The American Economic Review, 102(1), 131–166.

PubMed | Web of Science ® | Google Scholar

2. Aldy, J. E., Barrett, S., & Stavins, R. N. (2003). Thirteen plus one: A comparison of global climate policy architectures. Climate Policy, 3(4), 373–397.

Web of Science ® | Google Scholar

3. Ausubel, L., Cramton, P., Aperjis, C., & Hauser, D. (2014). Pilot auction facility for methane and climate change mitigation: Relevant auction theory. Power Auctions LLC.

Google Scholar

4. Betz, R., Seifert, S., Cramton, P., & Kerr, S. (2010). Auctioning greenhouse gas emissions permits in Australia. Australian Journal of Agricultural and Resource Economics, 54(2), S. 219–S. 238.

Web of Science ® | Google Scholar

5. Bodnar, P., Brown, J., & Nakhooda, S. (2015). What counts: Tools to help define and understand progress towards the $100 billion climate finance commitment. Washington, DC: World Resources Institute. Retrieved from http://www.wri.org/publication/what-countstools-help-define-and-understand-progress-towards-100-billionclimate-finance-commitment

Google Scholar

6. California Air Resources Board. (2017). SB 1383 pilot financial mechanism possible methods to enhance the certainty of the value of environmental credits to dairy-related projects producing low-carbon transportation fuels. Retrieved from https://www.arb.ca.gov/fuels/lcfs/lcfs_meetings/062617presentation.pdf.

Google Scholar

7. Carbon Pulse. (2015). Germany launches initiative to buy CERs from nitric acid projects. Retrieved from https://carbon-pulse.com/12967/

Google Scholar

8. Ciplet, D., Mueller, B., & Roberts, J. T. (2010). How many people does it take to administer long-term climate finance? Oxford: European Capacity Building Initiative. Retrieved from http://www.oxfordclimatepolicy.org/sites/default/files/StaffingIntensityOctober2010.pdf

Google Scholar

9. Clarke, L., Edmonds, J., Krey, V., Richels, R., Rose, S., & Tavoni, M. (2009). International climate policy architectures: Overview of the EMF 22 International Scenarios. Energy Economics, 31, S64–S81.

Web of Science ® | Google Scholar

10. Climate Focus and Ecofys. (2016). Pilot auction facility: Opportunities beyond the piloting phase. Retrieved from https://www.pilotauctionfacility.org/sites/paf/files/PAF20Opportunities20Beyond20the20Piloting%20Phase_Final_1.pdf

11. Climate Investment Funds. (2017). https://www.climateinvestmentfunds.org/about

Google Scholar

12. Climate Policy Initiative. (2015). Global landscape of climate finance 2015. San Francisco, CA: Climate Policy Initiative. Retrieved from http://climatepolicyinitiative.org/wp-content/uploads/2015/11/Global-Landscape-of-Climate-Finance-2015.pdf

Google Scholar

13. Cramton, P. (2009). How best to auction natural resources. Retrieved from ftp://www.cramton.umd.edu/papers2005-2009/cramton-auctioning-natural-resources.pdf

Google Scholar

14. Darby, M. (2017, April 6). Green Climate Fund ‘a laughing stock’, say poor countries. Climate Home. Retrieved from http://www.climatechangenews.com/2017/04/06/green-climate-fund-laughing-stock-ethiopia-bid-left-limbo/

Google Scholar

15. Duke, R. D. (2002). Clean energy technology buydowns: Economic theory, analytic tools, and the photovoltaics case. Dissertation presented to faculty of Princeton University. Woodrow Wilson School of Public and International Affairs. Retrieved from http://rael.berkeley.edu/old_drupal/sites/default/files/very-old-site/PhD02-Duke.pdf

Google Scholar

16. Duke, R. D., & Kammen, D. M. (1999). PV market transformation: The virtuous circle between experience and demand and the strategic advantage of targeting thin-film photovoltaics. Presented at the IEA Workshop on Experience Curves for Policy Making: The Case of Energy Technologies, Stuttgart, 10–11 May.

Google Scholar

17. Ecofys. (2016). Auctions for renewable support: Lessons learnt from international

http://www.ecofys.com/files/files/aures-wp4-synthesis-report-final.pdf

Google Scholar

18. Edwards, R. (2016). Linking REDD+ to support Brazil's climate goals and implementation of the forest code. Washington, DC: Forest Trends Association.

Google Scholar

19. Figueres, C. (2006). Sectoral CDM: Opening the CDM to the yet unrealized goal of sustainable development. McGill Journal of Sustainable Development Law and Policy, 2(1), 5–25.

Google Scholar

20. Figueres, C., & Streck, C. (2009). The evolution of the CDM in a Post-2012 Climate Agreement. The Journal of Environment & Development, 18(3), 227–247.

Google Scholar

21. Fitch-Roy, O. W., & Woodman, B. (2016). Auctions for renewable support in the United Kingdom: Instruments and lessons learnt (AURES report D4.1-UK). Retrieved from http://auresproject.eu/files/media/countryreports/pdf_uk.pdf

Google Scholar

22. Ghosh, A., Muller, B., Pizer, W. A., & Wagner, G. (2012). Mobilizing the private sector: Quantity-performance instruments for public climate funds (Duke Environmental and Energy Economics Working Paper EE 12-09). Durham: Duke University.

Google Scholar

23. Government of Australia Department of Energy and the Environment. (2017). Emissions reduction fund. Retrieved from http://www.cleanenergyregulator.gov.au/ERF

Google Scholar

24. Granoff, I., Hogarth, J., & Miller, A. (2016). Nested barriers to low-carbon

10.1038/nclimate3142

Web of Science ® | Google Scholar

25. Green Climate Fund. (2013). Business model framework: Private sector facility. Retrieved from http://www.greenclimate.fund/documents/20182/24934/GCF_B.04_07_-_Business_Model_Framework__Private_Sector_Facility.pdf/fb909f84-1c95-42bd-973f-54bc9bcada8f?version=1.1

.

Google Scholar

26. Green Climate Fund. (2017). GCF consultations on REDD+ results-based payments. Retrieved from https://www.greenclimate.fund/reddplus-results-based-payments. See submissions from Finland, Hungary, and Switzerland (joint statement), Australia, Brazil, Ecuador, Uruguay, and the United States

Google Scholar

27. Gunther, M. (2015, May 6). Rich countries have pledged billions in climate aid. Why has progress been so slow? Vox. Retrieved from http://www.vox.com/2016/5/8/11600940/green-climate-fund

Google Scholar

28. Hof, A. F., den Elzen, M. G., Admiraal, A., Roelfsema, M., Gernaat, D. E., & van Vuuren, D. P. (2017). Global and regional abatement costs of nationally determined contributions (NDCs) and of enhanced action to levels well below 2 °C and 1.5 °C. Environmental Science & Policy, 71, 30–40.

Web of Science ® | Google Scholar

29. International Energy Agency. (2017). Perspectives for the energy transition – investment needs for a low-carbon energy system. Retrieved from https://www.energiewende2017.com/wp-content/uploads/2017/03/Perspectives-for-the-Energy-Transition_WEB.pdf

Google Scholar

30. International Renewable Energy Agency. (2013). Renewable energy auctions in developing countries. Abu Dhabi: International Renewable Energy Agency.

Google Scholar

31. IPCC. (2014). Climate change 2014: Synthesis report. Contribution of working groups I, II and III to the fifth assessment report of the intergovernmental panel on climate change. (Core Writing Team, R. K. Pachauri & L. A. Meyer (Eds.)). Geneva, Switzerland: Author.

Google Scholar

32. Irawan, S., Xie, F., Li, C., Meng, X., & Heikens, A. (2012). Case study report: China clean development mechanism fund. United Nations Development Programme. Retrieved from http://www.asia-pacific.undp.org/content/rbap/en/home/library/climate-and-disaster-resilience/NCF_China_Clean_Development.html

Google Scholar

33. Kay, J. A. (1980). The deadweight loss from a tax system. Journal of Public Economics, 13(1), 111–119.

Web of Science ® | Google Scholar

34. Keohane, R. O., & Victor, D. G. (2011). The regime complex for climate change. Perspectives on Politics, 9(1), 7–23.

Web of Science ® | Google Scholar

35. Klemperer, P. (2004). Auctions: Theory and practice. Princeton, NJ: Princeton University Press.

Google Scholar

36. Kreiss, J., Ehrhart, K.-H., & Haufe, M.-C. (2017). Appropriate design of auctions for renewable energy support – prequalifications and penalties. Energy Policy, 101, 512–520. doi: 10.1016/j.enpol.2016.11.007

37. Lacerda, J. S., & van den Bergh, J. C. J. M. (2014). International diffusion of renewable energy innovations: Lessons from the lead markets for wind power in China, Germany and USA. Energies, 7(12), Retrieved from www.mdpi.com/1996-1073/7/12/8236/pdf

Web of Science ® | Google Scholar

38. Lesser, J., & Su, X. (2008). Design of an economically efficient feed-in tariff structure for renewable energy development. Energy Policy, 36(3), 981–990.

Web of Science ® | Google Scholar

39. Low Carbon Contracts Company. (2017a). Transparency tool. Retrieved from https://sofm.lowcarboncontracts.uk/landingpage.aspx

Google Scholar

40. Low Carbon Contracts Company. (2017b). Q4 2017 supplier obligation levy rate & 15 month forecast. Retrieved from https://lowcarboncontracts.uk/sites/default/files/publications/Q4&per;202017&per;20Supplier&per;20Obligation&per;20Levy&per;20Rate&per;20&per;26&per;2015&per;20Month&per;20Forecast.pdf

Google Scholar

41. Maurer, L. T. A., & Barroso, L. A. (2011). Electricity auctions : An overview of efficient practices. Washington,DC: World Bank http://documents.worldbank.org/curated/en/114141468265789259/Electricity-auctions-an-overview-of-efficient-practices

Google Scholar

42. Meckling, J. (2011). Carbon coalitions: Business, climate politics, and the rise of emissions trading. Cambridge, MA: MIT Press.

Google Scholar

43. Michaelowa, A. (2012). Carbon markets or climate finance? Low carbon and adaptation investment choices for the developing world. London: Routledge.

Google Scholar

44. Michaelowa, A., Füssler, J., Honegger, M., Hoch, S., Warland, L., Matsuo, T., … Streck, C. (2015). Market mechanisms: Incentives and integration in the post-2020 world. Berne: Swiss Federal Office of the Environment.

Google Scholar

45. Mikolajczyk, S., Brescia, D., Galt, H., Le Saché, F., Hunzai, T., Greiner, S., & Hoch, S. (2016). Linking the clean development mechanism with the Green Climate Fund: Models for scaling up mitigation action. Perspectives, Climate Focus, and Aera, 1–69. http://perspectives.cc/fileadmin/user_upload/Linking_the_Clean_Development_Mechanism_with_the_Green_Climate_Fund_v3_0_5_.pdf

Google Scholar

46. Milgrom, P. (2004). Putting auction theory to work. New York: Cambridge University Press.

Google Scholar

47. Mueller, B. (2015). Engaging micro, small and medium enterprises in developing countries. Enhanced direct access and the GCF private sector facility (Working Paper, Oxford Climate Policy). Retrieved from http://www.eurocapacity.org/finance/documents/Mobilizing_MSMEs_Annexes_final_pdf

Google Scholar

48. Multilateral Development Banks. (2015). Joint report on Multilateral Development Banks' climate finance. Retrieved from https://www.adb.org/sites/default/files/institutional-document/189560/mdb-joint-report-2015.pdf

Google Scholar

49. Nitric Acid Climate Action Group. (2017). http://www.nitricacidaction.org/

Google Scholar

50. Onifade, T. T. (2016). Hybrid renewable energy support policy in the power sector: The contracts for difference and capacity market case study. Energy Policy, 95, 390–

Web of Science ® Google Scholar

51. Organisation for Economic Co-operation and Development & Climate Policy Initiative. (2015). Climate finance in 2013–2014 and the USD 100 billion goal. Retrieved from http://www.oecd-ilibrary.org/docserver/download/9715381e.pdf?expires=1492027852&id=id&accname=guest&checksum=E2E6A2B8283AE706B3A581DF0DF6BE47

Google Scholar

52. Overseas Private Investment Corporation. (2010). Annual report. Retrieved from https://www.opic.gov/media-events/annual-reports

Google Scholar

53. Overseas Private Investment Corporation. (2011). Annual report. Retrieved from https://www.opic.gov/media-events/annual-reports

Google Scholar

54. Overseas Private Investment Corporation. (2012). Annual report. Retrieved from https://www.opic.gov/media-events/annual-reports

Google Scholar

55. Overseas Private Investment Corporation. (2013). Annual report. Retrieved from https://www.opic.gov/media-events/annual-reports

Google Scholar

56. Overseas Private Investment Corporation. (2014). Annual report. Retrieved from https://www.opic.gov/media-events/annual-reports

Google Scholar

57. Overseas Private Investment Corporation. (2015). Annual report. Retrieved from https://www.opic.gov/media-events/annual-reports

Google Scholar

58. Pavlenko, N., Searle, S., Malins, C., & El Takriti, S. (2016). Development and analysis of a durable low carbon fuel investment policy for California. International Council for Clean Transportation. Retrieved from http://www.theicct.org/sites/default/files/publications/California&per;20Contracts&per;20for&per;20Difference_white-paper_ICCT_102016.pdf

Google Scholar

59. Peake, S., & Ekins, P. (2017). Exploring the financial and investment implications of the Paris Agreement. Climate Policy, 17(7), 832–852.

Web of Science ® | Google Scholar

60. Pizer, W. A. (2011). Seeding the market. Auctioned put options for certified emission reductions. Nicholas Institute for Environmental Policy Solutions, Duke University.

Google Scholar

61. Pyrgou, A., Kylili, A., & Fokaides, P. A. (2016). The future of the feed-in tariff (FiT) scheme in Europe: The case of photovoltaics. Energy Policy, 95, 94–102.

Web of Science ® | Google Scholar

62. Rogelj, J., Luderer, G., Pietzcker, R. C., Kriegler, E., Schaeffer, M., Krey, V., & Riahi, K. (2015). Energy system transformations for limiting end-of-century warming to below 1.5 [deg] C. Nature Climate Change, 5, 519–527.

Updates | Web of Science ® | Google Scholar

63. Soares-Filho, B., Rajão, R., Macedo, M., Carneiro, A., Coe, M., Costa, W., … Alencar, A. (2014). Cracking Brazil's forest code. Science, 344(6182), 363. doi: 10.1126/science.1246663

PubMed | Web of Science ® | Google Scholar

64. Soares-Filho, B., Rajão, R., Merry, F., Rodrigues, H., Davis, J., Lima, L., … Santiago, L. (2016). Brazil's market for trading forest certificates. PLoS ONÊ, 11(4), e0152311. doi: 10.1371/journal.pone.0152311

65. Ueno, T. (2007). Reengineering the climate regime: Design and process principles of international technology cooperation for climate change mitigation. Resources for the Future. Retrieved from http://www.rff.org/files/sharepoint/WorkImages/Download/RFF-DP-06-48-REV.pdf

Google Scholar

66. UN Framework Convention on Climate Change. (1992). United Nations Framework Convention on Climate Change. New York: United Nations General Assembly.

Google Scholar

67. UN Framework Convention on Climate Change. (1997). Kyoto Protocol to the UNFCCC, Bonn.

Google Scholar

68. UN Framework Convention on Climate Change. (2015). Paris Agreement, Paris.

Google Scholar

69. UN Framework Convention on Climate Change. (2017a). CDM Voluntary Cancelation Notices, Bonn. Retrieved from https://cdm.unfccc.int/Registry/vcnotices/notices_list

Google Scholar

70. UN Framework Convention on Climate Change. (2017b). Standardized Baselines. Retrieved from https://cdm.unfccc.int/methodologies/standard_base/index.html

Google Scholar

71. United Kingdom Department for Business, Energy & Industrial Strategy. (2017a). Policy paper: Contracts for difference. Retrieved from https://www.gov.uk/government/publications/contracts-for-difference/contract-for-difference&hash;key-documents-relating-to-the-first-round-october-2014-to-march-2015

Google Scholar

72. United Kingdom Department for Business, Energy & Industrial Strategy. (2017b). Contracts for difference: Allocation framework for the second allocation round. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/601120/Allocation_Framework_for_the_second_Allocation_Round.pdf
.

Google Scholar

73. United Kingdom Department for Business, Energy & Industrial Strategy. (2017c). New clean energy projects set to power 3.6 million homes. Retrieved from https://www.gov.uk/government/news/new-clean-energy-projects-set-to-power-36-million-homes

Google Scholar

74. United Nations Environment Programme. (2017a). Clean development mechanism pipeline, March 2017. Copenhagen: UNEP.

Google Scholar

75. United Nations Environment Programme. (2017b). Programme of activities pipeline, March 2017. Copenhagen: UNEP.

Google Scholar

76. Wagner, G., Kaberger, T., Olai, S., Oppenheimer, M., Rittenhouse, K., & Sterner, T. (2015). Energy policy: Push renewables to spur carbon pricing. Nature, 525(7567), 27–30.

PubMed | Web of Science ® | Google Scholar

77. Wilkinson, J. (2017). Lessons and innovations to spur green investment in developing countries. San Francisco, CA: Climate Policy Initiative.

Google Scholar

78. World Bank Group. (2013). Methane finance study group report: Using pay-for-performance mechanisms to finance methane abatement. Washington, DC: World

Google Scholar

79. World Bank Group. (2015). Lessons learned: The first auction of the pilot auction facility. Washington, DC: World Bank Group.

Google Scholar

80. World Bank Group. (2016). State and trends of carbon pricing. Washington, DC: World Bank Group.

Google Scholar

81. World Bank Group. (2017a). Results based climate finance in practice: Delivering climate finance for low-carbon development. Washington, DC: World Bank Group. Retrieved from https://openknowledge.worldbank.org/bitstream/handle/10986/26644/115053-WP-PUBLIC-111p-RBCFinPracticeFinalMay.pdf?sequence=1&isAllowed=y

Google Scholar

82. World Bank Group. (2017b). 13 Private companies compete in $13 million World Bank auction. Washington, DC: World Bank Group. Retrieved from https://www.pilotauctionfacility.org/content/third-auction-results

Google Scholar