International Carbon Action Partnership

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EMISSIONS TRADING AND ELECTRICITY SECTOR REGULATION

A conceptual framework for understanding interactions between carbon prices and electricity prices

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Glossary

Ancillary services	Services related to the stability of an electrical system; e.g., generation of reserve capacity, regulation of voltage.
Average cost pricing	Setting prices according to average costs.
Base load	The minimum level of electricity required over a fixed period (e.g. 24 hours).
Base load plant	A baseload plant refers to a power plant that is planned to run continually except for maintenance and scheduled or unscheduled outages.
Bidding	To make an offer of; to propose. Specifically: To offer to pay (a certain price, as for a thing put up at auction), or to take (a certain price, as for work to be done under a contract).
Bundled service	Including a variety of services in combination. Electricity supplier might combine generation, transmission, distribution, and related customer service and support functions as a combined service.
Capacity	The maximum power that can be produced by a generating resource at specified times under specified conditions (measured in MW).
Carbon cost	The cost resulting from CO_2 emissions when carbon is priced.
Central planning	Planning characterized by state allocation of resources in association with production goals to meet targeted growth rates.
Consignment auctions	A consignment auction is a mechanism through which recipients of free allowances are required to offer their allowances for auctioning, but in exchange receive the revenues of such sales.
Cost-of service regulation	A form of regulation that determines prices based on the costs of serving different customers and producing different services.
Cost-plus pricing	When a firm adds a given percentage mark-up to average cost.
Cost pass-through	Cost pass-through is the mechanism through which the CO_2allowance price is reflected in electricity prices and/or in prices of electricity-intensive goods.

Demand-based pricing	Prices set according to customers' willingness to pay.
Depreciation	Reduction in the value of an asset overtime. Depreciation is not a cash outlay, but an accounting tool for allocating cost over the service life of the physical asset.
Dispatch	The sequence in which the generating sources are called upon to generate power to serve fluctuating loads.
Distribution	The transport of electricity to the point of final consumption, such as homes and businesses.
Economic dispatch	Start-up, shutdown and allocation of load to individual generating units to effect the most economical production of electricity for customers.
Double-coverage	Double-coverage refers to the situation where two allowances are generated for one unit of carbon emissions; once for direct emissions and again for indirect emissions. They are typically allocated to two different installations in different sectors.
Investor owned utilities (IOUs)	A privately-owned utility organized as a corporation for the purpose of providing electric power service and earning a profit for its stockholders.
Fixed costs	Production expenses that are independent of the level of output; e.g., administrative overhead, loan repayments.
Grid	A system of interconnected power lines and generators that is managed to meet the requirements of customers connected to the grid at various points.
Independent system operator (ISO)	An independent system operator (ISO) maintains balance of the grid system by controlling the dispatch of plants and ensuring that loads match system resources.
Load	The amount of electricity delivered to or required by a power system at a given point.
Marginal cost	The cost of providing the next unit of output.
Monopoly	Exclusive control of a market by a single provider, supplier or seller.

Opportunity cost	The value of the next best alternative foregone when a choice is made.
Public utility	Enterprise providing essential public services, such as electricity, gas, telephone, water, and sewer under legally established monopoly conditions.
Public utilities Board/Commission	Public institutions with the primary objective of ensuring reasonable costs for consumers, alongside objectives such as reliability and quality of electricity service.
Peak load	Peak load refers to the maximum electrical load demand in a period of time. On a daily basis, peak loads normally occur at midmorning and in the early evening.
Peak load plant	A peak load plant is normally operated to provide electricity during maximum load periods. Peak load plants might also be called on when renewable generation is low.
Shadow-price	The estimated price for a good or service for which no market exists. Where markets are not present but carbon costs are considered relevant, a shadow carbon price can guide supply (generation, dispatch, investment, and demand decisions).
State-owned enterprise (SOE)	An organization that produces goods or services for sale to its clientele and that is organized in the form of a corporation or other business association and is owned by a government.
Stranded investment or stranded asset	When changes in public policy have a significant impact on the cash flows that can be obtained from productive assets, those assets are less valuable than before the policy change. In electricity markets, this might result in generation facilities, owned by existing utility companies, that produce electricity at above-market marginal prices.
Tariff	A rate, charge or condition approved by regulatory agency for a regulated utility.
Transmission	Transmission refers to the process of transporting electricity in bulk from one point to another in the power system, rather than to individual customers.
Unbundled utility services	Disaggregating components of a previously vertically integrated network. For example, separating electricity service into its basic components (generation, transmission distribution, and retail) and offering each component for sale.

Variable costs	The total costs incurred to produce electricity, excluding fixed costs which are incurred regardless of whether the resource is operating. Variable costs typically include fuel, maintenance and labor.
Vertical integration	It refers to the arrangement whereby a utility owns the generating plants, transmission system, and distribution lines used to provide all aspects of electricity service.
Wholesale power market	Purchase of electricity from generators for the purpose of reselling it to others, who then sell to retail customers.

Source: Berg et al.(2005); Burtraw and McCormack (2016); NWPPA, n.d.

1. Introduction

An emissions trading system (ETS) is a market-based mechanism that is applied to achieve emissions targets at least cost. By fixing a quantity of emissions (the cap), requiring that companies surrender one allowance for each unit of emissions generated and making the allowance tradable, a carbon market is created through which an allowance price emerges. For producers, the allowance price is treated as a marginal cost in operation decisions and is a commodity that needs to be reflected in investment appraisals. It encourages them to optimize their operations with a view on the system-wide emissions constraint, render their goods less emissions-intensive or to make low-carbon investments. For consumers, carbon-intensive goods become more expensive, encouraging a switch to low-carbon alternatives or to change consumption patterns (e.g., energy efficiency). The relative change in prices creates incentives to invest in low-carbon assets and to develop new products, processes and technologies that use carbon more efficiently. At the same time, high-carbon assets become less competitive, which could lead to an accelerated decommissioning of these assets.

When declining emission caps are set also for future periods, an ETS serves not only as an economic (carbon pricing) mechanism but also as an informational instrument; that there will be less scope for emissions-intensive activities in our future economies. This can provide visibility and accountability on the longer-term pathways for time horizons that potentially go beyond the periods that are most relevant for decision-making on long-lived assets. The long term signal will be strongest where the ETS is embedded within a credible, long-term policy architecture that reduces uncertainty for participants.

For an ETS to achieve emission reductions at least cost, markets ideally must function freely and transmit uniform and non-distorted price signals to all decision makers in the economy. That is, the cost of emission allowances (allowance costs) can be freely reflected in the price of carbon-intensive goods and economic entities are free to adjust their economic operations and investment decisions (Boute and Zhang, 2017). The ability of the covered entities to pass through some of the costs of CO_2 allowances to consumers is also fundamental for recouping the costs of long-term low carbon investments and enhancing the credibility of future reduction targets (Hintermann, 2014).[1]

This is the case for liberalized electricity markets where customers are free to choose their electricity supplier; there is unbundling of supply, generation, and networks ensuring competition in wholesale and retail markets; generators are free to supply the market and independent regulators are assigned to monitor the market and regulate the natural monopolies (networks) to ensure non-discriminatory and unimpeded access to the networks. (Matthes 2017; Ecofys, 2016). Under these conditions, a liquid allowance market, where price

[1] Throughout this paper, the term cost pass-through refers to the mechanism through which the allowance price is reflected in power prices and/or in carbon-intensive goods.

discovery is facilitated through allowance auctions and where there are no distortions from free allocation[2], will drive cost effective emission reductions.

In practice, different forms of electricity sector regulation interact with real-world ETSs in ways that may prevent or change how participants respond to the allowance price. At one end of the regulation spectrum, vertically integrated (and in some cases non-profit driven) monopolies deliver all services of the electricity sector, from generation to electricity retailing and power prices and/or investment decisions are subject to regulatory oversight. In partially liberalized markets, regulators fix power prices with multiple policy objectives in mind (e.g., affordability and reliability) and impose output, investment and technology requirements on firms' industrial activities (Boute and Zhang, 2017). More flexible forms of power sector regulation might include market conditions with maximum or minimum prices for certain consumers or performance standards for power producers. Even in partially liberalized markets, access to the grid is regulated through tariffs, and planning such as renewable energy targets and portfolio standards can influence the role for and strength of the allowance price signal.

The interaction of market-based carbon pricing mechanisms with sectoral regulation is particularly pertinent for the electricity sector. Firstly, the electricity sector[3] is a major source of emissions, globally responsible for 45 percent of CO_2 emissions in 2015, with 72 percent of global electricity emissions generated from coal combustion (IEA, 2017). Secondly, reducing emissions from the power sector is generally cheaper than in other sectors. Thirdly, a clean power sector will play a key role in decarbonizing the heat and transport sectors. For these reasons, large emission reductions are required both at a domestic level for cost effective attainment of Nationally Determined Contribution (NDC) goals for many countries and at a global level to achieve net zero emissions by the mid part of this century. Indeed, ETS as a cost-effective instrument for emissions control is now being implemented or considered in China, South Korea, Mexico, Chile, Colombia, Vietnam, Turkey, Thailand, and the Ukraine, in addition to established systems in North America, Asia-Pacific and Europe (ICAP, 2018).

In this paper, we develop a conceptual framework to analyze the interactions between allowance prices and power prices. The framework explores how different abatement levers operate in diverse power-sector regulation settings, from liberalized markets to highly regulated command and control systems. We aim to better understand what role an ETS might play under differing regulatory structures, and furthermore, understand the instances where regulation may create a barrier to abatement. Options to strengthen an ETS and overcome hurdles resulting from traditional centrally planned regulation are discussed.

The paper is structured as follows. Section 2 provides an overview of the electric power sector. Section 3 discusses the functioning of ETS in liberalized and competitive electricity sectors and introduces a framework to understand the interaction of allowance prices and electricity prices. In section 4 the framework is applied to understand interactions between ETS and different forms of power sector regulation. Options to strengthen an ETS under different

[2] For potential distortions from free allocation, see discussion in Section 3 below.
[3] Includes electricity and heat production (IPCC, 2014).

regulatory settings are then discussed in Section 5. The effect of companion policies under different “types” of regulation is considered in Section 6. Section 7 concludes.

2. The electric power sector

2.1. The electricity grid

Electricity is fundamental to nearly all elements of the modern economy. It powers residential homes, commercial offices, industrial activities, health care services, communications and increasingly transportation. The electricity grid connects diverse sources of electricity generators, to the vast variety of electricity consumers (homes, factories, hospitals, office buildings). Electricity demand must be matched with electricity supply at every moment throughout the day (Cleetus et al., 2012).

To do so, large "baseload" generation plants operate almost continuously supplying the underlying electricity demand. These "baseload" plants are normally large coal or nuclear power plants because they are reasonably costly to start up but relatively cheap to operate (ibid.). Intermediate or cycling plants are more expensive to run than baseload plants, but are also more flexible and can be scaled up and down to match cycles in electricity demand. Those plants are often gas-powered but can also be coal (e.g., Germany) or nuclear (e.g., France). Finally, peaking plants which are cheap to build but expensive to operate are relied on for periods of maximum daily or seasonal demand (ibid.). Their importance also grows with increasing penetration from variable renewables (wind and solar) that require back-up capacity when the supply of renewable electricity is low.

Grid operators balance energy demand with supply. They signal to power generators when to increase electricity output or when lower output is required by consumers. Grid operators are responsible for system security on a real-time basis. They operate the grids and ensure that demand at all times meets supply and the quality of supply (voltage, frequency etc.) is ensured. For this they operate or contract different reserves and balancing capabilities. They might also be able to manage electricity use to adjust demand in response to electricity supply if needed to guarantee system security.

With an increasing share of variable renewables in an electricity system, new market arrangements like intraday trading can shift a part of the short-term balancing responsibilities from the grid operators to the market.

2.2. Electricity markets

Economists often refer to liberalized and competitive electricity markets, (Baumol and Oates, 1988; Layard and Walters, 1978), meaning:

- customers are free to choose their electricity supplier;
- generators have free access to the market;
- generation, supply, and networks are unbundled; ensuring competition on wholesale and retail markets; and
- independent regulators are assigned to monitor the market (Matthes 2017; Ecofys, 2016).

When electricity markets are fully competitive, electricity prices are set by the market on the basis of supply and demand. Power generators offer electricity at a price that reflects their marginal costs of production. The lowest cost electricity is dispatched to the market first, with increasingly expensive options utilized until demand is met. In this way, electricity is supplied at least cost. The order in which electricity is supplied to the grid is called the “merit order curve”. The final bid required to meet demand or the willingness to pay from the consumer side if no additional supply is available determines the wholesale market price, which all generators are paid. Under these (ideal) conditions, neither operations nor investments are centrally planned by governments or state agencies, but rather based on expected profits.

As electricity demand is relatively inelastic prices can rise and fall steeply. The requirement to balance the market at times of excess supply can result in negative electricity prices, a feature uncommon in other markets. Conversely, many jurisdictions operate with electricity price caps, to avoid extreme prices during periods of high demand and limited supply (Boute 2016).

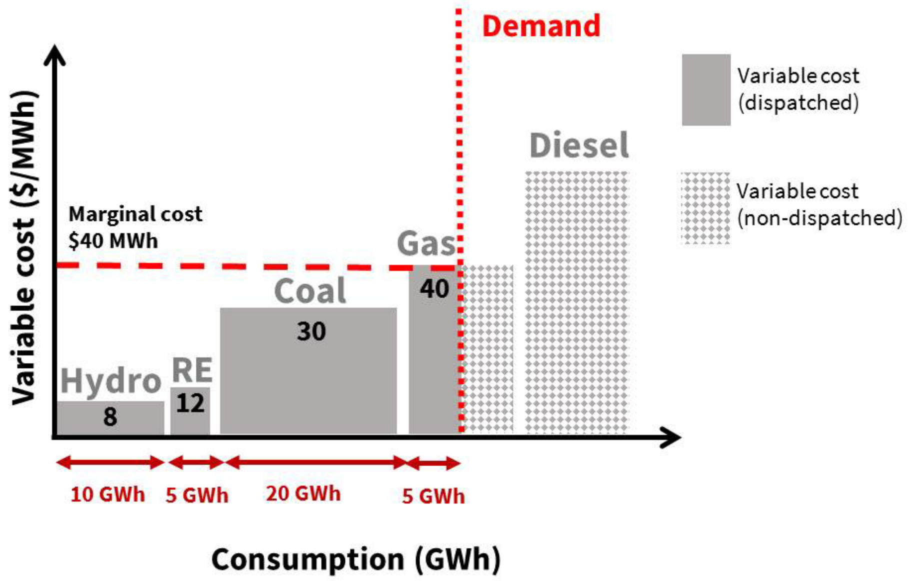


Figure 1: Merit order and price determination in competitive wholesale electricity markets. Based on RTE France (2016)

Changing the electricity generation mix and/or changing commodity prices that determine the short-term (marginal) costs of operation will change the shape of the electricity supply curve and therefore likely have an impact on electricity prices (Cook et al, 2013). For example, shutting down coal plants would shift the curve depicted in Figure 1 to the left and would increase electricity prices, at least in the short term. Vice versa, the increase of power production from renewable energy sources with very low marginal costs will decrease the price levels in the wholesale market.

In theory, allowing the prices of electricity to reflect the short run supply and demand equilibrium will create market signals and provide adequate financing for investments in generation options or demand response technologies (Oren, 2003). That is, by allowing electricity prices to rise during times where demand is close to capacity generators will earn profits, often referred to as scarcity rents, which in turn provide an incentive to invest in increased capacity. However, given the importance of electricity to welfare, existing regulatory interventions, market imperfections and uncertainty, regulators have traditionally been reluctant to rely on the market to dictate future capacity (ibid.). Therefore, in practice a broad range of remuneration mechanisms exists to trigger investments or cover other fixed costs because of political targets (e.g., roll-out of renewables, cogeneration) or revenue constraints arising from the wholesale market as described above.

As a result, the typical arrangements for competitive markets consist of four parts:

- The coordination (spot) market delivers price signals for the dispatch of the power generation and forms wholesale market prices. Traditionally it is organised as a day-ahead market for electricity delivered in blocks of an hour or fractions of an hour. With the growing role of power generation from variable renewables, the day-ahead-markets are increasingly complemented by intraday trading.

- The markets for ancillary services cover the diversity of system services (balancing, quality of supply). The prices in the spot market are important indicators whether it is attractive for the power generators or the consumers to get contracts for system services in the ancillary services market.

- To trigger certain structures of the power generation fleets and/or to safeguard security of supply, a broad range of (capacity) remuneration mechanisms is normally in place. The spectrum ranges from targeted remuneration mechanisms (e.g., for renewables, cogeneration) to technology-neutral capacity mechanisms. These remuneration mechanisms close the gap between the revenues from the spot markets and the pay-back needs for the investments concerned, particularly where price caps are in place.

- A regulatory framework for the remuneration of network infrastructures, when these infrastructures are built and operated by natural monopolies (See Section 2.3).

At least for the first three segments, commodity prices and among them carbon costs can and shall play a significant role in delivering efficient and cost-effective electricity. This also means that potential distortions of the carbon price signal due to specific designs of these markets or system segments needs to be carefully considered in ETS and electricity market design.

In addition to the generation costs that are reflected in wholesale electricity prices, retail prices also include the cost of electricity distribution, transmission, market operation, ancillary services as well as additional taxes and charges. Electricity retailers are tasked with providing “full requirements service”, which ensures that all end customers’ demand for electricity is met. This involves additional costs to pure electricity generation as some base capacity is maintained but not always dispatched.

Last but not least, many electricity market or system arrangements also include financial products (e.g., futures, options, and power purchasing agreements) that can be used to hedge costs and revenues for suppliers and consumers beyond the short-term time horizons of the coordination of markets. These markets are often based on the spot markets and depend on their fundamentals (among others also the carbon price) but can play an additional and important role for market liquidity and the functioning of the allowance market.

2.3. Electricity tariffs

Where markets are dominated by a small number of large firms, regulators have a range of tariff options that can introduce price signals similar to those that would be present in a competitive market. Under "Cost of Service" price setting, the regulator estimates the cost of providing electricity for generators, including a "fair"[4] rate of return for investments and capital assets. Then, through the tariff structure, a direct link is established between the costs incurred by the utility and the rates that consumers pay (Cook et al., 2013). Other methods focus on operating costs and the cost of capital (Rate of Return Regulation) or on the performance of the electricity provider when compared to similar providers (Performance Based Regulation). See Box 1 for an overview of regulation methodology.

Box 1: Wholesale electricity regulation methodology

Cost of Service Regulation – A form of regulation that determines prices based on the costs of serving different customers and producing different services.

Cost Plus Regulation – Tariffs are based on expected future costs incurred by the utility plus an agreed "fair" profit. Given that costs are covered, there may be an incentive to inflate costs and therefore accurate estimates of costs that reflect efficient performance are required by the regulator.

Rate of Return Regulation – Sets a tariff based on operating costs and costs of capital. Used commonly for regulated monopolies and attempts to mimic consumer prices that would prevail in competitive markets. However, it has been criticised that it results in inefficient spending on capital to raise tariffs (known as Gold Platting).

Performance-Based Regulation – Any rate-setting mechanism that links rewards to desired results or targets by setting rates (or rate components) for a given time according to external indices (Benchmarks) rather than a utility's actual cost of service. Also called incentive-based regulation, it is designed to encourage cost savings and improved performance. The most common forms of performance-based regulation are award-penalty mechanisms and multi-year rate plans.

Sources: Berg et al. (2005); Dixit et al. (2014); World Bank, Ecofys and Vivid Economics, (2016); Averch and Johnson (1962).

Retail tariffs set the rules and procedures that determine how different categories of consumers are charged for their electricity use. Depending on the objectives of the regulator, different rate structures are possible. The simplest is a "single part tariff" that charges a single price for all units of electricity consumed. The most common is a "two part tariff" where consumers pay a fixed price fee per billing period (i.e., load charge, connection fee) as well as a

[4] For example, in 2012 in California a fair profit is considered to be 10 percent Return on Equity (ROE) and 8 percent Return on Rate Base (ROR) (Cook et al., 2013).

variable component that depends on actual consumption. "Increasing block tariffs" increase as the volume of electricity consumed increases. Other tariffs aim to better mirror marginal costs of electricity production such as time of day tariffs, peak load tariffs and seasonal tariffs (Dixit et al. 2014). Box 2 provides an overview of different tariff structures.

The entity responsible for determining electricity tariffs differs between jurisdictions. They include regulatory commissions, government ministries, or the parliament (ibid.). Review periods also vary between annual to multi-year determination periods.

Box 2: Examples of electricity tariff structures

Single Part Tariff – The operator charges a single price per unit of electricity for the entire amount of electricity consumed by the consumer. Although easy to administer, single part tariffs do not reflect cost structures and therefore might result in inefficient electricity consumption.

Two (Multiple) Part Tariff – The customer pays a monthly fee for access and a usage fee for consumption of electricity. Can better reflect electricity generators operating costs.

Block Tariffs – Charges reflect how much electricity is consumed. Increasing block tariffs increase as larger amounts of electricity are consumed. Decreasing block tariffs decrease in price as smaller amounts of electricity are consumed.

Time of Use Tariffs – Rates that vary depending on when the electricity is used throughout the day. Such a tariff can encourage shifting consumption from peak to off-peak. They are normally set in advance and adjust little to actual conditions.

Real Time Pricing (Dynamic) Tariffs (RTP) – Charging for electricity according to its cost at the time of demand. RTP reflect current conditions and provide the best available signal about the marginal value of power. However, billing consumers requires sophisticated measurement of consumer use.

Sources: Berg et al.(2005); Dixit et al. (2014); Hogan, (2014); World Bank, Ecofys and Vivid Economics, (2016).

3. Allowance prices and electricity prices

Within competitive and liberalized electricity markets, an explicit price on carbon in theory drives abatement through six levers (Howes and Dobes, 2010). First, it makes low-carbon electricity generation more competitive, encouraging a shift in the power mix away from fossil-based generation technologies towards low-carbon alternatives (supply or clean dispatch lever). Second, it increases the price of fossil fuel-based electricity, pushing consumers to use electricity more efficiently or to purchase cleaner electricity products (demand side or consumption lever). Third, under a well-functioning carbon market less emissions-intensive forms of generation become relatively more profitable, providing an incentive to invest in low-carbon technologies and their development (investment lever). Fourth, high carbon assets earn lower margins and are therefore encouraged to shut down (accelerated decommission lever). Together, these levers also provide a broad signal to invent new products, processes and technologies that use carbon more efficiently (innovation lever).

These abatement levers are represented in the conceptual framework presented in Figure 2. The conceptual framework distinguishes between operation decisions by producers and consumers of electricity, which drive short term static efficiency as well as investment criterion, which drives dynamic efficiency. For abatement to occur efficiently, the allowance market must generate a clear and credible carbon price signal, and this signal must be passed from producers to end consumers. We apply this framework to understand the opportunities and constraints for abatement under different forms of electricity sector regulation (Section 4). The effect of allocation and compensation decisions on carbon price pass-through and the resulting price signal is considered. The effect of companion policies on the ETS is treated separately in Section 6.

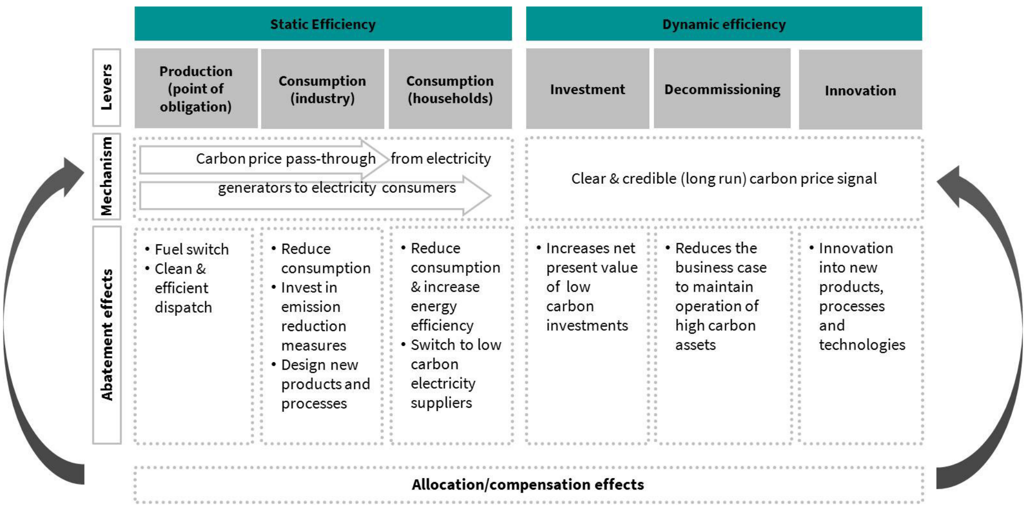


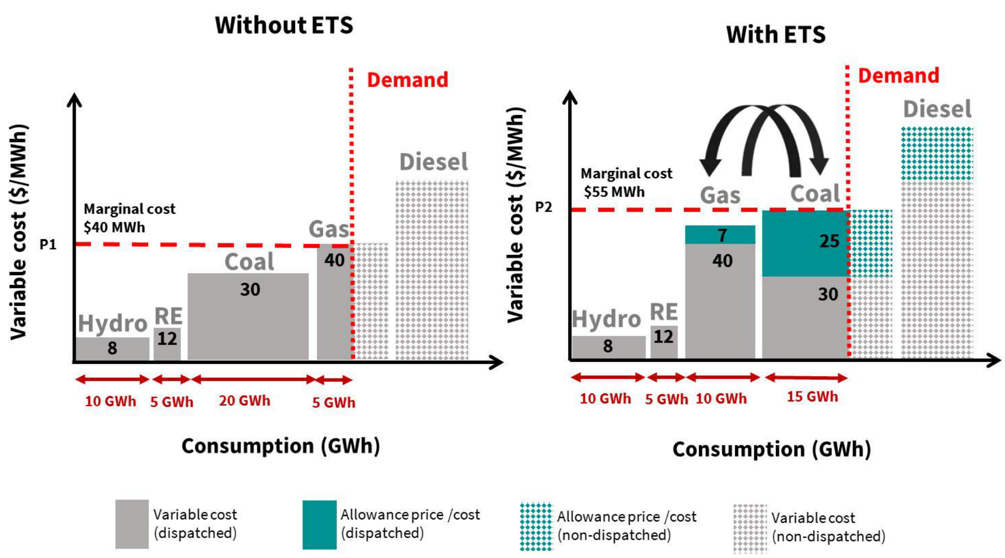
Figure 2: Framework for understanding interactions between power sector regulation and emissions trading

3.1. Low-carbon production (clean dispatch)

When electricity markets are fully competitive at least at the wholesale level, electricity prices are set by the market on the basis of supply and demand. Power generators offer electricity at a price that reflects their short-term variable costs of production (short-term marginal costs). Electricity markets dispatch (or send) the cheapest sources of electricity first and then source from increasingly expensive options until demand is met. The market price paid to all generators regardless of their bid is set at the value of the final (and most expensive) MWh supplied (Cook et al., 2013). This process is called economic dispatch and ensures electricity prices are minimized.

Carbon pricing and economic electricity dispatch interact by including the cost of allowances in generators' variable costs. The variable costs of carbon-intensive generators increase compared to low (or zero) carbon generation which can lead to changes in the dispatch or merit order. Simultaneously, power generators implement abatement technologies to reduce their carbon costs. When the marginal plant, the plant supplying the final MWh, is carbon intensive, the allowance price is reflected also in the wholesale price. This price increase will occur regardless of whether allowances have been distributed for free or purchased at auction as in competitive markets, allowances received for free can be sold and hence have value (Burtraw et al., 2002). The higher electricity price will benefit all power producers but will make especially non-fossil fuels more competitive (Baron et al., 2012).

If however the carbon price is distorted/impaired, e.g., by certain allocation mechanisms[5], the generator will only include the distorted price in its bid to the wholesale market which is then no longer a uniform price signal for the market (see. Section 3.5). How the electricity dispatch can hypothetically be affected by the introduction of an ETS is depicted in Figure 3.



[5] If an operational decision of a generator has an impact on the future free allocation to the generator (e.g., in a system of free allocation where the allocation for the next year is based on the production or even the emission of the recent year), the generator will adjust his bid by the lost value of free allocation in the future. Such mechanisms can erode the carbon price signal significantly.

Note: This figure illustrates the effects that the emissions allowance prices have on the dispatch, namely: 1) increasing the marginal price or wholesale price of electricity, 2) raising the variable generation costs of carbon intensive plants; and 3) shifting the merit order of different technologies by e.g. placing gas first and pushing coal down the merit order. Under an ETS, the allowance price is added to the variable costs of each fossil based technology (see the case of gas, coal and diesel).

Figure 3: Electricity dispatch after an ETS is implemented (hypothetical example). Based on RTE France (2016)

3.2. Low-carbon consumption

In theory, when the carbon price is also reflected in the power market, higher electricity prices trigger lower consumption of electricity, both at the household and industrial level. Large industrial consumers of electricity seek new operating and production processes that use electricity more efficiently as well as investment in energy efficiency equipment or reduction of wasteful consumption.[6] For an overview of allowance price pass-through in the EU ETS power sector, see Appendix A.

3.3. Low-carbon investment

Besides driving efficient production and consumption decisions, an ETS will steer capital towards low-carbon investments and away from carbon-intensive ones. The incentive for investment in new capacity and for investment in major capital additions on an existing unit – e.g., for the installation of emission control technology – is driven in part by expectations of the net present value of revenues to be earned in wholesale electricity markets (including the effects from carbon pricing) and all investment and operational costs (including all costs for allowances and benefits from free allocation) (Hibbard, Tierney, and Franklin, 2017).

An ETS shifts the relative cost structures of generation capacity in favor of low-emission generators. The allowance price increases the variable cost of carbon-intensive generators, ultimately increasing their levelized costs[7] (a measure for comparing the cost-competitiveness of different generation technologies) when compared to low-carbon alternatives. By increasing the relative marginal cost of carbon-intensive generators, an ETS also renders them less competitive in the wholesale market and therefore they are, everything else being equal, utilized less and sell less electricity (IEA, 2017; Harthan, 2014). Assuming no distortions (see Section 3.5), these factors combine to make carbon-intensive generation less profitable under an ETS.

The opposite is true for low carbon generators. As the wholesale price increases (see Figure 3) in response to allowance prices, the net return for low-carbon generators also increases. As a

[6] In practice, a minimum level of allowance price may be required before emission reduction activities are implemented.

[7] The levelized cost of electricity (LCOE) is a measure that reflects capital expenses, operating expenses and variable costs over the lifetime of the technology; it indicates the revenue per kWh needed to achieve a zero-net present value of an investment. Note that although the LCOE is broadly used as a measurement of cost-competitiveness of different technologies, it is an imperfect measure, because it is only valid to compare technologies serving the same load segments (IEA, 2017; Jean, Borrelli and Wu, 2016).

result, less emissions-intensive forms of generation become relatively more profitable which increases investments in clean generation capacity.

Both the stability and magnitude of the allowance price matters for the costs structure of electricity generation technologies and investment decisions. The larger the expected allowance price, the higher the expected net-return of low-carbon power plants, making it more attractive to invest in low-carbon technologies (Lambie, 2010). Clear and credible allowance price signals are required, such that investors can have sufficient certainty that they will recover the very high upfront investment costs with future sales of low-emission electricity. Where markets are not liquid and trade occurs infrequently and over the counter, the allowance price will be volatile and will not reflect the marginal cost of abatement. Increased price volatility raises the riskiness of investment and therefore might delay or reduce investments (Neuhoff et al., 2015) in low-carbon generation or encourage existing carbon-intensive operators to continue production. This highlights the importance of a credible long-term policy framework that generates a stable and increasing carbon price (Acworth et al., 2017).

3.4. High-carbon decommissioning

As carbon-intensive assets age, decisions must also be made on whether to modernize and continue the operation of existing generators, or to close these fleets and make way for new generation capacity. Ultimately, the decision will depend on whether the operating costs of the existing plant and resulting revenue from generation will be competitive with new technologies. Where the allowance price increases to the point at which the running costs or short-run marginal costs (fuel, carbon, fixed and variable operations and management) become higher than the costs of new investment (long-run marginal costs, including the cost of capital) in lower-carbon plants, a high-carbon asset will be pushed out of the market (Guivarch and Hood, 2010). Changes to the wholesale electricity market induced by emissions trading will also favour early retirement, for example, where emission intensive generation run less and earn lower margins and are hence increasingly less competitive than low emission alternatives (Cleetus et al., 2012). Importantly, expectations of increasing future allowances prices will further encourage operators to shut down carbon-intensive generation units, rather than maintaining them as back up generation (Guivarch and Hood, 2010).

3.5. Allocation and compensation effects

The efficient functioning of an ETS will also be affected by how compensation is provided to affected stakeholders. In the worst case, even with competitive electricity markets, an ETS might not operate efficiently where allocation decisions together with compensation mechanisms distort the incentives that the ETS is designed to deliver.

1. Compensation to generators (free allocation)

Where allowance costs can be passed to consumers, free allocation will result in windfall profits (Hintermann, 2014; Neuhoff, 2011; Point Carbon, 2008). The size of these profits is dictated by the portion of carbon costs that are passed to consumers and changes (if any) to the volume of electricity sold once an ETS is in place.

Windfall profits from free allocation are mostly a distributional issue. They might be desirable in the initial phase of an ETS where compensation for carbon-intensive assets is deemed politically necessary (because of the devaluation of assets that have been invested in the past). However, where free allocation is present and changes to allocation are made based on output (updating provisions) and carbon costs can be passed on to consumers, the resulting windfall profits might have perverse outcomes on investment and disinvestment decisions and disrupt the efficiency of an ETS (Flues and van Demer, 2017; ICAP-PMR, 2016).

For instance, where adjustments are made for new entrants, the potential for large windfall profits might alter investment decisions in favor of carbon-intensive assets (Paul et al. 2008). Similarly, the removal of free allowances from decommissioned plants provides a financial incentive for old and carbon-intensive capacity to continue production. Hence, free allocation[8] could translate into implicit capacity payments, distorting the allowance price signal in favor of fossil-fuel suppliers and delaying decommissioning of old high-carbon assets (Paul et al. 2008; Matthes, 2015; Turmes 2015).

Besides windfall profits, high shares of free allocation can have a second distortionary effect. Following Burtraw and McCormack (2016), firms that receive a high share of free allocation relative to their (short-term) compliance needs, may have limited incentive to trade, resulting in thin (non-liquid) markets. Thin markets where trade is seldom and often over the counter will not reveal a clear allowance price signal and hence provide little information regarding the value of mitigation activities. An unclear market price may in turn make firms reluctant to trade particularly when they face regulatory scrutiny for the recovery of their costs and encourage hording behavior. Together, these factors will prevent firms from recognizing the opportunity cost of allowances and disrupt the efficiency of the market.

2. Compensating indirect costs

Electricity price increases resulting from higher carbon costs may also create competitiveness concerns of energy-intensive trade-exposed industries. Governments can use compensation measures and other special provisions to address these concerns. A key consideration is to preserve the incentives to reduce energy consumption or shift to low-carbon alternatives. This can be done by means of compensation support measures that preserve the electricity price signal such as direct transfers[9] , re-investment, or energy efficiency support measures.

3. Compensation for households

Emission costs passed through to consumer prices will have welfare impacts on households, particularly when there are few low-carbon alternatives. Therefore, governments may wish to compensate some households to offset the cost of climate policy. However, compensation measures must be designed to preserve the CO_2 price signal and incentives created by

[8] For example, free allocation based on grandfathering, as well as fuel- and process- specific benchmarking, introduce distortions for investment decisions in the form of implicit capacity payments (Matthes, 2015).

[9] To the extent that state aid rewards companies for purchasing carbon intensive electricity compared to clean electricity, it may also have perverse incentives.

emissions trading; otherwise end consumers will not have an incentive to reduce the carbon intensity of their electricity consumption.

Governments have a number of options to offset or even reverse the effects of an ETS on low-income households, while leaving the carbon price signal intact. When the allowance value is returned to consumers in a separate envelope (instead of returned on electricity bills), consumers will see a higher electricity bill, but their real income will remain unaffected as their budgets are equivalently compensated (Burtraw, Mclaughlin and Szambelan, 2012). Alternatively, utilizing auction revenues to invest in measures like energy efficiency can lessen the impact on ratepayers by allowing electricity prices to increase, but reducing their electricity bill.

4. Emissions trading and electricity sector regulation

In this section, we discuss the interaction of electricity prices and carbon prices under different regulatory settings. Taking competitive and liberalized electricity markets as the benchmark case, four types of power sector regulation are described which represent the spectrum from fully liberalized competitive markets to heavily regulated, centrally planned systems, namely: (i) liberalized markets with regulated retail prices; (ii) markets with regulated wholesale prices; (iii) market/systems with regulated and/or centrally planned (dis)investments; and (iv) a system with regulated and/or centrally planned production.

4.1. Retail price regulation

Retail price regulation can be aimed at multiple goals. Where natural monopolies supply electricity in non-competitive markets, governments can set tariffs[10] to mimic the prices that would be present under competitive markets. Alternatively, governments can set retail electricity tariffs to limit the impact of power price increases on households[11] and other end consumers or to achieve broader energy affordability goals.

Emissions trading and retail price regulation

The interactions between power sector regulation and emissions trading under retail price regulation are depicted in Figure 4. The incentive for end consumers to reduce their emissions will depend critically on the electricity rate levels and rate structure. In the best case, rate levels and structures will reflect the marginal costs of generators and an ETS can transmit a price signal to end consumers even under price regulation. However, marginal tariffs require sophisticated measurement of consumer electricity use and might not be possible in all jurisdictions. In other cases, rates might reflect the average cost of electricity production. In this case, some pass-through can be expected to end consumers based on an increase in total average generation costs. However, an ETS will not encourage efficient consumption decisions at the margin. In the worst case, tariffs are set ad hoc by the regulator. In this case, depending on the type of considerations that are factored into the price-setting process, different degrees of cost pass-through to residential consumers can be envisaged. Where little or no pass-through occurs, the incentive to reduce electricity consumption or switch to less carbon-intensive goods and services is not delivered (Boute 2016).

[10] Here we use tariffs and rates interchangeably.

[11] In Europe, the retail tariff for households was regulated in 12 out of 28 member states at the end of 2015 (ACER/CEER, 2016).

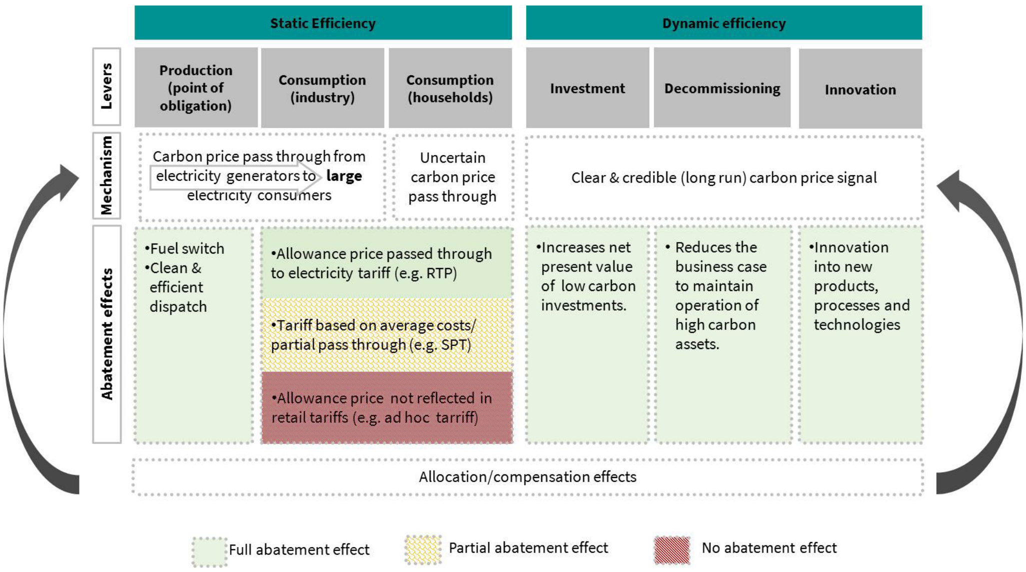


Figure 4: Interactions between power sector regulation and emissions trading under retail price regulation

4.2. Wholesale price regulation

Governments pursue multiple goals through regulating the wholesale electricity market. Where electricity is supplied by a small number of large utilities, regulation may be required to ensure fair and equitable electricity pricing. Governments may also want to ensure predictability and avoid price spikes that affect large industries and businesses. The inelasticity of demand and supply (when output nears capacity) in electricity markets can translate into supply shortages that drive rapid price increases (Borenstein, 2002). In such cases, governments may impose wholesale price caps combined with policies that ensure sufficient capacity during peak electricity periods. Governments may also intervene in the wholesale market to ensure that sufficient supply exists for different needs, from baseload to peak demand cycles, or to prevent blackouts. This may result from a need to ensure or enhance energy security throughout a given jurisdiction, including expanding electrification in remote and rural areas that are less densely populated (Dixit et al., 2014). To achieve these goals, governments can incentivize producers by setting a minimum wholesale price, thereby guaranteeing minimum revenues for the power generated. Alternatively, governments may subsidize electricity inputs to maintain low electricity prices.

Emissions trading and wholesale price regulation

How wholesale markets are regulated and structured has a profound effect on the cost effectiveness of emissions trading. It affects dispatch decisions, price pass-through and resulting downstream effects as well as investment and decommissioning decisions (see figure 6 at the end of this section).

The tariff methodology and structure will be important for how regulated power generators behave under an ETS (Boute, 2016). In the best case, tariffs are set against emissions performance benchmarks (performance-based regulation) with allowances purchased at auction. In this case, utilities have an incentive to generate clean electricity and the carbon costs will be passed onto intermediate and final consumers through the tariff structures, triggering downstream emission reduction activities. Furthermore, ageing high-carbon assets will find production less profitable and hence will be decommissioned earlier, in favor of new low-carbon generation technologies.

Cost plus regulation can also trigger abatement, but to a limited extent. Where tariffs are set based on costs and generators are required to purchase their allowances at auction, the allowance price can be passed through to intermediate and final consumers, triggering downstream abatement activities. However, where high-carbon asset operators can fully recover the cost of purchasing allowances, they will have little incentive to invest in low-carbon infrastructure or to close down high-emitting plants. That said, an indirect incentive may be present where demand side effects signal a preference towards low-carbon alternatives. Where cost plus regulation is combined with high shares of free allocation, the addition to the cost basis and hence associated price increase would be zero (Baron et al., 2012; Paul et al., 2008). The effect of allocation on firms' actual costs is represented in Figure 5 below.

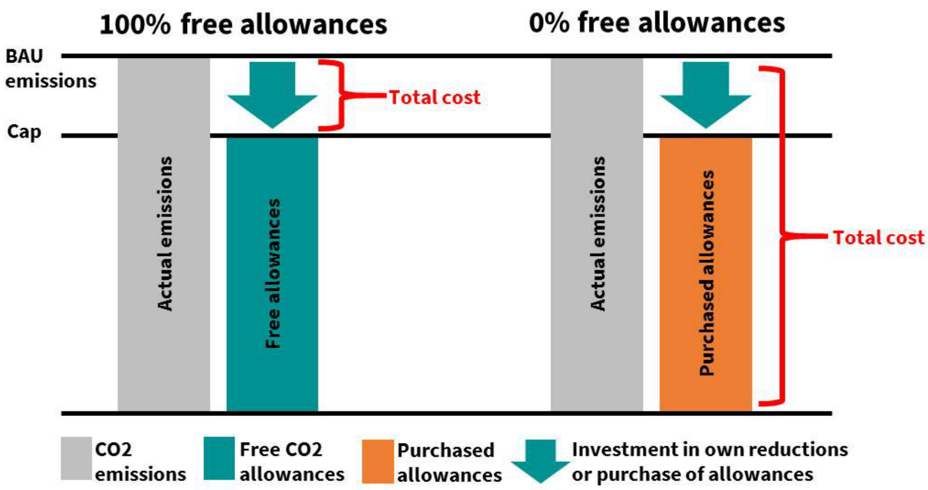


Figure 5: Relationship between actual costs under 100 percent versus 0 percent free allocation (Baron et al. 2012).

Under Rate of return regulation, rates are determined by capital expenditures and depreciation rather than total costs. When combined with full auctioning, operators will have an incentive to invest in new low-carbon capital as this: (i) reduces the number of allowances they are required to purchase and surrender and (ii) increases both their operating costs and depreciation costs and pushes their tariff base up. As the cost of this capital will be reflected in electricity rates, intermediate and final consumers will also see increased electricity prices and hence engage in emission reduction activities. However, when rate of return regulation is combined with free allocation, the incentive to invest in low-carbon capital is removed and operators might equally invest in high-carbon infrastructure if this were to increase their tariff base.

In the case of "ad hoc" price-setting, the power tariff is set following a gross cost basis, whereby only a reasonable return on capital investments is added to the cost of production, taking into account: general price management rules; the competitiveness of energy intensive sectors;

income redistribution; and energy security needs (Kim and Lim, 2014). Where the tariff level and structure does not reflect the allowance price, the resulting changes in dispatch and downstream abatement cannot take place.

Wholesale price caps will also limit the role an ETS can play in reducing emissions from the electricity sector. Firstly, price caps will limit the extent to which fossil-based generators can increase their bid in the wholesale market. When the price cap is set below the variable cost (including the allowance cost) of the marginal generator, it will prohibit the shift in the merit curve that an ETS is designed to deliver (clean dispatch). Further, the limited increase in wholesale electricity price will limit the net present value and hence incentive for investment in low-carbon generation technologies (Baron et al., 2012). Where governments intervene to cap (or artificially lower)[12] the cost of electricity production, the full cost of generation might not be reflected in electricity prices, dampening the incentive to reduce electricity consumption or use electricity more efficiently. [13][14]

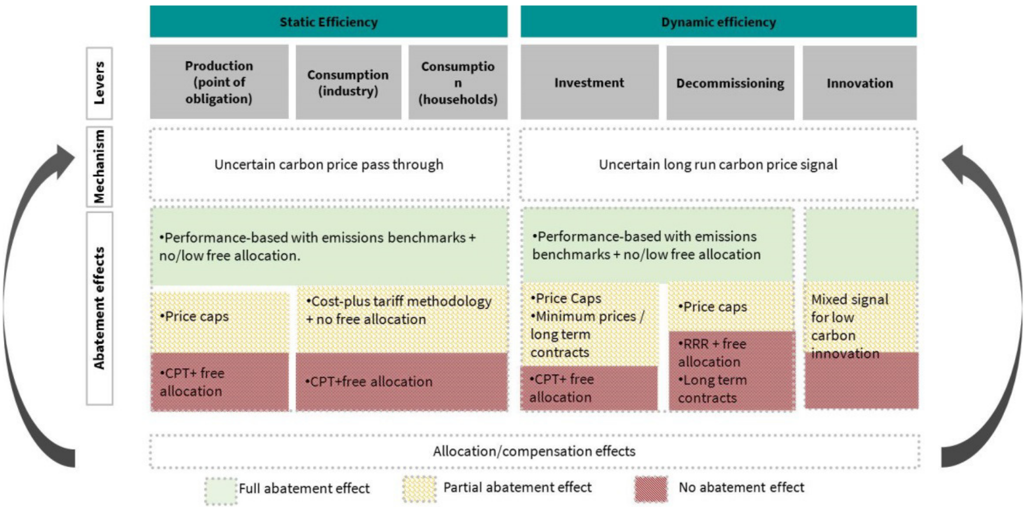
Minimum wholesale prices guaranteed to generators could also slow down the shift towards low-carbon alternatives that an ETS is designed to accelerate[15]. By guaranteeing the revenues of fossil fuel generators over long term contracts, minimum wholesale price contracts lock the energy system into carbon-intensive infrastructure, rather than accelerate its decommissioning.

[12] This can be done by subsidizing the cost of fossil fuel generation inputs such as coal and gas, or where regulators set wholesale electricity prices below the cost of generation.

[13] The cost pass-through onto smaller electricity consumers (e.g. residential sector) is market-specific and depends on the extent to which retail prices change when wholesale prices increase. For example, in the EU-15, short term changes in wholesale prices are a poor driver of changes in retail prices (VaasaETT, 2014). This is not the case, however, for countries such as Finland, Belgium, Denmark, and Sweden where empirical evidence confirms a strong correlation between wholesale and retail prices (Jonsen and Olsen, 2008).

[14] Price caps can also have a positive effect on accelerated decommissioning as they limit the potential rents that old plants can otherwise obtain from price hikes.

[15] Note that the effects of the capacity mechanisms are context specific. Indeed, low carbon technologies (e.g. hydro, geothermal and storage systems) can also be incentivized through capacity mechanisms.



Note: CPT means “Cost Plus Tariff”; RRR means “Rate of Return Regulation”

Figure 6: Interactions between power sector regulation and emissions trading under wholesale price regulation

4.3. Planned investments/disinvestment

Governments can centrally plan expansion of electricity infrastructure to achieve specific goals such as service reliability, energy access/security or environmental targets. To this end, investments are sometimes driven by yearly tenders based on government’s expectations of future capacity needs (Boute, 2016). Similarly, a regulator might require approval through a licensing authority for investments into new generation capacity. In some cases, Renewable Portfolio Standards (RPS) are also in place to ensure a certain proportion of electricity is generated by renewable technologies. With regards to existing generators, regulators can enforce installation specific performance standards (Boute and Zhang, 2017).

Emissions trading with planned investment

The regulation of investments prevents the proper functioning of an ETS (See Figure 7). The market signal that in the liberalized setting drives investment is not created. Rather, investments are made based on government forecasts and broader objectives.

The efficiency effects of closed investment levers can be more or less severe according to how decisions take place. Non-profit driven State Owned Enterprises (SOEs) may not always respond to economic incentives for clean investments, yet SOEs may typically have the direct access to funding that is needed to drive technology changes (Baron et al., 2012). Indeed, investment regulation can also be aimed at replacing old and inefficient plants or phasing out certain technologies. For example, over the course of the 11th Five-year plan, China implemented a program called “Building big, closing small”, aiming to close 77GW of small, inefficient coal plants, and substituting them with high-efficiency plants (ibid.).

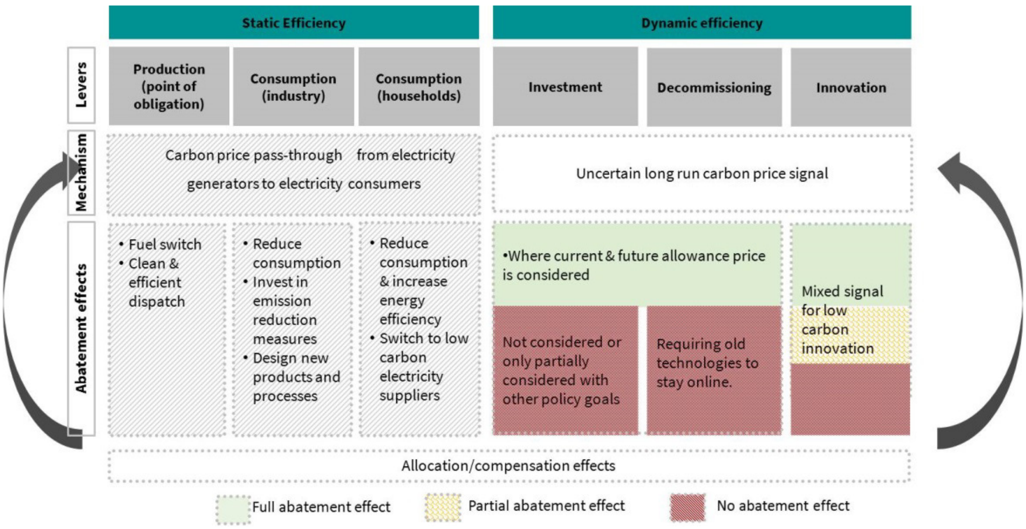


Figure 7: Interactions between power sector regulation and emissions trading with planned (dis)investments

Emissions trading with planned disinvestment

In some circumstances, planned investments might also preclude disinvestments in inefficient or obsolete plants. In some jurisdictions, decommissioning is subject to a strict approval process for reasons of security and reliability of supply (Boute, 2016). Furthermore, the system operator may have the right to require old technologies to stay online as back up capacity, again creating a barrier to shifting to cleaner alternatives. Where this is the case, the current and expected future allowance price will not enter decommissioning decisions. This is a concern not only for cost-effective mitigation from within the current electricity system. Planned disinvestment will also dampen the long term "information signal" that an ETS is intended to send that high-carbon assets will no longer be profitable in future energy systems.

4.4. System with regulated/planned production

In a system with regulated power production, electricity generation and dispatch do not follow least-cost rules. Instead, planning agencies instruct the dispatch using administrative approaches alongside technical, economic, and political considerations. The regulator forecasts electricity demand for the coming period (normally annually), and then allocates this demand to generators. The allocation of generation quotas can be designed so that all plants are allocated the same annual utilization hours, or that each plant is assigned different utilization hours according to pre-established rules (Ho, Wang, and Yu, 2017). The allocation of the same utilization hours to different plants implies that less efficient plants will run the same number of hours compared to more efficient ones (Karhl, Williams, and Juanhua, 2011; Ho, Wang and Yu, 2017). Therefore, electricity will not be distributed at least cost.

Furthermore, planned dispatch limits the business case for investing in more flexible coal and gas power plants as well as renewables (Dupuy and Li, 2016). It is not sufficiently flexible to support the increased variability in electricity supply as a result of increasing renewable energies and it can cause wind and solar curtailment[16], creating uncertainty surrounding the revenue flow for renewable operators and therefore affecting investment decisions.

Emissions trading with regulated generation

When electricity is dispatched following administrative instructions, operation will no longer follow the least-cost approach and investment decisions will not be driven by current and expected market prices. Electricity dispatch will not follow the merit order and cannot, in consequence, be altered by emissions allowance costs resulting from the ETS. As a result, the clean dispatch effect that the ETS is designed to deliver, will not take place (See Figure 8).

Additionally, in an administratively dispatched system, the rate received by each generator would generally be pre-established in purchase agreements, either negotiated on a case-by-case basis or with a tariff regulation. These prices would differ from the wholesale spot market prices that emerge from the interactions of supply and demand. Thus, wholesale prices in these regulated systems typically do not reflect marginal costs of generation and, the effect of an ETS of increasing the wholesale electricity price will no longer take place. Consequently, no cost pass-through to industry and households would be possible under this system.

However, this is not to say that an ETS cannot still play a role in decarbonization. An ETS can also serve as a strong signal that emission intensive activities will play a declining role in future economic activity (Acworth et al., 2017). A clearly defined emissions reduction pathway provides predictability for economic actors, as it frames market expectations and sets a clear signal for necessary long-term investments (Eden et al., 2016). While the direct role of the current allowance price might be low, as long as reduction paths are credible, increasing future allowance prices will shift investment decisions in favor of low-carbon alternatives.[17] In a context where the power mix is dominated by a single generation source, such as coal and the demand response to increasing electricity prices is low, it will be investments in new clean generation that will largely drive emission reductions. Hence, a strong medium to long-term signal for clean investment can still play a critical role in the broader decarbonization process.

[16] Curtailment is a reduction in the output of a generator from what it could otherwise produce given available resources, typically on an involuntary basis.
[17] For a discussion surrounding the credibility of climate policy, see Helm et al. 2003; Brunner et al. 2012, Hepburn et al. 2016, Grosjean et al. 2014 and Acworth et al. 2017.

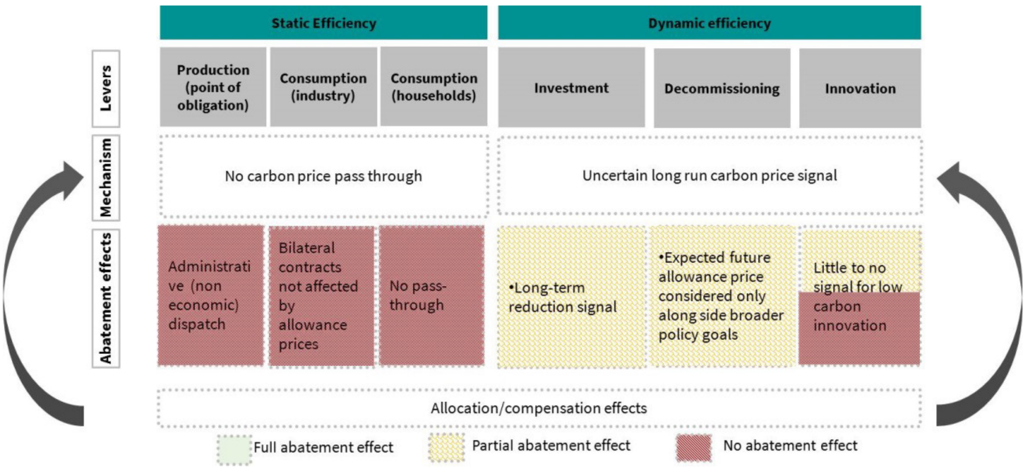


Figure 8: Interactions between power sector regulation and emissions trading with regulated / planned production

5. Options to strengthen the allowance price signal

This section presents options to restore abatement levers under different forms of power sector regulation, namely: consignment auctions, coverage of indirect emissions, investment boards, establishment of pricing committees, a consumption charge, and climate oriented dispatch. Some of these mechanisms are parts of the ETS design itself (section 5.1. and 5.2) and others make use of the carbon price signal that is created by an ETS in the broader regulatory framework for the power sector (section 5.3 to 5.6).

5.1. Consignment auctions

In a system with consignment auctions, recipients of free allowances may be required to offer their allowances for auction, but in exchange receive the revenues of such sales (Burtraw and McCormack, 2016). These revenues can either be "consigned" to a specific use, or contribute to general revenues. This can increase market liquidity, help price discovery and market efficiency as well as market initialization in ETSs that are dominated by free allocation (ibid.). Consignment auctions could enhance the functioning of an ETS where prices are regulated or where regulatory barriers impede price discovery.

In California, consignment of allowances to auction by Investor Owned Utilities (IOUs) is a feature of the California Cap-and-Trade Program. The California Cap-and-Trade Program administrator (the California Air Resources Board or CARB) allocates free allowances to IOUs on behalf of electricity ratepayers to ensure that ratepayers do not experience sudden increases in their electricity prices associated with the Cap-and-Trade Program. Functionally, this means IOUs consign their allowances to auction and buy back the allowances that they need for compliance (Burtraw et al., 2012). The consignment auction, which is held as part of the Cap-and-Trade Program quarterly auctions, is run by CARB (and Québec and Ontario) and IOUs are required to use the value of allowances to benefit retail consumers through methods consistent with the goals of the California Global Warming Solutions Act (AB 32) that do not counteract the price signal (CARB, 2014).

IOU retail rates are approved by the California Public Utilities Commission (CPUC) through ratemaking proceedings (CPUC, 2017). Retail prices are established every two years on the basis of the cost of generating and delivering electricity or purchasing power in the wholesale market, the cost of maintaining or investing in new assets and infrastructure, and government policies (see Cook et al., 2013). As part of the ratemaking process, CPUC authorizes IOUs to incorporate forecasts of Cap-and-Trade Program costs into their customer rates and oversees the return of all consigned allowance auction proceeds to the IOU´s residential, small business, and emissions-intensive, trade-exposed retail consumers.

5.2. Coverage of indirect emissions

When electricity prices do not reflect the allowance price, for example in the context of regulated wholesale prices, some jurisdictions require both electricity generators to surrender allowances for their direct emissions and large electricity consumers to surrender allowances for the indirect emissions associated with electricity consumption. This extends the scope of the ETS to include large electricity consumers such as office buildings, hospitals and hotels.

Under such an approach, the allowance cap no longer represents total emissions as some tons are allocated twice: once as a direct emission and again as an indirect emission (referred to in this paper as double coverage).

Under double coverage, where generators face a carbon cost (i.e., where they do not receive all required allowances freely), electricity generators have an incentive to reduce the costs associated with their compliance obligation and hence decrease the carbon-intensity of electricity production. Similarly, large electricity consumers that also face a compliance obligation have an incentive to consume electricity more efficiently or invest in energy efficiency programs. Where manufacturing entities also have an indirect emissions obligation (as in the Chinese pilots) the cost of carbon might also be passed through to consumer prices, and hence encourage a shift towards lower carbon goods (Munnings et al., 2016). However, as long as wholesale prices remain regulated, efficient dispatch decisions across generators with different emission factors will not be incentivized.

In practice, coverage of indirect emissions also increases the risk of over allocation and may introduce additional distortions to the carbon price. For example, the actual emissions resulting from electricity consumption may differ from the estimate of indirect emissions resulting in over- or under allocation. However, the gap between the two may be minimized through frequent updating of emissions factors (Munnings et al., 2016). Similarly, where allowances are allocated freely based on historical emissions (grandfathering) and there is a demand response to the inclusion of indirect emissions, electricity generators may receive more allowances than they need for compliance and hence will make windfall profits (Shim and Lee, 2016). Additionally, if the allowance price were to be represented in the electricity price over time, for example due to changes in the allocation method or electricity sector regulation, coverage of indirect emissions would result in a “double charge”. Finally, double coverage could also amplify the excess supply or demand during economic recessions or booms (Shim and Lee, 2016).

The Korean ETS (KETS) and Chinese Pilots are examples of systems that cover both electricity generators and large electricity consumers. The Korean electricity market is managed via a Cost Based Pool approach where both quantities and prices are fixed. Prices are determined on a Gross Cost Basis where the cost of production plus a reasonable return are considered in setting prices. End users face different prices with some paying above cost and essentially subsidizing others that pay below cost. The retail prices are updated irregularly and reflect a variety of political and economic considerations (Kim and Lim, 2014). In response to the design of the electricity market, the KETS places a compliance obligation on large electricity producers and consumers. Their compliance obligation is determined by their consumption of electricity and the average carbon intensity of the power grid (the emissions factor). The emissions factor is updated before each commitment period.

5.3. Climate oriented dispatch

In addition to careful ETS design, the carbon prices created by an ETS could be used in the broader regulatory framework for the power sector.

Where the production of electricity is regulated, administrative dispatch could be implemented as an option to deliver the effect on dispatch that an ETS is designed to deliver. Electricity dispatch could be prioritized based on technical specifications, such as emission levels and fuel efficiency. In such cases, instead of minimizing costs, the merit order would minimize environmental externalities, including CO_2 emissions. Operators would thus be ranked by fuel efficiency or emissions levels.

As an example Energy Conservation Dispatch (ECD) was implemented as a pilot in China. Operators are ranked first by fuel efficiency and later by emissions level. Indeed, a merit order for generators was created in China under the ECD pilot where renewables, followed by nuclear, and combined heat- and power cogeneration were dispatched first, and natural gas, coal, and diesel generators were dispatched last (Baron et al., 2012).

5.4. Carbon investment board

In systems with regulated investments, governments could mandate that the planning body consider expected allowance prices when making investment decisions. For example, carbon costs could be included as additional charges or shadow prices in the cost-benefit analysis that governs investments.[18] In this context, the term shadow pricing indicates that the costs are incorporated to guide investment decisions, but they do not represent additional costs for generators. Where an ETS co-exists with regulated investments, the resulting allowance price could be used to infer the level of the shadow price. Where there is not a functioning market, the level of shadow price would not be "market-based". However, it could be inferred from other allowance markets or modelling studies.

In the 1990s, a similar effort flourished among state-level regulatory commissions in the United States, where "environmental adders", as quantitative estimates of environmental costs, were incorporated in investment and operational decisions in electric utility planning (Palmer, Burtraw and Keyes, 2017; Burtraw and Krupnick, 2012; Busch and Krause, 1993). Similar approaches are applied in the United Kingdom and Germany for public investments for large infrastructure projects. Inspired by these methods, shadow pricing could be used in jurisdictions where electricity sector investments are made by a central planning body or where the political context does not allow imposing actual costs on electricity producers.

Shadow pricing could also be useful in the context of regulated production (dispatch), where a committee could establish shadow prices in determining dispatch. For instance, in the late 2000s Mexico designed a scheme[19] whereby the externalities caused by CO_2 emissions (as well as local air pollutants) were quantified and considered in the investment and infrastructure program of the Mexican electricity sector in all cost-benefit analyses of investment projects of

[18] This of course assumes that cost-benefit criteria play a prominent role in investment decisions. However, as discussed above, this may not be the case under certain regulatory settings.

[19] The scheme for incorporating the costs of externalities of local and global pollution as shadow prices was designed in Mexico via the approval of the Law for the Use of Renewable Energy and the Financing of the Energy Transition (LAERFTE, for its acronym in Spanish) in 2008 and the reforms to the Law for the Public Service of Electric Energy (LSPEE) in 2011.

CFE (the state-owned electricity company), as well as in the dispatch of electricity (SENER, 2013).

5.5. Pricing committee

A further option when electricity prices are regulated is to establish a pricing committee with the authority to determine how electricity rates adjust to changes in allowance prices.

In the context of markets with regulated retail prices, the committee could set and review retail prices in response to changes in allowance prices. A pricing committee could be created from existing structures, e.g., public utilities boards or commissions. A pricing committee could enable an ETS to co-exist alongside price setting by acknowledging the internalization of a carbon price into a utility's expenditures and then possibly allowing for the pass-through of such expenditures into retail tariffs.

Québec is an example of this approach where a public utilities board (REQ) illustrates the potential role of a pricing committee. Approximately 96 percent of all the electricity in the province is distributed through Hydro-Québec Distribution (HQD), a state-owned enterprise (SOE), and its retail tariffs must be approved by the province's utilities board (REQ) (see box 2 for an overview of electricity tariffs). Each year, HQD is required to submit a business plan to the REQ in which it outlines cost forecasts such as the electricity acquired, diesel purchased to generate power, and other operations and maintenance (O&M) costs such as customer service. The HQD annual business plan for distribution tariffs is then open to public scrutiny, with civil society and academic organizations able to submit their views of HQD's plan. The REQ, along with public organizations, can also submit questions to HQD, such as clarification queries on various components in order to make sure that HQD's estimates are accurate and reflect its various expenditures and O&M costs properly. Ultimately, the REQ can refer to this consultative process when setting the annual price level.

In markets with wholesale price regulation, the pricing committee could set and review the rules for determining how wholesale prices reflect carbon costs.

In all cases, the committee could operate either as an independent body with complete autonomy of decision making, or following pre-established rules. Under a rule-based approach, the pricing committee could set predetermined price hikes which are automatically triggered at different levels of the allowance price. When compared to rule-based mechanisms, assigning discretionary power to a pricing committee can allow for greater flexibility to respond to unforeseen events, including fluctuations in ETS prices, while rule based interventions might provide increased certainty for power generators.[20]

The timing of the intervention is also a relevant consideration. A rule on the frequency of review, for example, could mandate the Committee to adjust electricity rates either monthly, yearly, or once per compliance period. While more regular updates would more closely mirror

[20] See Grosjean et al. (2014) for a discussion of rule based versus discretionary adjustments in the context of emissions trading.

developments in the carbon market, limiting administrative costs might be an argument for quarterly or annual adjustments. In this regard, Metcalf and Weisbach (2009) argue that most significant abatement opportunities involve long-term investments and therefore there is likely to be little benefit from short-term price adjustments. Similarly, Ismer et al. (2016) have argued for annual adjustments to be made to a consumption charge based on the average annual allowance price (see section 5.6 below).

5.6. Consumption charge

A consumption charge could be introduced to facilitate downstream abatement (Munnings et al., 2016), even when pre-existing regulations might prohibit explicit retail or wholesale price pass-through. This charge would represent the allowance price in the ETS and the carbon intensity of the electricity consumed.

Under such a mechanism, allowances could be given freely to power generators which face price regulation and hence cannot pass through their carbon costs. When allowances are distributed freely according to product-based benchmarks[21] and there is no updating, power generators will incorporate the opportunity cost of allowances into their output decisions and consequently implement abatement options to reduce their costs. While electricity prices remain fixed, some final and intermediate consumers would face a consumption charge at the discretion of the government. If the carbon charge was levied on all consumers, then downstream mitigation options would also be triggered, equivalent to an ETS in competitive electricity markets. However, as power generators are somewhat shielded from the revenue implications of a carbon price, such an approach would not have a strong effect on new low-carbon generation investments and high-carbon disinvestment decisions. Neuhoff et al. (2016) and Ismer et al. (2016) have proposed a similar approach to ensure carbon price pass-through for energy intensive materials under the EU ETS.

[21] Other methods of free allocation will not generate the same effect (See Neuhoff et al. 2015).

6. Companion Policies

Regardless of the specific "type" of regulation, governments are likely to continue to have a strong role in the electricity sector. This might be through direct control of investments or through setting technology-specific targets, performance targets, phasing out emission-intensive technologies or supporting innovation in low-carbon alternatives. These policies will be guided by more than just emission reduction considerations and can either support the ETS overcome barriers from existing regulation or in some cases erode the economic efficiency of the system. Therefore, it is critical that regulators consider the effects of these "companion policies" on the allowance market.

6.1. Types of companion policies

Some companion policies work in concert with an ETS and can be applied to overcome some of the regulatory barriers that have been discussed in Section 4 (complementary policies). For example, under retail price regulation where policymakers decide not to pass carbon costs through to end consumers, or even in liberalized markets where there are information gaps plus market and regulatory barriers, other policy measures can target abatement from the residential sector. Information tools such as feedback programs and energy audits may be useful companion policies. Ayres, Raseman, and Shih (2012); Darby (2006) and Fischer (2008) found that providing feedback on consumption on electricity bills, particularly if coupled with strategies to encourage energy efficiency, has proven to be effective at lowering the residential sector's electricity use. Gans et al. (2013) found that advanced metering programs that allow electric ratepayers to track their electricity use in real-time correspond to a statistically significant reduction in electricity use.

Companion policies can also improve the functioning of an ETS in the wholesale market. For example, policies that encourage electricity storage (e.g., through ancillary service markets) can assist the market operator to balance a grid with an increasing share of variable renewable sources (World Bank, Ecofys and Vivid Economics, 2016). Introducing smart grid technologies will also be useful in this regard. Additionally, shortening the length of time in which electricity market contracts must be struck in advance to actual electricity supply can allow back up generation capacity to better reflect prevailing weather conditions and the associated renewable generation capacity (ibid.).

Other companion policies target the same sectors and sources as an ETS but operate independently from the ETS (overlapping polices). For example, renewable energy targets, installation specific performance standards or the forced decommissioning of fossil power plants will decrease emissions from specific sectors. However, as the cap is fixed, the emission reductions from one sector will result in downward pressure on the allowance price and hence increased emissions from other sectors or sources. This is often referred to as the "waterbed effect" (Begemann et al., 2016). When depressed allowance prices are the result of companion policies promoting specific technologies under the sources covered by the cap, they erode the additionality of those policies, undermining efficiency even further. To the extent that allowance prices are held low, companion polices might also delay investments into new technologies or low-carbon investments, locking economies into carbon intensive infrastructure.

While overlapping policies can erode the efficiency of an ETS, they might serve additional objectives and therefore can be expected to remain. For example, renewable energy targets can be considered an industrial policy where governments might wish to boost investments and jobs in sectors that are believed to reflect the future comparative advantage of the jurisdiction. Similarly, governments may wish to support specific policies to “buy down” their costs and in doing so reduce the social cost of decarbonization over the long run (World Bank, Ecofys and Vivid Economics, 2016). Additionally, overlapping policies might be required to improve air quality in regions where unchecked industrial growth has led to dangerous levels of pollution (Boute and Zhang, 2017).

Finally, some policies can work directly against the incentives that an ETS is intended to deliver (countervailing policies). For example, fossil fuel subsidies distort the power market in favor of carbon-intensive investment and production and decrease the incentive for more efficient energy use, working against the explicit price introduced through an ETS (IEA/OECD, 2017). By placing a positive price on emissions, an ETS can partially offset the perverse impacts of fossil fuel subsidies. Furthermore, where ETS revenues are used to compensate low-income households for increased electricity rates, this might help build trust and in turn support for the removal of fossil fuels.

6.2. Options for dealing with companion polices

Interactions between ETSs and companion polices can to some extent be accommodated through: (i) policy coordination and planning; (ii) building adjustment measures into ETS design; and (iii) through strengthening commitment to long-term targets.

Policy planning and coordination

Identifying, quantifying and evaluating the impacts of companion policies on the allowance market are an important parts of managing policy interactions (Gibis et al. 2016; IETA 2015; Poyry, 2017). Reliable and methodologically sound standards to estimate the impact of companion policies will allow policy makers to take better account of policy interactions when designing and reviewing their allowance markets. While ex-ante modelling is a good starting point, uncertainty will remain over the actual impact. As such, careful monitoring and transparent ex-post reporting on the impact of companion policies on covered emissions will also be beneficial.

The California Air Resources Board (CARB) provides one example of how this can be done in the 2017 Climate Change Scoping Plan (CARB 2017). Specifically, CARB estimates the expected greenhouse gas (GHG) emissions reductions from the policies and measures described in the 2017 Scoping Plan, including the Cap-and-Trade Program. In addition, as part of the 2017 Scoping Plan, CARB conducted an uncertainty analysis to examine the range of outcomes that may occur should policies and measures not perform as expected (see Figure 9). For the EU, ex-ante modelling of the expected impact on allowance demand, combined with a backwards looking ex-post re-assessment has been proposed as a method to calculate the impacts of member state energy policies on the EU ETS (Pöyry, 2017).

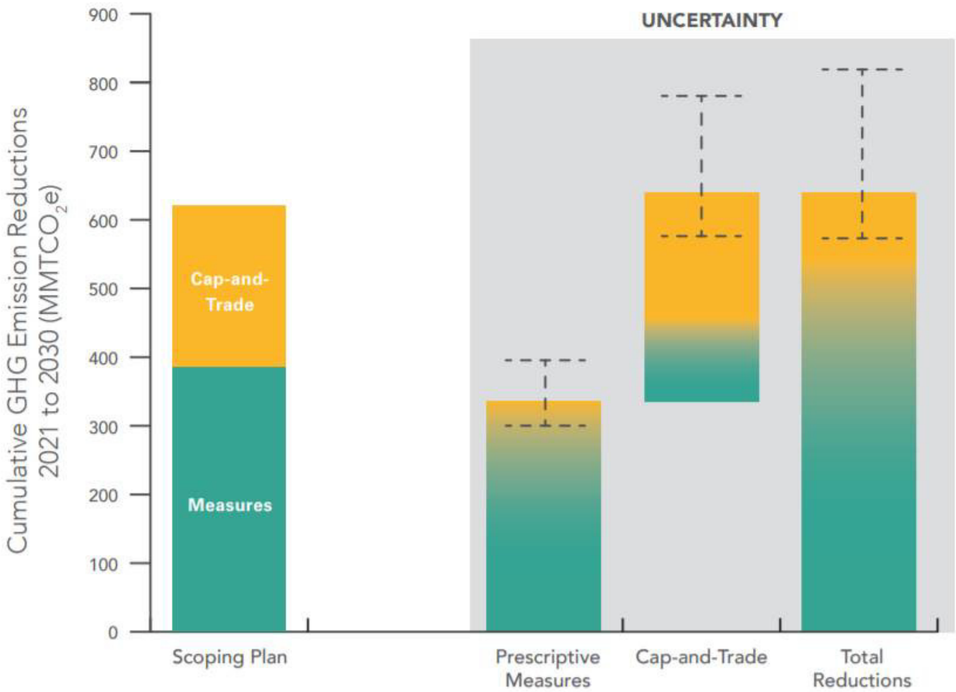


Figure 9: California's 2017 Climate Change Scoping Plan – Uncertainty Analysis of estimated cumulative GHG reductions by measure 2021-2030

The impact of companion policies is best estimated in fixed coordination cycles. With a clear understanding of the impact of companion policies on the allowance market, adjustments could be made to the emissions cap either within the cap period as cancellations (see discussion below), or when setting the emission reduction target for future phases. In light of the need to take account of companion policies in ETS design, some authors have argued in favor of shorter cap periods (5 years) and have advocated to align ETS phases with the "ambition enhancing mechanism" of the Paris Agreement (Gibis et al., 2016).

ETS adjustment measures

Where companion policies overlap with an ETS, adjustment measures can improve the functioning of the market and help ensure the additionality of overlapping policies. Adjustment measures can either come in the form of stability mechanisms that adjust the quantity of allowances auctioned based on price or quantity thresholds (see Acworth et al. 2017 for an overview), or by directly adjusting the cap to reflect companion policy induced changes in allowance demand. As an example, a reserve price at auction means that no additional allowances are added to the market until the reserve price has cleared. Indirectly, this compensates the downward pressure that companion policies might place on allowance prices. ETS in North America all operate with such a stability measure (ICAP, 2018). Similarly, the Market Stability Reserve (MSR) that will operate in the EU ETS from 2019 onwards allows for rule-based adjustments to auction volumes once the allowances in circulation[22] surpass a fixed threshold (European Commission, 2015). In this way, the MSR can remove a portion of allowances from the market that are generated through investments, for example, in renewable energy or coal phase-out.

Alternative approaches look to reduce the allowance supply to directly compensate emission reductions that have been achieved by companion policies (Gibis et al., 2016). For example, from 2021 onwards, member states will be able to voluntarily cancel their allowance auctions where national measures such as coal phase out has reduced emissions from sources covered under the EU ETS (European Commission, 2017). In addition, from 2023 onwards, allowances in the MSR will become invalid if the total amount of allowances in the reserve exceeds the amount sold at auctions in the previous year, putting an overall “cap” on the number of allowances that can be stored in the MSR and resulting in a cancellation of around two billion allowances in 2023 (Weinreich et al. 2018).[23] Similarly from 2021 RGGI will operate with an Emissions Containment Reserve that will automatically cancel allowances when the allowance price falls below a threshold level (RGGI, 2017). These reforms will reduce the dampening effect that companion polices have previously had on the allowance price. Alternatively, output-based allocation, as envisaged for the Chinese national ETS, would allow for the cancellation of allowances to compensate for emission reductions achieved through centrally planned legislation (Boute and Zhang 2017).

Integrating long-term targets

Where an ETS is embedded within clear and credible long-term policy architecture, the short-term impact of companion policies will have less relevance for long-term investment decisions (Matthes, 2010). Stronger commitment to longer-term targets – for instance, by embedding them in legislation – will reduce uncertainty and improve the conditions for low-carbon investment (Acworth et al., 2017). At the same time, pre-defined periods (or phases as in the EU ETS) in a trading program can provide a structured and transparent timeline for reviews and interventions, which as discussed above provide an opportunity to ratchet down allowance caps to take account of companion policies.

In addition to, or where long-term legislation is not possible, establishing long-term decarbonization plans can also play a role in policy coordination and helps linking short-term policies with longer-term decarbonization targets. According Duwe et al. (2017), long-term frameworks help set appropriate long-term targets, chart pathways towards them, and identify the policies necessary to achieve them. They help build political support for climate change

[22] Allowances in circulation are the cumulative number of allowances issued in the period since 1 January 2008 and entitlements to use international credits exercised by installations under the EU emission trading system in respect of emissions up to 31 December of year x, minus the cumulative tons of verified emissions from installations under the EU emission trading system between 1 January 2008 and 31 December of year x, any allowances cancelled in accordance with Article 12(4) of Directive 2003/87/EC and the number of allowances in the reserve (European Union 2015).

[23] Depending on the emissions forecast assumed.

mitigation measures, engage stakeholders and expert advice, and create accountability. These factors combined can strengthen the long-term perspective and the business case upon which investment decisions are made.

7. Conclusions

While power sector regulation can have many goals, different types of regulation can remove or dampen the mitigation signal an ETS delivers. An ETS can still be effective under different forms of power sector regulation, however, in designing, implementing and reviewing an ETS, it is important to understand where barriers exist, how much mitigation potential will be lost and what mitigation will be achieved by other policies in the policy mix.

To the extent that final end customers are shielded from the allowance price through retail price regulation, abatement opportunities in the residential sector will be lost. It is then an empirical question as to how much mitigation potential will be foregone that must be considered against the policy goals of retail price regulation. Consignment auctions, pricing committees and for large consumers, coverage of indirect emissions represent design options that allow an ETS to co-exist with retail price regulation. Furthermore, companion policies that improve information and target residential energy efficiency could be combined with an ETS that operates with retail price regulation.

A competitive wholesale market for electricity seems especially important for the coordination of a low-carbon electricity sector. Competitive wholesale electricity markets ensure the allowance price is reflected in dispatch decisions, incentivizing investments in low-carbon technologies and closing high-carbon generators. There are little alternatives to the coordination and incentive role that markets can play in delivering low-carbon electricity. This role will become even more salient in the face of an increasing number of small scale distributed renewable generators, associated with a growing share of small scale renewable capacity.

Where ETS is introduced within the context of a regulated wholesale electricity market, the regulation is likely to affect dispatch decisions, price pass-through and resulting downstream effects as well as investment and decommissioning decisions. Design options that look to ensure the carbon price signal reaches generation as well as consumption decisions are important. The coverage of indirect emissions has shown some promise in this regard, however, the effectiveness and broader applicability of this design option demands further attention.

A clear and credible carbon price signal creates a business case to invest in low-carbon generators and close high-carbon ageing assets. That said, electricity sector investment is rarely purely market driven and it is likely companion policies will continue to shape the structure of the electricity sector even where well-functioning carbon markets are present. The impact of these overlapping policies must be explicitly considered in the policy planning and coordination process, the design of the ETS, and the way in which long-term targets are set and communicated.

Appendix A: Empirical evidence of cost pass-through from the EU ETS

There is no single EU electricity market; instead, several electricity frameworks exist across Europe. There is, however, evidence of pass-through from the EU ETS to electricity prices across different Member States. For example, Hintermann (2014) finds that carbon price pass-through rates to wholesale electricity prices in Germany are at least 84 percent, with a central range of 98 percent and 104 percent for different load periods.

Matthes and Ziesing (2008) and Matthes (2013) provide empirical evidence (see Figure A.1) of carbon price pass-through to electricity prices for Germany. In Figure A.1., historical costs for hard coal, CO_2 allowances, and electricity prices are compared with the operating costs of a hard coal power plant. The analysis shows two important results. First, the allowance price is represented in the operating costs of the power plant. Second, the operating costs of a coal power plant, which is often the marginal plant and therefore determines the wholesale electricity price, explain developments in the electricity price.

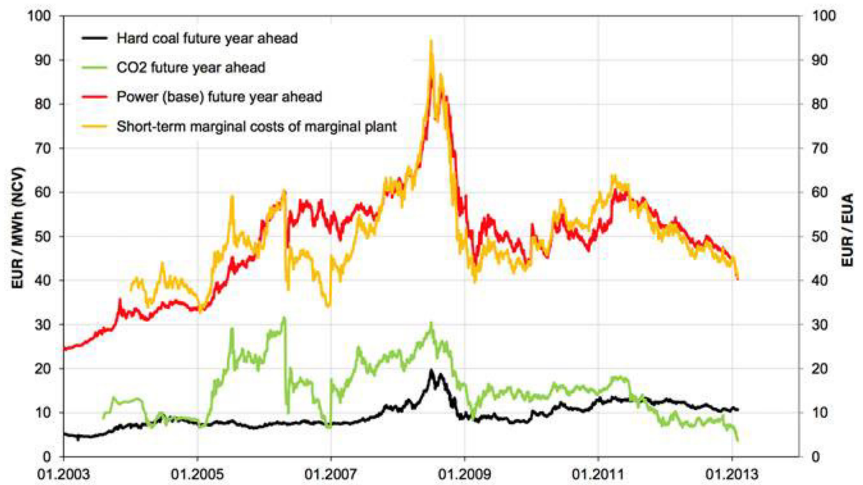


Figure A.1: Interactions between power rates, fuel and CO_2 costs in Germany Source: Matthes (2013) with data from Öko-Institute and EEX.

Fabra and Reguant (2013) found pass-through rates of 80 percent in the Spanish context, meaning that a one euro increase in allowance costs translated into an average increase in wholesale electricity prices of 80 cents. The authors explain the incomplete carbon cost pass-through due to imperfect demand elasticity for electricity and market distortions related to abuse of market power. Honkatukia et al. (2006) found 75-95 percent of allowance price changes were passed on to the Finish Nord Pool electricity spot price.

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