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Impacts of Emissions Trading on Power Industries and Electricity Markets

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***Abstract*—Climate change has become a problem of extensive concern especially in developed countries. Emissions trading, in principle an efficient way to reduce the emissions of greenhouse gases, has been implemented in the European Union, and has been proposed in a number of other countries including Australia and the United States. The power industry is the largest emitter of greenhouse gases in many countries. The purpose of this paper is to briefly review the literature concerned with the potential impacts of emissions trading on power industries and electricity markets, including key issues of emissions trading scheme design, the methods of allowance allocation and their impacts on generation investments, renewable sources and electricity prices.**

***Index Terms*—Power Industries, Electricity Markets, Emissions Trading, Generation Investments, Renewable sources, Electricity Prices**

I. INTRODUCTION

POWER industries around the world play a vital role for modern society through their convenient provision of a wide range of energy services. However, the power industry is the largest emitter of greenhouse gases (GHGs) in many countries, and is hence playing a significant role in climate change - one of the most important issues in the new millennium. Fossil fuels provide approximately 80% of the world's energy and around 67% of global power generation relies upon them [1]. The carbon dioxide emissions associated with this fossil fuel combustion are widely accepted to be contributing to the risk of dangerous climate change. This climate change injures human health, threatens animals and plants' survival, and damages the global economy. To control the emission of greenhouse gases and thus to mitigate the risks of climate change, it will be necessary to reduce the emissions from the power industry.

At the 1992 Earth Summit, under the United Nation Framework Convention of Climate Change (UNFCCC), over 156 countries agreed to an ultimate objective of stabilizing GHG concentrations in the atmosphere at levels that would avoid dangerous warming. In 1997, during the third conference of the UNFCCC in Kyoto, governments of many developed countries established the Kyoto Protocol and agreed to reduce their emissions of GHGs. In aggregate, they are required to achieve a 5% reduction below 1990 levels by 2008-2012. As such, the Kyoto Protocol sets a legally binding obligation for industrialized countries [2].

To fulfill the targets of the countries in an economically efficient way, the Kyoto Protocol created several new flexibility mechanisms, including Article 17 Emission Trading (ET), Joint Implementation (JI) and the Clean Development Mechanism (CDM). ET is a major feature within the Kyoto Protocol, and offers a cost-effective way to reduce the emission of pollutants.

ET may cover several sectors. In many countries, the electricity sector is the largest source of CO_2 emissions. On the one hand, the effectiveness of an Emissions Trading Scheme (ETS) depends on whether it can encourage the power industry to reduce its emissions significantly. On the other hand, the ETS might have a significant impact on electricity prices and generation investment, and hence on social welfare.

The purpose of this paper is to provide a brief survey on the impacts of ET on the power industry and electricity markets with special emphases on generation investments, renewable resources and electricity prices.

This paper is structured as follows. In Section II, a brief introduction to the emissions trading is provided. In Section III, the ETS employed in different countries to date is described. The approaches of allowances allocations and some related design challenges are presented in Section IV. The impacts of an ETS on generation investments, renewable sources as well as electricity prices are respectively surveyed in Sections V through VII. Section VIII concludes the paper.

II. EMISSIONS TRADING: AN BRIEF INTRODUCTION

The idea of the emissions trading was first proposed by J. H. Dales in 1968 [3], and further developed by W.D. Montgomery in 1972 [4].

A key feature of ET is the establishment of a legal right to emit greenhouse gases subject to the possession of pollution emission permits. These permits have an associated market by which emitters can trade this right amongst themselves. Major steps of an ET are:

First, a central authority (usually a government body or organization) sets a limit or cap on the amount of a particular emitted pollutant. Secondly, the cap is divided into many permits which are deemed as the rights to emit a specific amount. Typically, one permit (or allowance, credit) represents one unit of pollution emission. The total amount of permits cannot exceed the given cap, and hence the total amount of emissions is limited to the capped level. Then one of a range of approaches is employed for allocating emission permits among related entities. Finally, the permit transfer among companies can be carried out if and as necessary. A permit transfer is also referred to as an emission trade, in which the buyer pays a market price to the seller. Theoretically, if all emission trades could be carried out in a centralized manner, pollution reduction could be achieved in a most efficient way [4]-[7].

III. EMISSIONS TRADING SCHEMES

In order to accomplish emissions reductions, some countries or regions have established their own national or regional ETS, such as the European Union ETS (EU ETS), the Regional Greenhouse Gas Initiative or RGGI (North Eastern USA), the Japanese voluntary ETS, the New South Wales Greenhouse Gas Abatement Scheme (Australia), the Norwegian system, and the Albertan Climate Change and Emissions Management Act (Canada).

Designing an effective and efficient ETS is very important for mitigating greenhouse gases. Various mechanisms have been employed in different countries due to their respective histories, different economic and social development status. A well-designed ETS is in theory, the most efficient way to achieve emission reductions with as little impact on economic development as possible.

The ETS can be a "cap-and-trade" or "baseline-and-credit" system. The former is based on the emission-permit trading, in which the regulator defines the "cap" or emission limit for the regulated emission sources for a specified period. Typically, the cap is set in physical units (usually tonnes), and is usually lower than the past emissions of sources and reduces over time. Sources with emissions less than their permit allocation or purchases can sell excess permits to facilities wishing to increase emissions. Before the expiring date, the allowances can be traded throughout the ETS system, but at the end of this period participants have to submit allowances to the regulator corresponding to their emissions over that period. The latter approach is based on so-called emission-reduction credit trading, in which emission credits are generated when emissions are reduced below an agreed baseline, i.e. a reference level of emissions during a certain period; emissions above the agreed level have to buy credits. Theoretically, to obtain the same reduction amount, a baseline-and-credit system could end up with higher overall costs than a cap-and-trade one. Therefore, most of the ETSs implemented so far are cap-and-trade based ones [8], [9].

The milestones in the development of the ETS are shown in Fig. 1 [7].

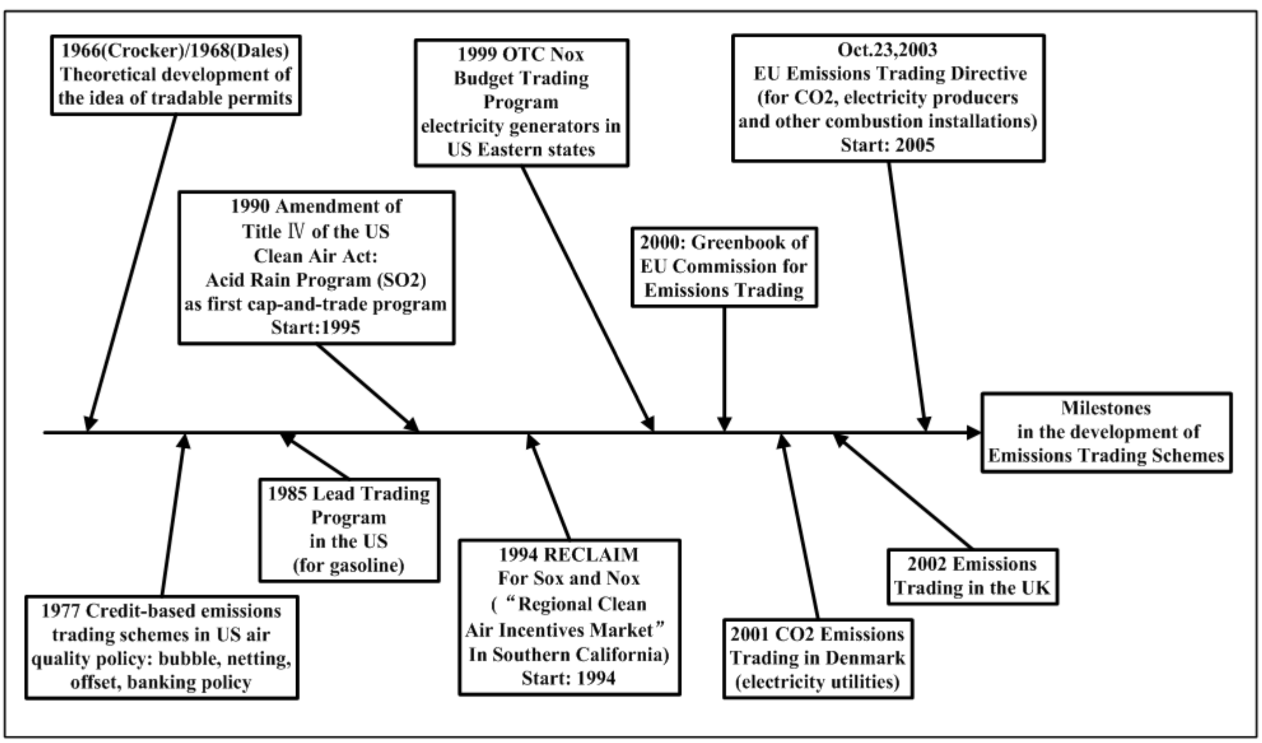

Figure 1. Milestones in the development of the ETS

The United States' Acid Rain Program was the world's first sophisticated emissions trading scheme, and is administered by the U.S. Environmental Protection Agency (EPA, Washington, D.C.). Since it was established in 1995, the basic elements in this scheme have been involved in every later emissions trading program. The scheme aimed at reducing emissions of nitrous oxides (NO_x) and sulphur dioxide (SO_2), and was very successful. Its cost was less than the predicted and the emission targets were achieved earlier than expected [10].

The EU Emissions Trading Scheme (EU ETS) was established under the Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 [11]. This scheme was linked to the Kyoto Protocol's flexible mechanisms through Directive 2004/101/EC [12]. The EU ETS is the largest "cap-and-trade" scheme in operation in the world: one billion tons of CO_2 with an equivalent worth €18.1 billion were traded in 2006. This scheme became the cornerstone of the EU member states to reach their emissions reduction commitments of the Kyoto Protocol, and has, to date, been implemented in two periods: the first from 2005 to 2007 and the second from 2008 to 2012 [13].

IV. Approaches of Allowances Allocations and Related Problems

A. Approaches of Allowances Allocations

The issue of allowance allocations is one of the most controversial challenges in the design of an ETS. How to allocate the allowances? Auction or free? And if free, to whom and on what basis; historical emissions, input or output based, or through some other methodologies. Various approaches have been developed to address allocation. It is possible that the approach employed for allowances allocations may have a substantial effect on the electricity price and hence load demand, the mix of generation technologies, the emission level and the cost of controlling emissions [14], [15].

However, in theory the approach employed only determines buyers and sellers in the market, but does not affect the allowance price. The price is determined by the cap of the allowances and the cost of the emission abatement measures. As a result, the primary focus is generally on equity impacts; how does allocation financially impact on different market participants?

Three main approaches for allowances allocations widely employed in power industries are Grandfathering (GF), Benchmarking and Auctioning (AU).

In the GF approach, the allowances are allocated free of charge on the basis of the sources' historical emission records, and both direct and indirect approaches could be applicable. In the direct approach, allowances are allocated directly to emission producers, while electricity users receive allowances in the indirect method [14], [16], [17].

In the benchmarking approach, emission allowances are also allocated free of charge. In contrast to the GF, emission allowances are granted on the basis of a relative quota or the Performance Standard Rate (PSR). The benchmark could be the energy/carbon efficiency per unit input or output. In the power industry, the most commonly used benchmarking allocation method is based on the Generation Performance Standard (GPS), in which allowances are allocated free of charge to all generators according to their generation amounts in the year concerned. The unit of the GPS is g/kWh, and represents the emission amount of a generator supplying one kilowatt-hour energy.

The auctioning allocation approach is widely deemed the best method with many advantages, particularly if the auctioning procedure is based on the nondiscriminatory principle even for the new entrants [14], [16], [17].

The efficiency and effects or impacts of the three allocation approaches mentioned above are analyzed in [15], [18]-[22], and it is concluded that in the case of nationwide CO_2 regulation, the free allocation of emissions allowances could dramatically lead to overcompensation to the power industry as a whole, although different impacts apply to various parts of the industry. In addition, the auctioning approach could lead to substantially higher costs to generators than those of the other two free allocation methods. The free allocation method has been argued to be a good option at the beginning of an ETS implementation for mitigating the political resistance from the sectors concerned, and then the auction mechanism could be employed step by step [23].

A mixed allocation mechanism, i.e. a large part of allowances is allocated by the GF or benchmarking approach, while the other part by the auctioning approach, has been used in several instances. For example, in the EU ETS it was stipulated that in the period 2005-2007 at least 95% of issued allowances be allocated for free, and this was then reduced to 90% for the next trading period 2008-2012.

B. Related Problems in Allowances Allocations

1) New entrants and closures

For economic reasons, it may not be realistic to adopt special rules to new entrants and closures. However, closing high-emissions power plants is encouraged since it makes space for new entrants. In order to mitigate the impacts on the new entrants and closures after introduction ETS, different allowances allocation approaches are employed for new entrants and closures in various ETSs.

For instance, in the existing USA scheme, new entrants do not receive allowances and therefore have to purchase the allowances if needed from the market, and closures are allowed to keep the initial allowances. While in the EU ETS, all 25 member states have set aside a certain proportion of the total amount of allowances for new entrants, and most member states require the owners of closures to forfeit the future allowances allocated free of charge at closure. Some member states have also developed transfer rules whereby the allowances from a closed company could be transferred to a new one under certain well-specified conditions [24].

The problem of how to allocate the allowances from closed companies is discussed in [23]. If a plant is shut down during its commitment period, the allowances allocated to it free of charge might expire.

Thus, this might postpone the closing of the plants concerned since the companies may hope to keep the allowances. Alternatively, allowances might be preserved for the companies after the closures of the plants, even until the end of the commitment period. In this way, the companies may be happy to close their old plants with intensive CO_2 emission, although it seems to be politically not acceptable with such a premium. A possible compromise approach between political acceptability and innovation stimulation is to permit the companies to keep the allowances allocated to their old plants if they build new ones. The allowance allocated to an old plant is normally higher than that for a new one, since a new plant is usually more efficient and thus emits less CO_2, thus the innovation incentive could be maintained.

2) "Hot air"

"Hot air" is a term commonly used to represent the gap between a participant's emission limit and its expected Business-As-Usual (BAU) emissions, i.e. the emission level without any abatement measure. In other words, "Hot air" could occur if a participant's enforced emission limit is higher than its BAU emission level. However, it is not easy, if not impossible, for every emitting source to keep the emission limit under its BAU emission level [25].

A better understanding of the consequence of "Hot air" in the international carbon emission trading by using some policy variants simulated with the general equilibrium model for energy-economy-environment interactions (GEM-E3) is given in [26]. The GEM-E3 model aims at investigating the interactions among the economics, energy system and environment, and has been applied to simultaneously represent 25 European countries, linked through endogenous bilateral trades. When the allocated emissions trading allowance increases beyond the need of a country, this might lead to the country to have the market power of increasing or decreasing the price of CO_2 allowances in the market. This could jeopardize the environmental effectiveness of the Kyoto Protocol.

In order to improve the environmental effectiveness of the Kyoto Protocol at moderately higher costs, a mechanism of banking for "Hot air" might be employed to enhance the development of workable emissions trading [27].

3) "Windfall"

The introduction of an ETS will generally increase the cost of electricity production. Even free allocation of emission allowances in the power sector is likely to see them passing on resulting permit prices to the electricity price for customers. The companies participating in an ETS could either use emission allowances for their own production or sell them to other companies that need additional allowances [28]. If a company is using an allowance, it will lose the opportunity to sell the allowance, which implies an "opportunity cost", whether or not such an allowances is allocated free of charge or purchased from an auction or the allowance market. Therefore, the company would generally add the cost related to the price of the customers. When the passing-on rate overcompensates for the value of carbon emission allowances, i.e. the marginal cost of mitigation, these companies may obtain windfall profits due to the high electricity prices.

It is demonstrated in [29] that the electricity sector as a whole would gain from the introduction of an emission trading scheme as long as the allowances are allocated free of charge. With respect to different allocation options, it is found that generation companies have different preferences depending on the fuel used. Low or non-emitting facilities such as gas, hydro or nuclear power plants could receive windfall profits as long as the marginal plant is fossil fuelled. A SIMulator for Electricity and Carbon markets (SIMEC) is developed in [30] for evaluating the impact of the CO_2 ET on the Iberian electricity market (IBELM). Given the power plants characteristics, demand data and EU ETS allowance (EUA) prices, SIMEC computes the resulting electricity market clearing price, power generation by technology, CO_2 emissions and power industry profits. It is concluded that the increase of electricity prices in off-peak hours is expected when the ET is introduced. Hydro, nuclear and natural gas plants would then benefit from the higher electricity prices.

The amount of the windfall profit of a company relies on the pass-through rates, which vary between 60% and 100% of the CO_2 cost in the wholesale electricity markets of Germany and Netherlands [9], [31]. The rates depend on the carbon intensity of the marginal production unit and various other market- or technology-specific factors. Additional profits due to EU ETS show that these 'windfall profits' may depend on the price of CO_2 and some assumptions made. For instance, at the price of €20/tCO_2, it is estimated that around €300-600 million per year windfall profits is resulted from the ETS in the power sectors of Netherlands, i.e. about €3-5 per MWh. A comprehensive market power in electricity transmission and energy simulator (COMPETES) is developed in [32]. COMPETES covers the Northwest European electricity markets (Netherlands, Belgium, France and Germany). It simulates the strategic behavior (oligopolistic competition) among large generation companies based on the Cournot and Conjectured Supply Function (CSF) models. A conclusion is drawn from COMPETES that the rates of the CO_2 pass-through are positively associated with the supply elasticity, but inversely related to the demand elasticity.

The pass-through of the CO_2 allowance cost into the electricity price reduces the profits of energy intensive users. However, this pass-through gives a strong price signal as it reduces the gap between the generation costs of renewable energy and coal-fired plants and therefore might stimulate investments in low CO_2 technologies in the long run [33].

In order to reduce the negative effects of the pass-through due to the opportunity cost of freely allocated CO_2 emission allowances, limit the windfall profits of generation companies, and reduce high electricity prices to end-users, less free allowances could be allocated to generation companies by either a more stringent allocation approach and thus more allowances purchased in the emission market, or the auction of a part of the allowances [34]. Less free allocation to generation companies implies less windfall profits. Another option is to compensate the ETS covered end-users by either allocating the CO_2 emission allowances or recycling the revenues from allowances auction to the users [34].

V. The Impacts on Generation Investment

A. *The Impacts on Short Term Investment*

The increase in generation costs is unavoidable for fossil fuel generation units when the ETS is introduced into the power industry and/or electricity markets. In the short term, the outcomes of the merit order dispatching are likely to be changed.

In [35], the situation for Europe is investigated. Under the EU ETS, generation companies or investors concerned would integrate the cost of CO_2 in their investment decisions. The industry will make low carbon investment with limited risk such as short-term investment to improve existing power plants.

A substantial price of CO_2 emissions could result in two main consequences in the short run [36]. First, consumers may purchase less electricity due to the increased electricity price, as represented by the price elasticity of demand. Secondly, the cost of emissions allowances would lead to the change of the dispatching merit order of the existing generators, which depends on their CO_2 emissions allowances and marginal fuel prices. Both the price increase and dispatch changes depend on the mix of generation technologies and fuels available in the region concerned, although the consumers' responses to higher prices are also very important.

In USA, it is estimated that the instantaneous imposition of a price of \$35/tCO_2 would lead to a 10% reduction of CO_2 emissions in PJM and MISO at a price-elasticity of -0.1, and about one-third as large of the reduction in ERCOT is expected. A price on CO_2 emissions bringing an incentive to invest in new generation technology also provides significant CO_2 reduction pressure before the new technology is deployed on a large scale [36].

How the generation investment decision-making procedure should be modified after the implementation of the EU ETS is explored on the European scale in [37]. In the short run, when the price of CO_2 is around €18.5/tCO_2, a switch in competitiveness between the combined cycle gas turbine (CCGT) and the coal plant could occur, because the CO_2 emission amount by a coal plant is more than twice of that by a CCGT plant for per MWh of output.

A switch from the coal-fired to gas-fired generation will be possible in Europe if some conditions are met [38]. First, an economical incentive, i.e. a sufficiently high European Union Allowance (EUA) price together with a sufficiently low natural gas price occurs. Secondly, the power system might have enough CCGT installations for switching, i.e. at a given load, enough CCGT power plants not running could substitute for coal-fired plants.

B. *The Impacts on Long Term Investment*

In the long term, if the CO_2 permit price is high enough, generation companies or potential investors may invest in low or zero carbon generators to replace the higher ones, and the ET would affect the investment in generation facilities and technology selection [39]. For example, under the EU ETS scheme, emissions trading has significant impacts on the investment decision-making in a country-specific setting in Finland by several variables: the price of the allowances, the number of allowances to be surrendered to authority, the EU ETS operating hours and the number of free allowances allocated for generation units [40]. With an investment appraisal based on quantity statistics, the impact of emissions trading not only depends on the expected level of allowance prices, but also on their volatility and correlation with electricity and fuel prices. For the thermal power plants in the case study, the uncertainty regarding the allocation of emission allowances is critical to the decision-making concerning if or not switching to natural gas.

For a generation company, in order to maximize expected profits, in making the strategic investment decision, detailed analysis should be made about the cost of R&D on the emission control technology, the cost of instruments for emission reduction, the fuel cost, the cost of operation and maintenance, the opportunity cost of permits or purchasing cost, and the opportunity cost of the non-dispatched generation capacity. The following choices are available:

- Investment to emission control technology and instruments.
- Purchasing the permits from an emission trading market.
- Reducing the electricity production so as to decrease the emissions.
- Mothballing the plants and selling the emission permits, until the price of permits decreases.
- Changing the fuel, and substituting the coal-fired units with CCGT or other low-carbon emission units.
- Retire.

The negative impact on overall investments in the power industry as the result of the ETS implementation appears inevitable, but on the other hand this does guide the choice of generation technologies for new entrants. A new generation plant is normally expected to keep operation for 20-30 years. However, in making the decision only limited and short-term market information is available for investors, and many uncertain factors will be encountered. Hence, setting a long-term ETS policy is crucial for providing a clear incentive for investing in new low-emission technologies.

VI. Impacts on the Development of Renewable Energy Generation Sources

Switching a fraction of the generating capacity from fossil fuels to renewable technologies such as hydro, wind, biomass, or geothermal turbines would be helpful to reduce carbon emissions from the electricity sector. However, because of the relatively high cost of non-hydroelectric renewable energy, their shares only reach 2% of the total electricity generation in OCED countries and 1% in non-OECD countries [41].

In Europe, a support system for Renewable Energy Sources was developed, and named as RES-E (the Electricity from Renewable Energy Sources) [42]. In the effective RES-E support system, if the increase of RES-E is higher than that of the electricity consumption, additional RES-E may substitute the electricity supply from fossil fuels, and CO_2 emissions from the electricity sector could then decrease. As a result, the demand for emission allowances could decrease, and the price of CO_2 will most probably decline accordingly. Thus, the opportunity cost of a generation company decreases and the marginal cost curve (merit order) changes, and so does the wholesale price. For instance, in the German electricity markets, the retail electricity price in the first trading period of the EU-ETS 2005–2007 was lowered by €2.6 /MWh due to additional RES-E.

Biopower is also one kind of renewable energy. The ETS may lead to the increase of the electricity price from fossil fuels plants, and hence improve the competitiveness of biopower [43]. For example, if the price of the CO_2 allowance is €10/tCO_2, it is estimated that the electricity price in German and Nordpool electricity markets would increase by around €3-8/MWh. A generation company or potential investor may compare the costs of investing on GHG reduction instruments or on biopower, foresee the equilibrium of the electricity supply and demand, and then decide which measure should be undertaken.

Wind energy is one of the most important renewable energy sources. In the future, how the EU ETS could comply with the 20% CO_2 emissions reduction target in Europe and promote wind energy investments at the same time is discussed in [51]. The CO_2 price reflects the benefit of wind after the implementation of the ETS. To support the wind energy development, it is estimated that around €40/tCO_2 should be attained.

VII. The Impacts on the Electricity Price

It is expected that all generation companies would like to pass through the full cost of emissions allowances to the end users by adding it to their short-run marginal cost. The cost would first be passed on to the wholesalers, and thus increasing the wholesale electricity price. Then it would ultimately be passed on to the end users, and lead to the increase of the end-user electricity price. In each stage, the pass-through rates and thus the impacts of the ETS implementation are different.

A. The Impact on Wholesale Electricity Prices

The wholesale electricity price is determined by many factors including market and non-market ones. Obviously, the ETS could have impacts on the wholesale electricity price. The degree of this impact will depend on many aspects [33], [34], [44]:

- The CO_2 intensity of the electricity generation. The carbon intensity of the fuel at the margin is the primary factor to analyze the carbon intensity of a country.
- Competition in the market or the intensity of competition, along with the chance that higher price will be acceptable by regulators or politicians.
- Current CO_2 price levels. If the CO_2 price is very high, it will significantly impact on new entrants.
- The rate of passing through carbon cost. The higher the rates, the higher the wholesale price would be.
- The flexibility of generation. Technical factors such as ramp rates, dispatch ability, age of the plant and the type of turbines limit opportunities for arbitrage between the CO_2 market and electricity markets.
- The price elasticity of demand – and the options available for energy intensive users to mitigate or avoid the increase in the electricity price.
- The network structure. The structure of the network limits the transmission capacity to some extent. This gives rise to congestion, and so some generation companies could use their market power to increase the wholesale price.

Much research work has been done concerning the impacts of ETS on the wholesale electricity price by developing some simulation models. In [16], the increased proportion of the electricity price with the introduction of the EU ETS is assessed. It shows that the electricity price increases by approximately 6.5% when the allowances price is €5/tCO_2, and increases by nearly 24% when the allowances price reaches €20/tCO_2. About 35% to 65% of the opportunity cost of CO_2 would be passed on to the wholesale electricity price, and will result in an increase of €5-9/MWh in various countries [33]. A competitive fringe model is developed in [45] to analyze the impact of the CO_2 emission allowances trading on the electricity price in the short-run. The results demonstrate that the impact of pass-through rates mainly depends on the electricity market structures concerned. In a perfectly competitive market, the marginal opportunity cost of CO_2 emissions allowances would be fully internalized in the electricity price.

In [50], the VTT (technical research centre of Finland) electricity market model [46]-[48] and The Integrated Markal - Efom System (TIMES) [49] energy system model are utilized for studying the impacts of the ETS. MARKAL/TIMES is an integrated energy systems modeling platform that can be tailored to analyze energy, economic and environmental issues at the global, national and municipal level over several decades. This set of software tools provides a framework for exploring, evaluating and quantifying alternative futures and the roles that various policy options may have on technology and resource choices. MARKAL is the acronym for MARKet Allocation while TIMES - which is the next generation version of MARKAL - stands for The Integrated MARKAL/EFOM System. The simulation results indicates that the annual average electricity price will increase by 0.74€/MWh if the allowance is €1/tCO_2 in the Nordic area.

A numerical example in [9] demonstrates that when the price of emission allowances is €10/tCO_2, the total cost of generating electricity in the Netherlands would increase by around €430 million or, on average, about 0.41€cent/kWh. Assuming that the emission factor for the gas-based generation is 0.42kgCO_2/kWh, it would lead to an increase of the electricity price in 2010 by 0.42 €cent/kWh. This implies an increase of the price of around 15% due to the EU ETS based on the commodity or producer cost price of 2.7€cent/kWh before the emissions trading.

B. The Impact on End-User Prices

Various restrictions could be imposed on generation companies to pass on the full extent of the wholesale electricity price to end-users. The impact of the ETS on end-users' price depends on a series of factors that vary in different markets and applied policies [9], [22], [33], [34], [44], [45], [51] :

- The type of contract.
- The retail market structure.
- The price elasticity of demand. The options available for energy intensive users to mitigate or avoid the increase in the electricity price.
- The government regulating level.
- The market power.
- The price of carbon in the ETS market.
- The carbon intensity of the electricity generation.
- The rate of passing through carbon cost.

As to the increasing degree of the end-user price, it is rather different in various countries. As far as Finland is concerned, when the allowance is €10/tCO_2, the ETS leads to the electricity price of private households, property owners and agriculture to increase, translating into an annual windfall profits of about €150 for generation companies [50]. On average, nearly 75% to 95% of the price change in EU ETS is passed on to the Finnish NordPool spot price [52].

VIII. Conclusion

In this work, a brief review is made about the potential impacts of an ETS on the power industry and electricity market, with special emphasis on the existing schemes, the approaches of allowances allocation, and the impacts on generation investments, renewable energy development and electricity prices.

An ETS of the "cap-and-trade" type is usually recommended since it guarantees a fixed amount of emissions and market operators' predictability, in contrast with the "baseline-and-credit" approach.

It is generally agreed that auctioning is a more efficient method for the allowance allocation than free allocation, as it treats all participants more equitably, and avoids potential unfairness in determining which participants are entitled to free permits. A trend is emerging towards the increasing use of auctioning, both in some recently proposed schemes and in future phases of the existing ETSs. However, for alleviating the resistance from the incumbents, and seeking their support for the scheme, allocating the allowances according to "grandfathering" is a potentially more pragmatic choice at the first stage of the ETS implementation.

The short-run impacts of the ETS include the change of the merit order dispatching in the electricity market concerned due to the variance of the generation costs of generation companies. In the long-run, when the price of CO_2 is high enough, the ETS may stimulate generation companies or investors to give more attention to low-emission or zero-emission technologies such as renewable energy generation.

The implementation of the ETS will inevitably leads to the increase of electricity prices. The degree of the increase will mainly depend on the price of the emissions allowance and the pass through rates which are affected by many factors.

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