Theory and Practice of Carbon Pricing Observations from three Emission Trading Systems (ETS)

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Abbreviations

BAU	Business as Usual
CCER	China Certified Emission Reduction
CDM	Clean Development Mechanism
CEA	China Emission Allowance
CER	Certified Emission Reduction (CDM-projects)
EAU	European Allowance Unit
EITE	energy-intensive, trade-exposed
ERU	Emission Reduction Unit (JI-projects)
EU-ETS	EU Emission Trading System
JI	Joint Implementation Projects
KAU	Korean Allowance Unit
K-ETS	Korea Emission Trading System
NDC	Nationally Determined Contribution
RoC	Republic of Korea
KRX	Korea Exchange
UNFCCC	UN Framework Convention on Climate Change

THEORY AND PRACTICE OF CARBON PRICING

1. International compliance regime for carbon abatement

1.1. 1992 Kyoto Protol – 2008-2020 compliance period

Based on the principle of 'common but differentiated responsibilities', the Kyoto Protocol in 1997 established *legally binding commitments* for the greenhouse gas (GHG) emission reduction targets of the 43 industrialised countries listed in Annex I of the UNFCC (OECD countries and "Countries that are undergoing the process of transition to a market economy."). Developing countries agreed to make *voluntary efforts* to reduce CO2-emission below BAU. Annex A of the Protocol listed six GHGs: Carbon dioxide (CO2), Methane (CH4), Nitrous oxide (N2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluoride (SF6).[1] The Protocol's first commitment period was from 200-2012, the second ended in 2020. Now the 2015 Paris Agreement applies.

Within the Annex I group of countries, the OECD-countries were in addition committed to provide financial resources and technology transfer to help developing countries and "countries that are undergoing the process of transition to a market economy » to undertake emission reductions and to adapt to adverse effects of climate change. To facilitate the promised finance and technology transfers, the Kyoto Protocol introduced two project based flexibility mechanism that could be used by OECD countries in meeting their emission limitation commitments. To offset some of their emission reduction commitments, they could purchase either:

- 'Certified Emission Reductions (CERs) from private 'Clean Development Mechanism (CDM)' projects in developing countries (article 12)
- acquire 'Emission Reduction Units (ERUs) from Government-to-Government 'Joint Implementation (JI)'-projects with "countries that are undergoing the process of transition to a market economy » (article 6).

The CDM and JI project credits comply with the economic philosophy of the carbon market mechanism. For the global climate it is irrelevant whether a tCO_2 is emitted in Vietnam or in Japan; if mitigation is cheaper in Vietnam, then the Japanese economy can save money by undertaking some of its emission reduction commitments through mitigation investments there. Depending on the type of CDM-project, Vietnam can gain additional benefits through early transfer of low-carbon technology for which no demand would have existed without the finance from the flexible mechanism.

[1] Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are also GHGs. They are phased out under the Montreal Protocol.

CDM suffered from structural flaws: (i) High transaction costs for the certification of CERs limit the implementation of CDM projects in low income developing countries where low levels of energy demand lead to small projects. (ii) Moral hazard risks arise from the hypothetical estimation of emission reductions from CDM projects, which is calculated as the difference between the measured annual emissions from a CDM project compared to the counterfactual emissions in the absence of the project ("baseline scenario"). The certification of CERs confirms that the baseline emission is the realistic counterfactual scenario and that the revenue from sales of CERs is an essential condition for the realization of the project. The economic incentives for quality control of the two statements exist neither on the demand side nor on the supply side of the CER credit market. Certifying consultants risked undermining future demand for their services from investors in CDM-projects if they were too critical of submitted projects. Officials in developing countries saw their national interest in getting a maximum of free foreign money; while OECD country officials purchasing offset credits on the international market were interested in securing as many credits as possible for their allocated amount of money.

The PoA (Programme of Activities) concept later called 'Programmatic CDM' was introduced to provide an entry point for project types in low-income countries that were unable to make it into the CDM project pipeline due to individual small size and comparatively high transactions costs. It involves the aggregation of a set of smaller emission reduction activities as a single CDM project. Yet, it was unable to effectively change the skewed distribution of CDM projects in favor of large CDM projects in China, India, and Brazil. More than 60% of the world's CERs were issued in China, inter alia, from contentious HFC and N_2O projects.

Critique of the low quality of international credits and seeing the price formation on the EU ETS market being undermined by the inflow of credits on the ETS market, the world's largest off-taker of CERs, led the EU to phase out use of project based credits in the EU ETS after 2020.

1.2. 2015 Paris Agreement compliance period 2021 and forward

The 2015 Paris Agreement establishes for the first time a global compliance regime for each signatory's 'nationally determined contribution' (NDC) towards the adopted goal of limiting global warming to +1.5 degrees Celsius. The regime begins in 2021. '*Developed country Parties'* have absolute emission reduction targets for 2030 and net-zero targets for 2050. '*Developing country Parties'* have relative emission reduction targets; their 2030 CO_{2e} reduction targets are expressed with reference to a business-as-usual (BAU) emission scenario.

Article 6 establishes new carbon market programs, trading in socalled "mitigation outcomes", as replacement for CDM/JI credits. The "JI-inspired" Article 6.2 enables states to "pursue voluntary cooperation in the implementation of their nationally determined contributions" by transacting 'Internationally Transferred Mitigation Outcomes' (ITMOs), i.e. emission reductions which result from specific projects. Buyer states may thereby outperform their national emission target or offset emissions that exceed their emission target. ITMOs are integrated in the NDCs; when an ITMO is

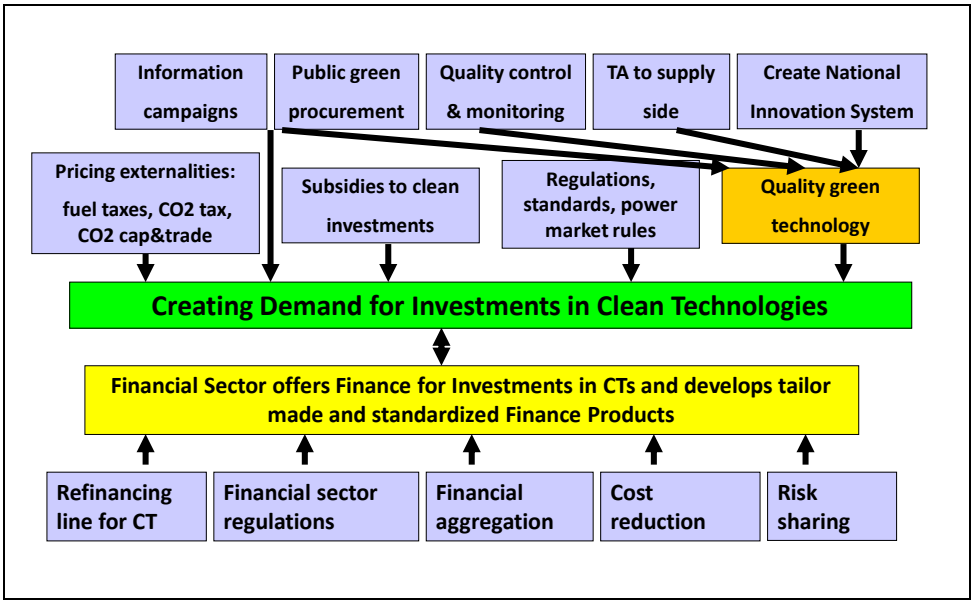
issued and transferred to another country, it cannot be counted as part of the host country's NDC. Some OECD country NDCs exclude ITMOs, whereas Switzerland has already signed deals with 11 countries under Article 6.2 and South Korea 7 deals (status October 2022). Projects range from an improved cooking stove project tin Peru to e-mobility projects in Thailand and Rwanda. The "CDM-inspired" Article 6.4 envisages a global carbon market in which credits can be traded by governments and private entities under the supervision of the Conference of Parties – the decision-making body of the UNFCCC. This includes transfers of emission units between internationally linked ETSs. The concept needs further development before becoming operational.

2. Policy framework to promote transition to a low carbon economy

National climate policy packages are composed for maximum effectiveness and efficiency. *Effectiveness*' means realizing the politically defined CO_{2e} reduction target and the green growth benefits for the national economy. '*Economic efficiency'* means realizing the politically defined goals at least cost to society, which is achieved if you succeed in equalizing the marginal costs of abatement across all sources and sectors in the economy. Costs include the direct investment and operational costs of producing and consuming agents, transaction costs for information collection and administration and adjustment costs arising from the induced changes in national production.

A large market demand for low carbon technology calls for (i) easy access to high quality low carbon technology, (ii) favorable relative prices and regulatory conditions and (iii) the availability of standard finance products for investments in low carbon technology. A carbon abatement policy applies a range of instruments to advance the transition to a low carbon society, see figure 1.

Figure 1 Generic framework for emission reductions



Source: VIET

Regulations – command and control instruments –force the use of more climate efficient technology; e.g. by setting maximum standards for CO_2-emissions per km for new cars. The other instruments improve either the price competitiveness and/or the quality of low carbon technology:

- Fuel taxes, carbon taxes taxes and the CO_2 cap&trade mechanism increase the market price of competing conventional technology; other market mechanisms create revenue income for low carbon technology through payments for environmental benefits.
- Technical and financial support to the development of a high quality green technology supply chain reduces the cost of investing in low carbon technology, and has the additional objective of generating national 'green economy' growth and employment benefits from the transition to a low carbon economy.
- Financial sector engagement tools reduce the cost and the supply of capital for low carbon investments which typically are more capital intensive than alternative technologies.

For effectiveness, comprehensiveness is essential, as the effectiveness of individual instruments depends on their interaction with others. The effectiveness of capacity building measures to develop a '*national low carbon innovation system*' - – a structured collaboration among enterprises, universities, government research institutes, ministries and finance institutions to maximize the nation's innovation potential - depends on the ability of demand side measures to create a market for low carbon technology. When finance institutions are insufficiently willing to support new technology through the initial proof of concept and market testing stages, there may be an economic case for setting up a '*Low Carbon Technology Innovation Fund*'. One finance window could support start-up technology SMEs with mezzanine-type finance and nurturing services, another could provide grants and low-cost loan finance to innovative, but risky, project proposals submitted by established firms.

3. The role of carbon pricing instruments in climate protection

3.1. Environmental taxes

By intervening in the market, all instruments, also regulations and standards that mandate use of more carbon efficient technology, change the prices which consumers and investors face in the market place. This is expressed by the concept of effective carbon pricing', which is the sum of carbon taxes, carbon markets, fuel taxes, fossil fuel subsidies, and of regulations with implicit and explicit carbon impact. 'Explicit carbon pricing' targets the carbon content of fossil fuels directly through CO_2 taxes or the imposition of carbon markets. 'Implicit carbon pricing' refers to environmental taxes which increase the price of fossil fuels as such, and thus, indirectly, the cost of emitting carbon.

Fuel taxes are imposed to raise revenue for the state budget, for energy security reasons (reducing fuel imports), and to achieve local environment benefits (reductions in SO_2 and lead emissions) and global environment benefits (reduction of CO_{2e}-emissions).

Because of the plurality of objectives in fuel taxation policy, the implicit carbon tax per tCO_2 varies from one fuel to the other. In Vietnam it ranges from \$0.27/tCO_2 for bituminous coal to \$36/tCO_2 for gasoline. In developed countries tax levels on fuels used by households are higher than on fuels used in industrial production (to maximise tax revenue and protect international competitiveness), in low income countries the opposite is the case (to satisfy basic needs of low income households). Worldwide one sees lower fuel taxes on diesel (commercial vehicles use overwhelmingly diesel) than on gasoline (gasoline cars dominate in household ownership).

The efficiency objective in climate policy – the equalization of the marginal costs of abatement across all sources and sectors in the economy – is at odds with the existence of a plurality of CO_2-price levels in the economy. When different agents receive and react to different price signals, the outcome is bound to be sub-optimal. Therefore, sooner or later, as a national climate policy progresses deeper and deeper into reducing total CO_2-reductions, fuel taxes will be based on the carbon content of fuels.

3.2. The resource allocation efficiency of carbon pricing

Market failure refers to the inability of a market to provide the right price signal for efficient resource allocation. Market failure can arise from inefficient organization of the market as such. In environmental and climate policy the most important market failure to address is the existence of socalled positive or negative 'externalities' associated with the production or the consumption of a particular product. Fossil fuel consumption leads to CO_2-emissions, being unwanted by society, it is a '*negative externality'*. Some forestry and agricultural practices do the opposite: they absorb carbon which otherwise would have remained in the atmosphere; being good for society this is a '*positive externality'*. Unless externalities are reflected in the prices of the products, the market prices will incentivize inefficient resource allocation:

- When the cost to society of GHG-emissions is not included in the price of a product, there will a non-economic excess market demand for this product. Carbon pricing introduced by carbon taxes or by emission trading schemes address this market failure directly.
- Unless producers are paid for the economic value of carbon sinks, their economic supply potential will be underexploited. Inter alia the REDD+ scheme addresses this market failure.

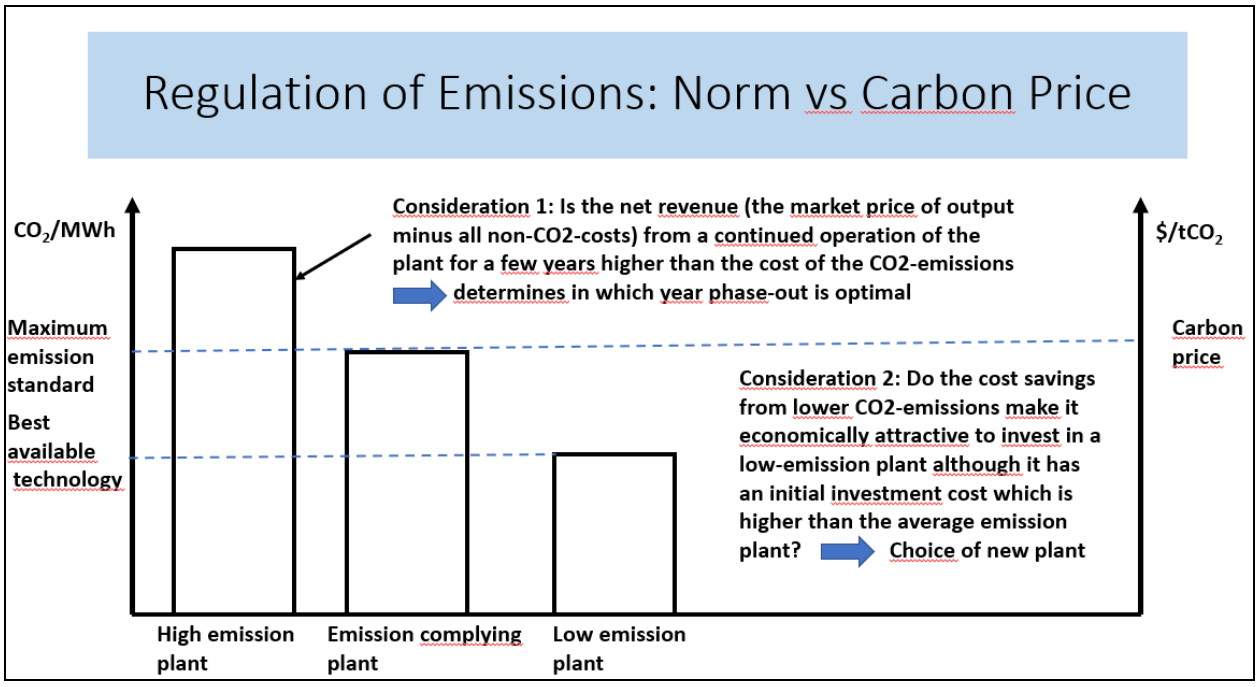
Carbon pricing is the most important climate policy instrument. But, to enhance its efficiency, companion policies (see figure 1 above) are implemented to address other market failures; e.g. R&D policies to accelerate the development of new low-carbon technologies, or the introduction of climate bonds to make more climate finance available and lower the cost of climate capital.

In a *carbon tax scheme*, politicians fix the price of CO_{2e} and expect the market's reaction to the change in relative prices in favour of low-carbon fuels and investments in renewable energy (RE) and energy efficiency (EE) to achieve the targeted greenhouse gas (GHG) reduction.

A *CO_2-cap&trade system* fixes a cap on CO_2-emissions, the market then sets the price per tCO_{2e} through initial auction prices and the trading of CO_2-emission rights between the participating agents.

Both tools intervene in the market to correct for market failures, but leave it to the affected firms to identify their specific lowest cost solution for the achievement of emissions reductions in response to new price structures. The economic advantage of flexibility and information advantage at micro-level can be shown by comparing the reaction of market agents to the introduction of a carbon emission norm versus the introduction of a carbon price as emission regulating instrument. Figure 2 illustrates the situation for three power plant technologies with different emission levels per MWh. The government can introduce a maximum norm for permissible carbon emissions per MWh, or fix a carbon price (directly via a carbon tax or indirectly by a trading regime) which is expected to make investments in new high-emission plants non-economic. Both instruments eliminate the option of investing in new high emission plants.

Figure 2: Regulation of emissions – norm vs carbon price



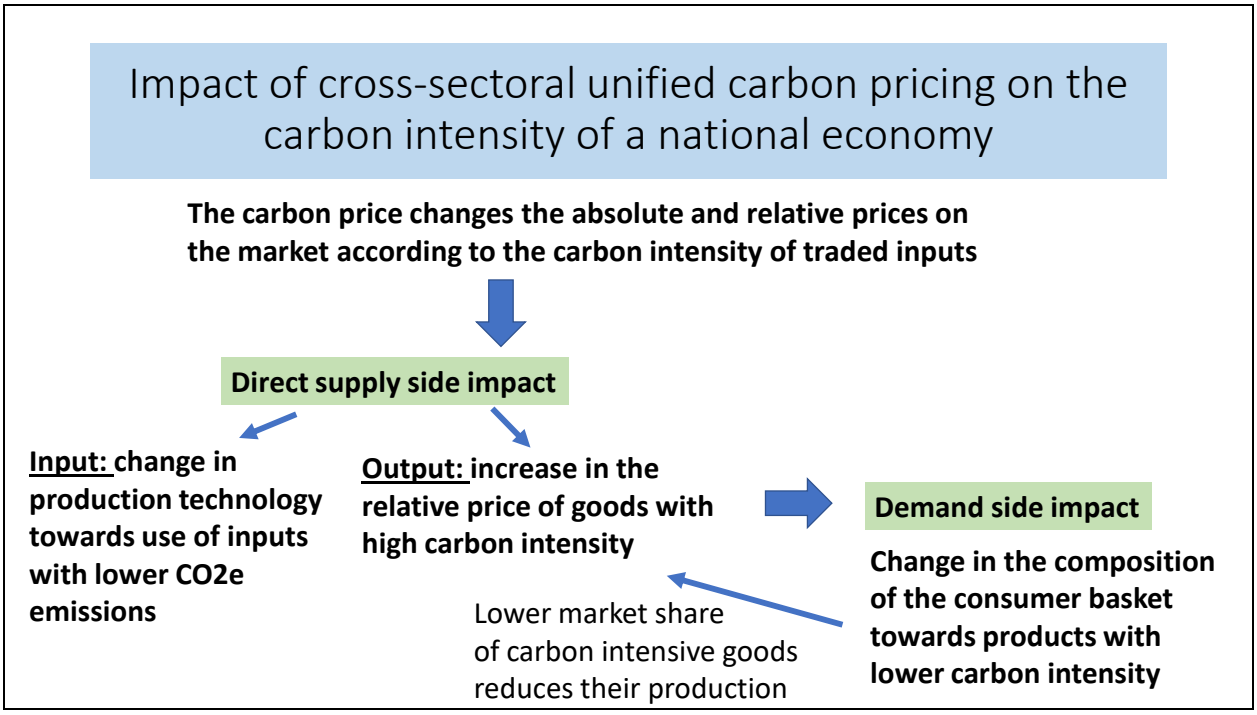
In terms of dynamic adjustment the two instruments differ. One difference concerns use of economic capacity. The emission norm forces the high emission plant to close down immediately: the investment in the plant is sunk cost immediately. The alternative of carbon pricing enables the high emission plant to continue its operation for some time until its operating revenue can no longer cover its

higher costs of operation: this prolongs the economic lifetime of installed capacity. The other difference is in terms of incentivising the switch to very low-carbon technology. Unless a very low emission technology by itself is the least cost technology option, firms have no economic incentive to invest in a technology which yields lower emissions than required by the norm; the norm risks becoming **the norm**. In carbon pricing, the operational cost savings from either the reduction in the carbon tax bill or from the revenue from excess emission allowances improves the economic return from investing in the purchase of lower emission technology and in the development and marketing of new low-carbon technology

However, because of consumer fashion preferences overriding EE-preferences – as witnessed by the continued expansion of SUVs on the car market – norms are an important tool for regulating GHG emissions on the final demand side. E*mission norms for the output of an industry* can be combined with a cap&trade scheme which provides price incentives for additional emission efficiency. The EU car emission directive fixes a norm of 95 CO_2 gr/km for the average emission of cars sold in the EU during the 2020-2024 period. A car manufacturer whose car fleet does not fulfill the norm, pays a fine for the average excess emission multiplied by the number of cars sold. Over-compliance of the norm is incentivized by allowance trading: car manufacturers whose car fleet has an average emission below the norm, can sell their saved emissions to manufacturers with excess emissions.

Another source of high allocative efficiency in carbon pricing is the existence of *feed-back effects*. The *first order impact* on the carbon intensity of a national economy is the supply side reaction towards use of low-carbon technology in production and increase in the price of products with a high GHG content, which shifts the composition of final consumer demand towards less GHG intensive products. The *second order impact* is that the change in consumer demand reduces the production of GHG-intensive products. For example in agriculture, that chicken production in response to a CO_2-tax is expanded while beef production due to its higher methane emissions is reduced.

Figure 3. Impact of cross-sectoral unified carbon pricing on the carbon intensity of a national economy



Source: VIET

3.3. Carbon tax as climate instrument

Four arguments favor use of the *carbon tax* as the primary instrument in climate policy. (i) Ease of administration: In the early 2000s, it was estimated that in the USA fewer than 3,000 entities would pay a carbon tax: the 149 petroleum refiners, 1,438 coal mines, and 530 natural gas processors plus importers at a few locations.[2] (ii) Comprehensiveness: Low transaction and monitoring costs enable taxation of all sectors and all levels of emissions. However, although allocative efficiency in theory requires that also the methane emissions in agriculture be taxed at the tCO_{2e} rate, this is difficult in practice as both the de facto emissions at a particular farm and the changes to emissions in response to the implementation of low-carbon practices can only be approximated. (iii) Price certainty for investment decisions: Fixing ex-ante the evolution of the carbon price during a pluri-year period reduces investors' uncertainty about the rate-of-return of investing in low-carbon technology. (iv) Ease of positive interaction with companion policy instruments: subsidies to investments in RE or in EE do not reduce the effectiveness of a carbon tax; in 'Climate Change Agreements' between sectoral industry organisations and the government, a discount from the carbon tax can be offered in return for a collective quantitative target for the industry's emission reductions.

How can politicians identify the correct 'optimal tax' rate?

[2] David Weisbach: "It's all about design", September 19, 2008. https://thebulletin.org/roundtable_entry/its-all-about-design/

One theoretical option is to equate the tax rate per tCO_{2e} with the "*social cost of carbon"* - the worldwide economic cost triggered by the emission of an additional tCO_{2e} into the atmosphere. Because the economic impact is not immediate but long-lasting, the approach leads to theoretical debates about the appropriate discount rate to apply to the economic cost of long-term environmental damage. An additional issue is uncertainty about the impacts, in particular how the risk of tipping points can be taken into account. Economists, therefore, present widely varying estimates of the social cost of carbon: some as high as $450 per tCO_{2e}, whereas Nordhaus in a 2014 paper came up with an estimate of $73 per tCO_{2e} (2021 prices).[3]

The alternative is to set the tax rate with reference to the "*marginal cost of abatement curve*", see the chart on the next page; which shows how the marginal cost of abatement increases with higher de-carbonization targets. According to estimates, achieving the EU's 55% CO_2 emission reduction target for 2030 will require an end-of period carbon price of up to €200 per tCO_{2e}. The carbon tax can be implemented either with a few stepwise increases during the target period, or at a fixed rate, but with decreasing reductions in exemptions from the full tax payment.

For achieving resource allocation efficiency, projects for long-term withdrawal of CO_2-emissions from the atmosphere, e.g. biomass-fired power plants with carbon-capture-and storage (CCS) and specific land-use projects, ought to receive a payment per withdrawn tCO_{2e} equal to the carbon tax rate.

3.4. Comparison CO_2 –tax versus CO_2 cap&trade scheme; CO_2 price path

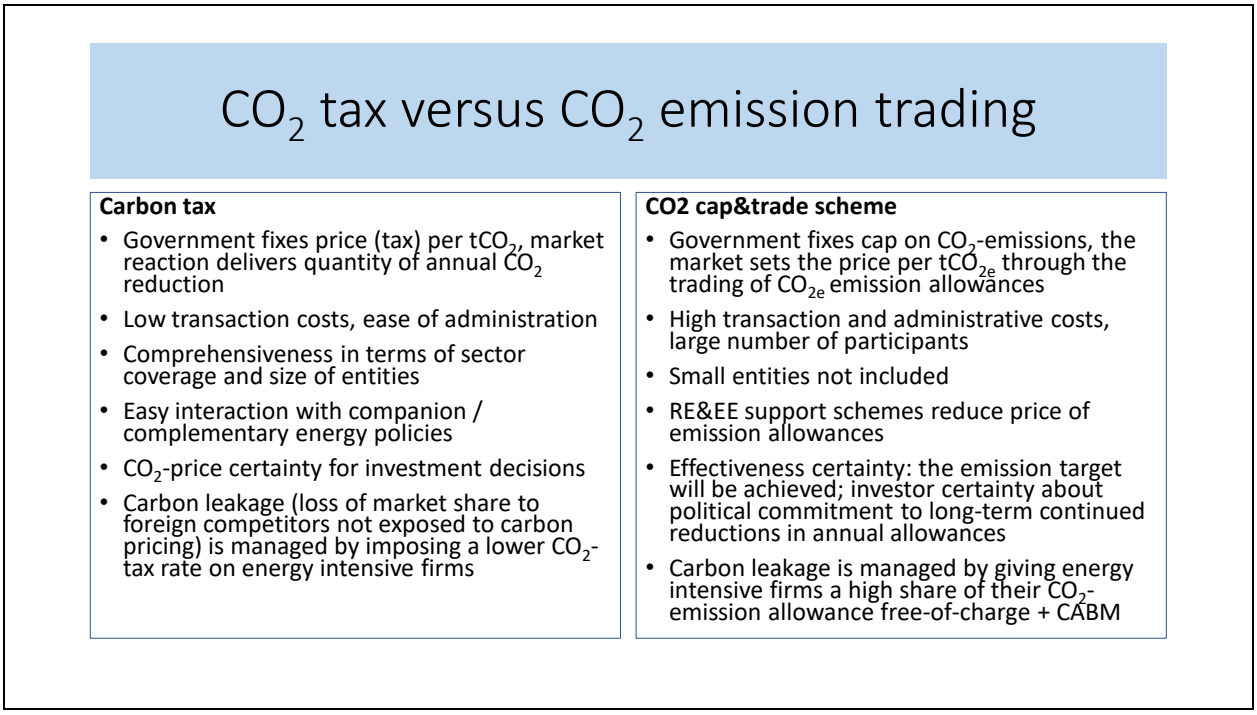
Three main arguments are made in favor of the carbon market instrument instead of the carbon tax alternative: (i) Markets are critical for price discovery; politicians cannot identify the optimal carbon price. (ii) Capping the emission quantity creates certainty that the targeted GHG-reductions are achieved in the sectors subject to a CO_2-cap. (iii) The creation of a market price for emission reductions in developed countries enables transfer of private finance to support mitigation projects in developing countries on a win-win basis for all involved parties – companies as well as nations.

The last argument overlooked that one cannot simultaneously maximize two or more variables unless they are monotonically functionally related (they always go up and down together). This basic premise in economics was confirmed by the strongly negative impact of the import of allowances from CDM and JI projects on the operation of the EU Emission Trading System (ETS) during the 2012-2020 period.

The chart below summarises the main differences between the operation of a CO_2-tax and a carbon emission trade scheme.

[3] William Nordhaus: "Estimates of the Social Cost of Carbon: Concepts and Results from the DICE-2013R Model and Alternatig4ve Approaches", JAERE, volume 1, numbers 1/2.2014.

Figure 4. Comparison CO2 tax vs CO2 emission trading

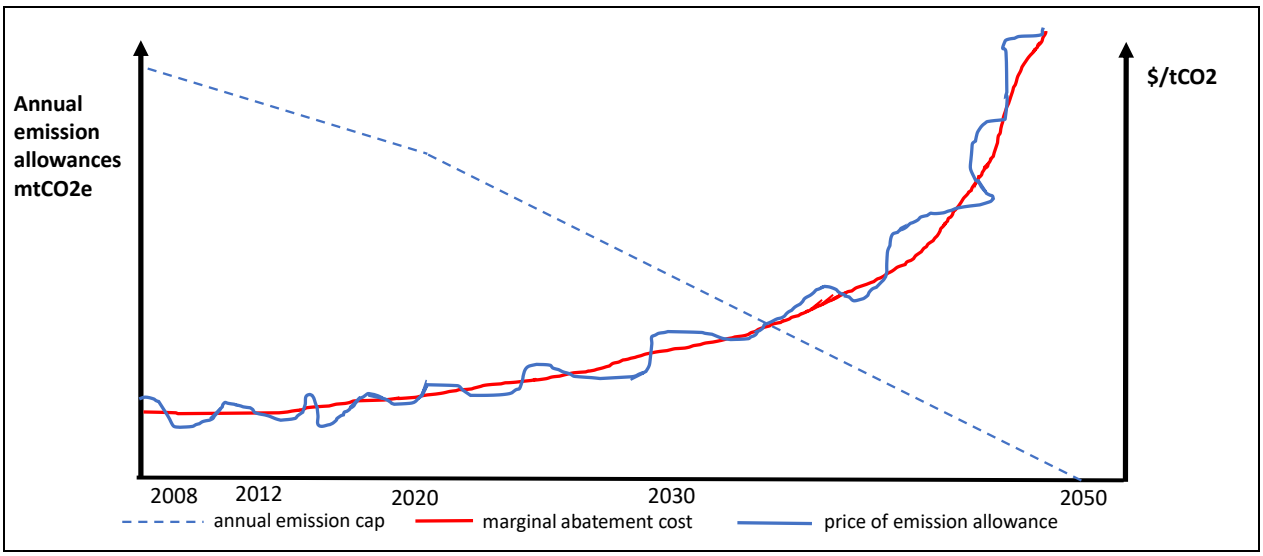


Source: VIET

Marginal price theory predicts the price path of emission allowances to follow the evolution in the ETS system's marginal abatement cost, that is, the incremental cost of CO_{2e}-reduction measures to keep total ETS CO_{2e}-emissions within the cap. The alternative of investing in lower-cost abatement measures keeps a lid on the market price of emission allowances. As sectors with low cost abatement options exhaust their reduction potential, the price will gradually increase. The finale carbon price in a net zero world is likely to be set by the cost of carbon capture and storage (CCS).

According to marginal price theory, the allowance price in an ETS with absolute and annually declining caps on total emissions is expected to evolve as shown in the chart below.

Figure 5: Evolution of Annual Emission Allowances and expected EAU price path



Source: VIET

4. Carbon markets as GHG reduction tool in practice

4.1. Absolute emission caps and output based emission caps

A cap-and-trade system places a limit on harmful pollutants and establishes a market-based price on emissions. Companies must hold permits called "allowances" to cover their emissions, which can be bought or sold at prices determined by supply and demand. This requires the establishment of systems for accurate emissions monitoring combined with significant penalties for noncompliance.

The differentiated carbon reduction responsibilities for developed and developing countries lead to different types of CO_2-cap&trade regimes.

- Developed countries apply *absolute emission caps*, which de-couple national emissions from GDP-growth. The traded emission rights instrument was born in 1990 by the US scheme for the reduction of SO_2 emissions in power plants, which imposed yearly declining caps on the total emissions of the power industry.
- Emerging economies apply *output-based emission caps*, which enforce a reduction in the emission intensity of production in the covered sectors relative to BAU, but enable CO_2-emissions to continue to expand in response to GDP growth.

4.2. Coverage by sector and type of entity and in terms of GHG

The EU-ETS includes three GHGs: CO_2, N_2O, PFCs; the Korea-ETS (K-ETS) all six Kyoto Annex A GHGs, that is also CH_4, HFCs and SF_6; China's national -ETS (C-ETS) only CO_2, its Provincial pilots all six Annex A GHGs.

The EU-ETS covers power plants; industrial sectors; aircraft flying between airports in the EU, Norway and Iceland; maritime shipping and from 2026 a separate ETS for road transport and buildings with fuel suppliers to these being required to surrender allowances. The K-ETS covers power generation, industry, buildings, transport, domestic aviation, and waste. The present C-ETS covers only the power sector; in the next phase six energy-intensive industrial sectors and domestic aviation plus indirect emissions from buildings will be added.

Due to the high transaction costs for monitoring, reporting and trading certificates, an ETS includes only the larger emitters. In the EU-ETS, stationary installations with an energy demand of at least 20 MW thermal; in the K-ETS, companies emitting more than 125,000 tCO_2/year and facilities emitting more than 25,000 tCO_2/year; in the C-ETS, coal- and gas-fired power plants with annual emissions above 26,000 tCO_2.

The EU-ETS covers more than 15,000 stationary installations and 1500 aircraft operators. The K-ETS 685 companies, and the C-ETS 2,162 enterprises.

A weakness of the ETS is that it cannot be all-comprehensive. Some entities have a demand too small to justify the transaction costs of ETS reporting and trading; some emission processes are not well-suited for the ETS-modality, e.g. methane emissions in agriculture due to the difficulty of objectively measuring changes in these emissions at a farm. To get reductions from emitters outside the ETS, other policy tools are used. A carbon tax can cover the 'entities below eligibility' in sectors covered by an ETS as well sectors outside the ETS. Other options include direct regulation of productive activities; e.g. of agricultural practices.

4.3. Allocation and acquisition of allowances

Participants in a carbon market purchase their allowances partly at auctions organized by Government and partly from other entities offering surplus allowances on carbon exchange markets or directly from these in socalled OTC (over-the-counter) trades.

To soften the cost impact of the introduction of an ETS, covered entities receive in the initial years some or all of their annual allowances free of charge; over time permits are increasingly auctioned to raise revenue for the state budget. When data is available, the volume of free allocations to an entity is based on best practice benchmarking, otherwise it is based on the historical emissions of the entity during a period (socalled 'grandfathering'). The highest percentage of free allowances is awarded to carbon-intensive production sectors that are exposed to intensive international competition.

According to evaluations of the EU-ETS, K-ETS and C-ETS, a high share of free allowances leads to a slight reduction in investment intensity. This is counter to the prediction from 'rational economic person' theory, according to which the percentage of free allowances received by an entity has no influence on its investment behavior – except in the positive sense that money saved on allowances makes more internal finance available for investments. Economic agents are assumed to make their investment

decisions by comparing marginal costs and benefits. The economic investment incentive for low carbon investments exists irrespective of the number of free allowances: if an entity sees opportunities for the implementation of carbon reducing measures with a cost per ton reduced emission, which is lower than the market price for allowances, it will implement them and sell any excess allowances on the market. The outcome however, corresponds to "loss aversion" theory in behavioral economics: it predicts that a manager will react stronger to seeing a high annual cost item on the firm's balance sheet, than to the possibility of earning revenue from a non-core activity.

4.4. The importance of flexibility mechanisms: banking and borrowing

The claim that carbon pricing is capable of generating superior economic outcomes of rests on the flexibility which participant agents have in deciding both the technology and the timing of the investment. In the design of carbon market, entities are given flexibility to optimize the timing of their low carbon investments through 'borrowing' and 'banking' of allowances within and across compliance periods.

'Borrowing' refers to the practice of using some of the allowances received in the beginning of year "n" to cover insufficient allowances for the compliance obligation of year "n-1" rather than purchasing allowances on the market. This helps firms to avoid purchasing allowances during peak-price periods (which helps to reduce price hikes on the market at the end of a compliance year), to deal with a short term liquidity problem and/or to postpone the implementation of a carbon abatement investment to the year "n".

"Banking" of allowances refers to the use of excess allowances from compliance year "n" to be used for the compliance obligation in the next year(s). Banking across compliance periods is essential to avoid allowance prices to drop to zero at the end of a compliance period, which was the experience of the EU-ETS at the end of the 2005-2007 trial period. The theory of inter-temporal permit trading suggests that allowance banking in a GHG control system with smoothly declining caps (which generate expectation of future price increases) incentivizes early investments to decrease emissions below the cap to minimize abatement costs over time (Zaklan/Valero/Ellerman 2015). This was born out by the experience of the EU-ETS with unlimited banking during 2008-2020 period, which resulted in over-compliance and significant amounts of banked allowances.

The K-ETS suffers from low liquidity – only 3-4% of the annual volume of allowances is traded. One reason is the low number of participants in the K-ETS - some 695 in 2021. The other is that they have little need to trade as they receive more than 90% of their allowances free-of-charge, Trading is typically concentrated at the end of the compliance period, and results in price hikes. The K-ETS, therefore, introduced a limit on banking proportionate to an entity's selling quantity during the year.

Most ETS include the option to implement lower cost 'off-set investments' in other parts of the national or international economy as an alternative to the purchase of higher cost allowances. The main objective of this tool is to spread experience to branches and sectors outside the ETS.

4.5. Measures to reduce the volatility of carbon prices

In all three ETS, administrators were surprised by higher than expected volatility of allowance prices. The demand for allowances is driven by a number of factors outside the control of the allowance emitting authority: the business cycle in the form of economic downturns and upturns, hot or cold temperatures, rainfall affecting the level of water reservoirs in hydropower. In the EU-ETS prior to 2020, an additional factor was that the emissions market got flooded by international off-set credits. The original design of the EU-ETS overlooked, that to operate efficiently, a market need simultaneous adjustments on the demand and on the supply side: from 2005 to 2017, the EU-ETS had no discretionary market stabilization instrument. The outcome in terms of price fluctuations can be seen in the chart on page ..

ETS worldwide use one or two discretionary market stabilization instruments. One is the 'allowance floor price' for the auctioning of allowances; when bid prices hit the floor, the selling of allowances is discontinued. The other is the "Market Stabilisation Allowance Reserve", managed by the public authority in charge of the ETS, which receives a percentage of the annual allowance allocation and intervenes actively with selling and buying allowances on the market.

4.6. Impact of ETS on emission reductions, competitiveness and low-carbon innovation

The experience of the EU-ETS, of the K-ETS and of China's Provincial ETS-pilots confirms that the carbon market achieves the goal of keeping emissions within the cap. (Annex I has the references). Emissions in EU-ETS sectors had by mid-2021 decreased by -43% compared to the 2005 level of emissions; China regional ETS pilots achieved 16.7% reduction in emissions and a 9.7% reduction in emission intensity from 2013-2015, a 1% increase in carbon price resulted in a 0.043% decline in total emissions and a 0.022% decline in emission intensity.

The evaluations showed that the entities included in the ETS on average achieved higher emission reductions than similar type entities outside the ETS. This result is somewhat surprising as the average prices of allowances have been too low to serve its purpose as a strong motivating signal for abatement investments: in the EU-ETS the EAU price from 2005-2017 hovered most of the time in the €5-€9 range, in the C-ETS and Provincial pilots around USD7 and in the K-ETS from 2018-2020 around €14. The outcome can be interpreted as implying, that it is not just the annual prices which drive investments, but that the existence of the ETS as such serves as a strong signal about the political commitment to pursue a continued decarbonisation of the economy, and, therefore, about the probability of a long term increase in allowance prices.

The low price did not incentivize break-through innovations in energy intensive industries; only incremental innovations that are close to the market and an accelerated phase-out of outdated technologies in the power sector. Investments were typically small-scale, with short amortisation times (e.g., three to five years), producing incremental emission reductions. As the market stabilization measures are now

driving up emission allowance prices, and caps on emission allowances are tightening from year to year, one can expect that the EU-ETS will begin to drive deep-decarbonisation investments as well.

In all three ETS, evaluations demonstrated that neither the competitive situation of ETS-firms nor their profits was negatively affected. Firms within ETS achieved higher average productivity gains and a higher firm-level revenue created per unit of carbon emission. In the Provincial China ETS, the regulated firms reduced their labor inputs to maintain their competitive advantages.

The experience of the Chinese Provincial pilots with absolute emission caps and output-emission intensity caps respectively, indicates that carbon markets with absolute emission caps achieve higher firm level emission reductions.

5. Companion policies to carbon markets

The role of a carbon tax is to expand the CO2-price signal to sectors and entities not covered by the ETS. Other companion policies address specific market failures.

5.1. Carbon tax

EU Member States have national carbon taxes and energy taxes in addition to the EU ETS. The motivation is to drive carbon reductions in non-ETS sectors and achieve nation-wide GHG reductions in the most cost effective manner. Efficiency in resource allocation requires that the agents within and across sectors base their investment and consumption adjustment decisions on the same CO_{2e}-price. In the EU-member states with de-carbonisation targets above the EU average (a consequence of the application of national differentiated responsibilities) impose carbon taxes also on entities included in the ETS to correct for the inability of the ETS to raise carbon prices sufficiently to reach their higher national targets.

5.2. Regulation

The EU's "FIT-for 55" package has a 2030 RE-penetration target of 40% of final energy consumption, an EE improvement target of 36% for final and 39% for primary energy consumption, stronger CO_2 standards for the car fleet, major expansion of low-carbon infrastructure for transport.

5.3. Use of subsidies

Although energy and carbon tax-schemes can be designed in a manner that is revenue neutral for households and for an industry as a whole, use of '*negative' instruments,* which increase the price of fossil fuels, has been limited out of fear of their negative impact on the real income of low-income households and on the international competitiveness of national industries. The relative price changing policy of emerging and developing economies has, during the last 30 years, therefore focused mainly on use of '*positive measures'*, to subsidize clean energy investments as a means to counterbalance the under-pricing of fossil fuels.

In the industrial economies, subsidies are used as a driver for low carbon innovations (R&D grant funds) and to ease the initial market entry of low carbon technologies. Price support and guaranteed market entry support are given to new RE technologies to enable these to gain cost reduction advantages from economies of scale and from investments in faster technological progress which a larger market incentivizes.

5.4. Risk capital to support national green economic growth potential

Finance institutions are typically insufficiently willing to support new technology through the initial proof of concept and market testing stages and most countries do not have sufficient 'angel' and 'venture capital' investors to fill the void. This provides the case for setting up publicly financed 'Low Carbon Technology Innovation Funds to support the development of internationally competitive green technology supply chains. The funds are structured to support both start-up technology SMEs with mezzanine-type finance and nurturing services, but also innovative, but risky, project proposals submitted by established firms with grants and low-cost loan finance.

Annex I: Comparative Description of the Emission Trading Systems in EU, Republic of Korea and China

I.1 EU-ETS

History and special characteristics

The EU's Emissions Trading Scheme (ETS) for emission allowances called EAUs (Emission Allowance Unit) is the EU's single most important decarbonisation tool. The EU-ETS covers entities in the power and energy intensive industries in 30 countries (EU + Iceland, Lichtenstein, Norway) and flights between airports of participating countries, accounting for 40% of GHG emission in the EU. Each year, a proportion of the allowances are given to some participants for free, the rest are sold through auctions. At the end of a year participant must return an allowance for every tCO_{2e} emitted during the year. A participant with insufficient allowances must take measures to reduce emissions, buy more allowances on the market from other participants or from speculators, or pay a fine of €100 per tCO_{2e} excess emission. Emission reduction obligations for non-ETS sectors are set by the Effort Sharing Regulation and translated into legally binding annual limits for each member state differentiated according to ability. Each country decides how and with which policy instruments the reduction obligation is to be achieved. The Swiss ETS linked with the EU-ETS in 2021.

The first ETS phase from 2005-2007 was a pilot for developing and testing the basic reporting, monitoring and trading procedures of the system. The 2008-2012 and 2013-2020 phases coincided with the two commitment periods of the Kyoto Protocol; under which the countries in the EU had concrete emissions reduction targets to meet.[4] In 2008, the EU adopted the "20-20-20" climate and energy targets for the year 2020, including a reduction in GHG emissions of -20% below 1990 levels, equal to a -14% reduction compared to year 2005 emissions. The ETS cap imposed a 2020 reduction of -21% compared to 2005 GHG emissions; for the non-ETS sectors, the Effort Sharing Decision set a collective reduction of -10%, the specific reduction for individual Member States ranged from +20% to –20%.

The Paris Agreement defines the legal obligations of the EU from 2021 onwards. The EU's "Fit for 55" policy regulations presented in 2021 set a -55% GHG reduction target for 2030 compared to 1990 levels of 5,720 Mt, leading to emissions of 2,574 Mt in 2030.[5]. The ETS-sector is to reduce its emissions by -61% compared to its 2005 level; the target for the non-ETS sectors is a -40% reduction.

[4] Signing the Kyoto Protocol in 1997, the then 15 EU-members committed to an 8% cut for the bloc as a whole; each EU country has an individual higher or lower binding target.

[5] Source : What a 55% 2030 emission reduction target means for the EU ETS | ICIS

Specific characteristics of the EU-ETS include: (i) It is supra-national. (ii) Its operation in the EU's liberalised energy-only day-ahead/hour-ahead power market enables efficient pass-through of allowances prices from generation to demand, which incentivizes fuel switch and demand-side responses and stimulates the integration of variable renewable energy. (iii) The introduction of a Carbon Border Adjustment Mechanism (CBAM) to protect carbon intensive industries against imports from foreign competition not subject to a carbon price. (iv) An initial ambitious attempt to integrate the international flexibility mechanisms (CDM/JI) into the EU-ETS. (v) A majority of market transactions take the form of derivative contracts (forward sales, futures, swaps, and options).

Scope of the ETS

The ETS includes three of the six 'Annex A GHGs': CO_2, N_2O, PFCs.

Up to 2020, the sectors included in the ETS were: power plants; energy-intensive industrial sectors; aircraft flying between airports in the EU, Norway and Iceland; 15,000 stationary installations with an energy demand of at least 20 MW thermal and 1500 aircraft operators reported their emissions.[6] The 2021-2030 phase expands ETS coverage to include maritime shipping. A separate ETS is implemented from 2026 for road transport and buildings with fuel suppliers required to surrender allowances; the cap is reduced over time to 43% of 2005 levels by 2030.

ETS governance and administration

The Commission has the powers to determine the allocation of free allowances and monitoring, reporting and verification of emissions in the EU-ETS; the Directorate General for Environment is the authority in charge. Member States prepare a "National Implementation Measures (NIM)" document for approval by the EU Commission, which details the allocations planned for each installation in the country. Member States are responsible for data collection and final allocation.

Every year, ETS participants must hand in an annual emission report (AER), verified by an independent accredited verifier, to the Competent Authority.

Transactions of allowances in the EU ETS take place between accounts in the Union Registry; an electronic accounting system that ensures the accurate accounting of EU allowances issued under the EU ETS and international credits. Anyone with an account in the registry can engage in the trading of EUAs. The European Union Transaction Log (EUTL) automatically checks, records, and authorises all transactions that take place between accounts in the Union registry, including the details of all CDM/JI GHG emissions trading units that enter, circulate or leave the Registry. During the initial years, the system was subject to substantial criminal activities : carrousel fraud across nationa jurisdictions to VAT, insufficient checks on trader applications in Danish registry, CDM credit recycling, fake registry scams, straight hacking to steal credits.

[6] For details on the phase up to 2020, see European Union: "ETS handbook", 2015

The EU Market Stability Reserve, in operation since 2019, brings allowances into (or retires them from) the market if the quantity of allowances reaches pre-determined thresholds that signal whether the market is under-supplied (or over-supplied). The reserve operates according to pre-defined rules that leave no discretion to the Commission in its implementation.

EAUs are classified as financial products. The trading of EAUs for immediate delivery (spot trading) and of EUA derivatives. is subject to the rules of EU financial markets, including the Markets in Financial Instruments Directive (MiFID).

The Modernisation Fund, financed by a share of the EU's auction revenue, supports investments proposed by the eligible Member States, 'including the financing of small-scale investment projects, to modernise energy systems and improve energy efficiency'.

Cap setting and Allowance Allocation

During the first two phases, the annual allowance was kept unchanged during the period. Since the 3rd phase, the annual allowance is decreased each year by a linear factor to the level of the end-of-phase emission target in the final year. For the 2013-2020 phase the annual reduction was 1.74% of emissions in 2010 (midpoint of 2008-2012). For the 2021-2030 phase the linear reduction factor will be 3.2% (50% reduction target) or 3.7-4.2% (55% reduction target) depending on the agreed target.

Power companies get no free allowances. During phase 3, aircraft operators got almost all allowances free of charge, during phase 4 the free allowances will gradually reduce to full auctioning by 2027. In the first year of phase 3, industries got 80% of allocations free of charge, the percentage dropped annually to 30% by 2020, from 2026 to 2030 the percentage drops to zero. Industries particularly exposed to carbon leakage (risk of dislocation of production to countries not exposed to carbon pricing) get up to 100% of allowances free of charge. This risk is defined in terms of: (i) the sector's carbon intensity in gross value added, (ii) its trade exposure expressed as the sum of a sector's imports and exports divided by the total market value. The free allowances to EITE-firms will be reduced during phase 4 as the Carbon Border Adjustment Mechanism (CBAM) becomes the tool for controlling leakage.

Operators apply for free allocation to the national agency preparing the NIM by providing verified data and the calculation methodology. The level of free allocation per installation is determined taking into account benchmark values – a total of 54 - based on the average performance of the 10% best installations, the risk of carbon leakage of each sector and the historical activity level of each installation.[7] The formula for allocation is: "benchmark x historical activity level x carbon leakage exposure factor x linear correction factor". Allocation is based on four methodologies which are applied in hierarchical order: (i) Product benchmarking (allowances/unit of production), (ii) Heat benchmarking (62.3 allowances/TJ heat consumption or export) (iii) Fuel benchmarking (56.1 allowances/TJ fuel

[7] Source : Emissions cap and allowances (europa.eu)

consumption), (iv) Process emissions approach (0.97 allowances/tCO_2 process emissions).[8] Allocations to individual installations may be adjusted annually to reflect increases and decreases in production; the threshold for adjustments is 15%. The 54 benchmarks are subject to annual reduction rates of between 0.2% and 1.6% depending on the level of innovation in the sector.

The penalty for non-compliance was €40 per tCO_2e during phase 1, and €100 since phase 2.

Flexibility options for operators

An ETS participant holding a surplus of allowances at the end of a trading –phase can 'bank' these to count towards the operators compliance obligations in the next phase.

Because the allocation of free allowances takes place in February each year, but the surrender of allowances for the previous year takes place by the end of April, installations can use some of their new allocation to count towards the previous year's compliance obligation. Such 'borrowing' is only permitted within a phase, not for years between two phases.

The so-called Linking Directive allowed businesses from 2008 to 2020 to use CERs and ERUs generated under the CDM and JI Kyoto Protocol mechanisms to meet their obligations under the EU ETS. The regulations for the phase, which allowed businesses to buy international credits totaling 1.4 billion tCO_{2e}, made the EU ETS the largest source of demand for these.[9] Since their inflow undermined the price formation on the ETS market, using CDM or JI credits is not possible in phase 4.

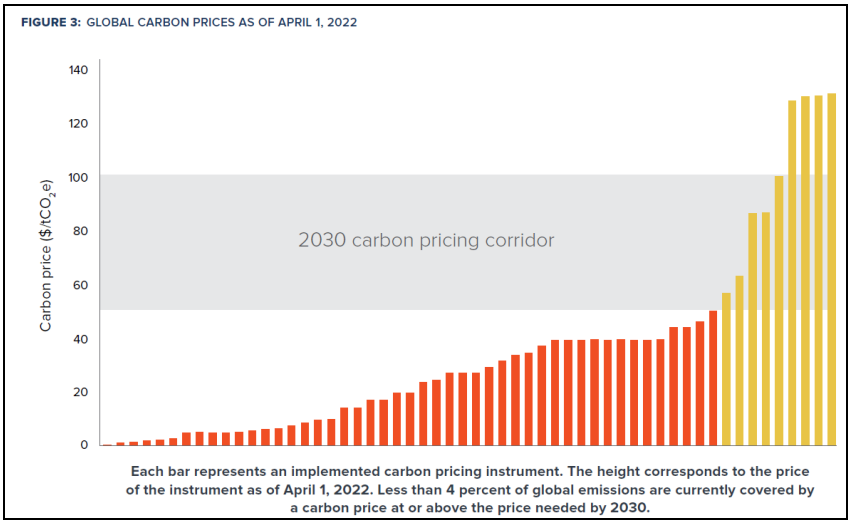
Carbon border adjustment mechanism

In the EU, a carbon tax of €50 per ton increases production costs in the short term by 0.7% on average. In carbon-intensive manufacturing subsectors the increase in production costs is higher, but limited to 4% or less in most Member States.[10]

The expected increase during phase 4 of the EAU price to more the €100/tCO_2, and the gradual reduction of free allocations to the carbon intensive sectors, increases the risk of carbon leakage - the transfer of production to other countries with laxer emission constraints. Not all countries in the world apply carbon pricing and those who do, apply vary different rates, see the chart below.

[8] For details see Ecofys, Frauenhofer, Entec: "Allocation in phase 3 of EU ETS", Workshop powerpoint presentation
[9] The EU regulations for Member States' compliance of their annual emission allocations (AEAs) allowed the option to cover part of the reduction obligation by purchasing international credits from CDM/JI projects and AAUs from eligible Annex I countries. Carbon sinks reductions from Land Use, Land-Use Change and Forestry (LULUCF) were also valid.
[10] Source: DeNederlandscheBank: "Improved European carbon pricing has limited impact on competitiveness", 30 August 2021

Figure 6: Level of international carbon prices



Source: CPLC 2022

The EU, therefore, will levy a carbon tax at the European border, known as the Carbon Border Adjustment Mechanism (CBAM), which applies to the carbon content of imports of electricity, iron, steel, cement, aluminum and fertilisers. The import tax is to mirror the ETS price, minus a correction for the free allowances given to the covered industry sectors. The CBAM is expected to enter into force as early as 2023 in a transitional form, and to apply fully from 2026, when importers of CBAM-covered goods have to register and buy CBAM certificates from a CBAM authority for their imported products, in amounts that correspond to the embedded emissions of their imports. Whether the amount of CBAM certificates to be bought by the importer is to take into account also indirect emissions – the carbon intensity of the electricity grid used by the foreign producers – is still debated.

Free allowances in ETS sectors covered by the CBAM will gradually be phased out over 10 years of the operation of the CBAM, except that EU producers may continue to receive free allocations for products destined for export to third countries without carbon pricing.

Companion policy tools, interaction with CO_2 tax

EU Member States have national carbon taxes and energy taxes in addition to the EU ETS. The motivation is to drive carbon reductions in no-ETS sectors and to correct for the inability of the ETS to raise carbon prices sufficiently to reach national de-carbonisation targets that are more ambitious than the average EU country target.

Other companion policies address specific market failures. Price support and guaranteed market entry support given to new RE technologies enable these to reach cost advantages from economies of scale and from incentivized faster technological progress. Some experts critizise that the high penetration rate of solar PV and wind energy systems in power supply, enabled by tax-paid or consumer-paid price

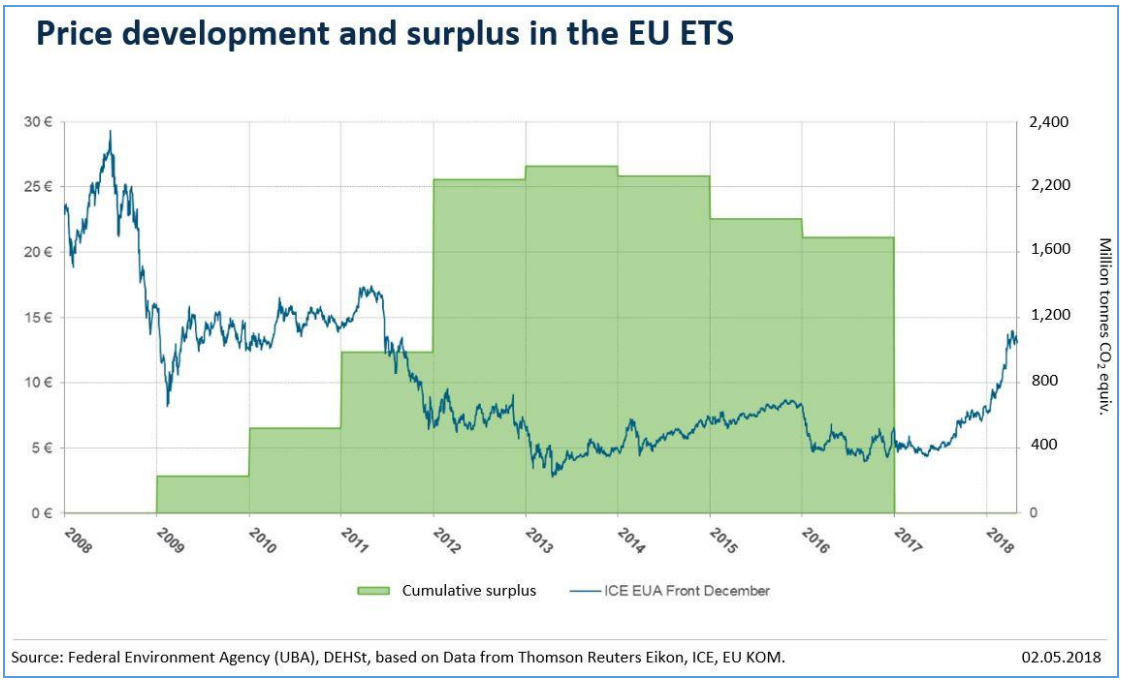
support to the systems, does not reduce overall emissions. By reducing emissions in the power sector they liberate emission allowances for use in other ETS sectors. The net effect is a shift of emissions to sectors who purchase them. The criticism exaggerates the "waterbed effect": any such impact dies with the end of an ETS phase; whereas the RE-systems continue to reduce power sector emissions also in the next phases.

The EU's "FIT-for 55" package has a 2030 RE-penetration target of 40% of final energy consumption, an EE improvement target of 36% for final and 39% for primary energy consumption, stronger CO_2 standards for the car fleet, major expansion of low-carbon infrastructure for transport.

Emission allowance price (EAU) and active market interventions

The EAU price experience, shown in the chart below, differed from the theoretical price path. The design of the ETS during the first two phases and during the initial years of third overlooked that efficient price formation in a market requires simultaneous adjustment on the demand and on the supply side. The supply side response - that a low price reduces supply of allowances and vice-versa - was originally missing in the ETS. Worse, the option to use off-set credits in place of EAUs meant that supply of allowances could go up when the opposite was needed.

Figure 7: Carbon-price and allowance surplus in EU -ETS 2008-2018



Source: Appunn 2019

During Phase 1 the price of EAUs touched €30 initially. But accumulated oversupply drove the price of EAUs to zero at the end of the first phase, as participants were not allowed to bank their permits from Phase 1 for use in Phase 2. In the second phase (2008-2012), carbon prices initially reached €30,

only to collapse when the financial crisis caused an economic downturn. A surplus of emission allowances built up from 2009, reaching 2 billion allowances at the start of phase 3, amounting to about a year's worth of emissions, as the banking provision allowed firms to bank allowances left over from the second ETS trading period.[11.] From 2012 and until the beginning of 2018, the price fluctuated between €4 and €9.

The first reaction to control excessive price volatility was to implement "backloading": 900 million allowances were temporarily removed from auction between 2014 and 2016.[12] The temporary reduction of the surplus allowances stabilized the EAU price but did not increase it. The next move in 2018 was an institutional reform: the creation of the Market Stability Reserve into which a share of allowances slated for auction is automatically transferred when too many allowances are in circulation. The third adjustment, starting in 2023, is to cancel the number of allowances in the MSR which exceed the number of allowances auctioned in the previous year.

The approval of the ETS reform in 2018 drove within a few months the price above €20; end of 2020 the price was €34. The tightening of the phase 4 reforms, which includes the elimination of unused allowances, led to a price in the €80-€90 range from the end of 2021 and during the first half of 2022.

Use of revenues to address carbon efficiency and distributional objectives

Roughly 40% of the close to 11 billion allowances in phase 4 will be given as free allocations to industry.[13] The auctioning of the rest minus expected absorptions of allowances by the Market Stability Reserve may generate revenues of €425 billion; using the July 2022 €85/tCO_2 price as conservative price estimate.

Most of the auctioned allowances from the EU ETS are divided among Member States according to their share of verified emissions, although the 'Solidarity Provision' redistributes 10% of all auctioned allowances towards 16 lower- income Member States with GDP per capita below 90% of the EU average. The auctioning revenues can be used at a Member State's own discretion, subject to Article 10(3) of the EU ETS Directive, which stipulates that "at least 50% of the revenues generated from the auctioning of allowances should be used to combat climate change in the EU and third countries". In 2018 and 2019

[11] Brink, Corjan; Vollebergh, Herman R. J.; van der Werf, Edwin (2015) : Carbon Pricing in the EU: Evaluation of Different EU ETS Reform Options, CESifo Working Paper, No. 5633, Center for Economic Studies and Ifo Institute (CESifo), Munich.

[12] The UK Government had, independently of the EU, introduced a Carbon Price Floor (CPF) to support the EU ETS. The CPF taxes fossil fuels used for by energy generators to generate electricity. The price floor fixed by the Government consisted of: (i) The EU ETS allowance price; and (ii) the Carbon Support Price, which tops up the EU ETS allowance price to the carbon floor price target. The CSP ws capped at a Maximum of £18/tCO<2>.

[13] Estimate based on Andrei Marcu, Domien Vangenechten, Angelina Bartosik: "Recommendations of funding mechanisms in the revised EU ETS", ERCST/CEEP April 2021

Member States generated some 14 billion Euro from auctioning ETS allowances, 77% of which was spent on advancing climate and energy objectives.[14]

Around 2% of allowances will be used to fund the 'Modernisation Fund', which supports investments in 10 lower-income Member States in modernising their power sector and wider energy systems to boost EE.

At least 4% of allowances will be allocated to raise funds for the 'Innovation Fund' which supports the commercial demonstration of innovative low-carbon technologies and breakthrough innovation in industry. The Fund applies grant financing through two calls for proposals per year, for large-scale projects (capital expenditure > €7.5 million) and small-scale projects (capital expenditure < €7.5 million).

Impact on emission reductions and economic competitiveness

The reduction targets for total EU ETS emissions were overachieved in all three periods. Emissions in the covered sectors had by mid-2021 decreased by -42.8% compared to the 2005 level of emissions.[15] In the eyes of the European Commission, "the EU ETS has proven to be an effective tool in driving emissions reductions cost-effectively".[16] However, use of the target achievement argument as proof of success is too simplistic, as several other factors contributed to the emissions reductions.

Until 2021, the EAU price had been too low and too volatile to serve its intended purpose as a guide for low-carbon investment: commercial investors focus on the lower end of a price range when they face volatile prices. One study claims that the EU-ETS saved more than 1 billion tons of CO_2 between 2008 and 2016; a reduction of 3.8% of total EU-wide emissions (twice the percentage for ETS-covered sectors) compared to a world without the EU ETS.[17] However, if so, it is because the existence of the ETS as such lends credibility to the EU's adopted long-term decarbonization targets. Investments in profitable decarbonization investments are pushed upwards in the internal prioritization order of covered firms because they know that survival in the long-term requires a change to low carbon technology.

In Phases I and II, low-carbon investments brought about by the EU ETS were typically small-scale, with short amortisation times (e.g., three to five years), producing incremental emission reductions.[18] The EU-ETS (i) has been useful in driving investments in incremental innovations that are already close to the market; (ii) has accelerated the phase-out of some outdated technologies in the power sector, speeding-up a shift that was primarily kicked off by other instruments (RE-support, power sector environmental regulations), (iii) has failed to incentivize the development of breakthrough innovations to reduce emissions in the energy-intensive industry sectors.[19]

[14] Source: EU Directorate-General for Climate Action: "Report on the functioning of the Carbon Market".2020
[15] Source: Liboreiro(2021)
[16] Source: https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets
[17] Source: Patrick Bayer, Michaël Aklin. Edited by Arild Underdal
18 Source: Marcantonini/Teixido-Figueras/Verde/Labandeira(2017)
19 Source: Lehne/Moro/Nguyen/Pellerin-Carlin(2021)

Key insights from the EU ETS experience

A long preparation time, including a pilot scheme lasting of at least 3 years, is needed for the effective implementation of a ETS.

The EAU price was too low and too volatile to trigger investments and innovations. Yet, because the very existence of an ETS with annually declining caps on total emissions lends credibility to the political will to enforce transition to a low-carbon economy and the inevitability of higher EAU-prices in the future, it incentivizes the covered entities to reduce their emissions.

A carbon market with absolute quantity caps requires market stabilizing interventions by an allowance authority to reduce excessive price volatility on the market: the price of EUAs between 2005 and 2018 fluctuated between €30 and €0.01. Ideally, active market intervention in the form of price-responsive supply of emissions allowances from a Stability Reserve is combined with a price floor.

Borrowing and banking of allowances are essential components of an ETS. Banking of allowances from the end of one phase to the beginning of the next is essential for a smooth price path. The non-existence of this option for Phase 1 allowances reduced the EAU price to zero at the end of the period.

Contrary to ex ante expectations, the presence of a very active derivatives market does not seem to have had a price stabilizing effect on the ETS carbon market.

In a liberal power market, giving free allowances to power generators increases their profits without adding to the achievement of the carbon objective. The prediction of marginal cost pricing theory was confirmed during the first two phases when power generators received some of their required allowances free of charge. Whenever generators bid supply into a day/hour ahead energy only spot market, the market price of the EAUs which has to be rendered for the involved CO_2-emissions is part of their marginal cost of supply. Since the bid price always includes the full value of the allowances without a deduction for the free allowance part, the profits in the power sector increase.

Linking an ETS scheme with entry of carbon credits from foreign CDM and JI projects is not compatible with the achievement of national emission reductions: foreign offset credits replace investments in the decarbonization of the national economy in the short term without reducing the long-term need for these. The dual goal of EU emission reductions and the financing low-carbon projects in low-income countries is achieved more efficiently by assigning a percentage of sales from emission allowances to a fund which provides grant-support to low-carbon projects in these countries. The rules being defined for the Paris Agreement's ITMO-mechanism seem to address shortcomings of CDM/JI.

The theory, that allocation of free allowances does not influence the investment behavior of agents – gain without pain – is insufficiently supported by ETS evidence. Emissions from the industrial sector dropped by 1% between 2012 and 2018, while emissions from the power sector dropped by 22% over the

same period. "This difference can be partially attributed to the fact that the industrial sector received a high share of its emissions allowances for free, while there is almost no free allocation in the power sector.[20]

Considering that "the core of the low-carbon economy is low-carbon technology innovation"[21] the inability of the EU-ETS to become an important driver of low-carbon innovation underlines the importance of a separate dedicated program for the promotion of low carbon R&D&D and for support to their initial market penetration.

[20] Source: Lehne/Moro/Nguyen/Pellerin-Carlin(2021)
[21] Lyu/Shi/Wang(2020)

I.2 Republic of Korea EmissionTrading Scheme (K-ETS)

History and specific characteristics

The GHG emissions of the Republic of Korea (RoK) increased from 1990 to 2014 by 136% to 691 million tCO_{2e}. The industrial sector contributed in 2021 36% and the power sector 37% to annual national emissions.[22].

Korea's NDC presented at COP-26 in 2021 includes the goal of carbon neutrality by 2050 and a GHG emission reduction target in 2030 of -40% below the level in 2018.

Active institution and capacity building prior to the implementation of the K-ETS started in 2012 with the introduction of the mandatory Target Management System (TMS), which required annual reporting against firm-specific emission reduction targets from companies that were expected to be included in the K-ETS. During the first two phases from 2015-2017 and 2018-2020 the K-ETS covered GHG emissions from the power, industry, buildings, waste, (domestic) aviation sectors, about 70% of RoK's emissions. The third phase from 2021-2025 added transport and construction companies.

Specific characteristics of the K-ETS include. (i) Korea has a cost-based wholesale electricity market based on day-ahead settling. The Korea Power Exchange (KPX) is the market and system operator. All dispatchable plants submit their available power generation to the KPX a day in advance, which plans the following day's power generation based on the generators' variable fuel costs. Korea Electric Power Corporation (KEPCO) is the single buyer of electricity from the KPX and has a monopoly in the transmission, distribution, and retail segments; all retail prices are regulated. The CO_2 price, thus, is reflected neither in the wholesale dispatch bid prices nor in the electricity retail prices. (ii) The K-ETS, therefore, uses an indirect mechanism to pass on the price of KAUs used in the power and heat generation sector to the point of consumption: the indirect emissions from buildings – the implicit emissions from their consumption of electricity and heat - are included as a sector in the K-ETS. (iii) Five finance institutions operate as designated market makers in a carbon market, which is dominated by compliance transactions and OTC (over the counter) trade. (iv) Korea started the K-ETS when the country defined its emission reduction targets with reference to BAU scenarios; it is now moving to absolute emission reduction targets.

Coverage

The K-ETS covers six GHGs: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.

The K-ETS covers six sectors: power generation, industry, buildings, transport, domestic aviation, and waste, accounting for 73% of national emissions in 2019.

[22] Source: IEA(2021)

Companies emitting more than 125,000 tCO_2/year and facilities having emitted more than 25,000 tCO_2/year over the last three years are obliged to participate in the ETS. The same applies to consumers of electricity and heat, whose indirect emissions are calculated by multiplying their consumption levels with the average carbon intensity of electricity generation.

The number of companies participating in the KETS rose from 522 in 2015 to 685 in 2021.

KETS governance

The Ministry of Finance and Strategy (MOSF) prepared the 10-year Master Plan with the medium- to long term emission targets, chairs the Allocation Committee, a discretionary body, which implements market stability measures and manages the allowance reserve fund.

The Ministry of Environment (MOE) has overall responsibility for the K-ETS. MOE is responsible for the preparation of the National Allowances Allocation Plan, based on work by the pertinent sector ministries, and for the compliance process, receiving and verifying the certified emission reports submitted by K-ETS participants. Once reports are certified, facilities are listed in the Emission Trading Registry System (ETRS). The Greenhouse Gas Inventory and Research Center of Korea (GIR) provides information on transactions, surrendering of allowances, sanctions, and price developments.

The Ministry of Trade, Industry and Energy oversees industrial and power generation emissions; the Ministry of Environment the waste related emissions; the Ministry of Land and Infrastructure Transport the transportation and construction sector emissions; and the Ministry of Agriculture, Food and Rural Affairs the agricultural and food sector emissions.

Korea Exchange, KRX, is the designated spot market for the K-ETS.

Five financial institutions designated by the Government - two state development banks (Korea Development Bank and the Industrial Bank of Korea) and three private brokerage and finance institutions - participate in the K-ETS market as Market Makers to strengthen liquidity by offering daily allowance trades. Market Makers borrow from a government-held reserve of 20 million allowances, set aside for this purpose at the time of original allocation and return borrowed allowances or transfer the proceeds of allowances sold.

20 third parties were approved for participation in the carbon market from December 2021. To avoid excessive market share they can only hold up to 200,000 allowances each.

Cap setting and allocation of allowances

The cap on the issue of Korean Allowance Units (KAUs) is established in line with the national emission reduction target and is implemented through sector-specific emission reduction rates. For the first two phases, the national commitment of a 4% reduction in 2020 compared to 2005 was expressed for the KETS as a 30% reduction target compared to a business-as-usual (BAU) scenario for emissions in the year 2020. This allowed for growth in each sector.

From 2015 to 2018 the annual cap increased gradually from 540 $MTCO_{2e}$ in 2015 to 594 $MTCO_{2e}$ in 2018, then dropping to 563 $MTCO_{2e}$ in both 2019 and 2020. The average annual allowance for Phase 3 of 609 $MtCO_2e$ (including reserves), represents due to expanded sector coverage, a reduction of 4.7% compared to 2017-2019 baseline emissions.[23]

During its first phase, the KTES granted 100% free allocation using a mixed approach of grandfathering and benchmarking. The benchmarks reflect the median emissions intensity of facilities within a sector; fuel-specific benchmarks apply to electricity generators. The percentage of allocations done via grandfathering decreases as more reliable data for benchmarking becomes available; the share of sector-specific benchmarking is to reach 60 % in Phase 3.

A small share of allowances is set aside in the new entrant reserve.

Regular auctions began in 2019 with 3% of annual allocations being auctioned. In the third phase, sub-sectors that are subject to auctioning are to receive less than 90% of allowances for free; industry sectors subject to carbon leakage risk, the socalled energy-intensive, trade-exposed (EITE) industries (the formula looks at allowance cost in percent of value added and trade intensity) continue to get 100% of their allowances for free. In 2022 only 4% are auctioned. Participation in auctions is limited to companies that do not receive all their allowances for free and no one bidder can purchase more than 30% of the allowances offered.

The fine for non-compliance is KRW 100,000 (USD87) per tCO_2e, but shall not exceed three times the average market price of allowances of the given compliance year.

Flexibility options for participants

Borrowing from the following annual compliance period is allowed within a KETS phase.

Banking is allowed with restrictions across and within phases.

Covered entities can use offsets from domestic projects, converted into socalled KCUs (Korean Credit Units), to meet up to 5% of their allowance submission obligations.

Market stability mechanisms

The KETS included from the start three market stability mechanisms:

- The auctions are subject to a minimum price, the Auction Reserve Price, which is set by a formula which refers to past prices.
- The allowance reserve for new entrants, equal to around 5% of the annual allowance budget, but can be accessed by the Allocation Committee for purposes of market stability when KAU prices according to well-defined intervention triggers are either to high or too low. Pre-defined stabilisation measures include: early allocation from the reserve of up to 25%,

[23] Source: ICAP (2022)

setting minimum (70%) or maximum (150%) allowance possession limits, limiting or increasing the borrowing limit, limiting or increasing the ratio of offsets allowed for compliance, and temporarily setting of price ceilings and floors.[24]

- A number of discretionary measures to stablise the market can be decided by the Allocation Committee, e.g. temporarily changing borrowing limits or injecting more allowances.

During the second phase, the low volume of traded activity, and insufficiency of allowances on the market led the MoE to introduce a limit on banking proportionate to an entity's selling quantity.

Use of auction revenues

Since the beginning of the program auctions generated accumulated revenues of KRW 775.5 billion (USD 667.5 million), of which KRW 294.8 billion (USD 257.7 million) came in 2021.[25]

The revenue is placed in the Climate Response Fund, which provides support to ETS-covered entities for mitigation equipment, low-carbon innovation, and technology development.

Companion policies

Fuel excise taxes in 2021 amounted to €33 per tCO_2 on average, versus an average KAU price of €10 that year.[26] The introduction of a carbon tax is actively debated in Parliament. South Korea's road maps published in October 2021 aim to reach carbon neutrality by 2050 largely by replacing coal-fired power generation with renewable sources and internal combustion engines vehicles with hydrogen-powered and battery-based electric vehicles. In power generation, LNG will either be replaced completely or kept as a flexible power source, using carbon capture and storage and direct air capture capabilities so as to fully neutralize their carbon emissions.

The carbon market: price movements, traded volumes and reforms

KAU prices increased steadily from 2015 to KRW 40,900 (€32) in late December 2019 before dropping to levels around KRW 20,000 (€14) in 2020. The transaction volume grew from 1.2 million tons in 2015 to 21 million tons in 2020; jumping more than 44-fold in terms of value.[27]

The carbon market in Korea has a chronic problem of low liquidity. Only 3% of total allocated allowances were traded in Phase 1, compared to 25% for the EU ETS during its first trading phase.[28] The traded volume in 2020 amounts to 4% of allowances that year.

The structural explanation for low liquidity is the relatively small number of participants on the carbon market in Korea - some 695 in 2021 - and the 96-97% share of free allowances which reduces the requirement to trade. The market is dominated by compliance-focused transactions. Companies prefer to

[24] Source: ADB(2018)
[25] Source: ICAP (2022)
[26] Source: OECD (2022)
[27] Source: Kim Gyu-sik & Lee Ha-yeon (2021)
[28] Source: German Environment Ministry (2021)

engage in OTC transactions over spot trading. Large entities are able to establish reliable trading partners, which decreases their need for spot trades and enables them to avoid exchange-based fees.[29]

The low liquidity and the absence of forward prices for KAUs due to the nature of trading being limited to intraday and OTC markets gives rise to an unusual price formation on the market: During 2021, the average auction price of KRW 26,373 was significantly higher than the average secondary market price of KRW 19,709.[30]

A number of measures were introduced to increase liquidity.

- The preference for covered entities to use banking and borrowing to meet their surrender obligations, rather than engage in market transactions, was addressed through rules that tie banking and borrowing limits to an entity's trade activity. The amount of banking from Phase 2 to 3 is restricted to the higher of two limits: the net annual amount of allowances sold in Phase 2; and company and facility-specific limits of 250 and 5 $MtCO_2$, respectively.
- The number of Market Makers was expanded from 2 in the second phase to 5 in the third.
- Domestic financial intermediaries and other third parties can participate in exchange trading since 2021
- A futures market will be introduced at some time during Phase 3. The introduction of a futures market improves price predictability by bringing about a forward curve which,in principle, reveals information about participants' expected future abatement costs.

In response to concerns about what was perceived as unwanted price instability, a Market Stabilization Reserve (MSR) was introduced to control spot prices by releasing allowances when prices became too high or grew too fast.

Impact on emission reductions and economic competitiveness

Results from firm level investigations showed that firm-level carbon productivity - firm-level revenue created per unit of carbon emission - increased significantly under the ETS; the trend was particularly evident for high-emission industries.[31]

Lessons learned

The complex K-ETS governance structure with four sectoral ministries and shifts in the responsibility for overall oversigt of the K-ETS between the MoE and the MOSF led to inconsistent

[29] Source: …
[30] Source of prices: ICAD (2022)
[31] Source: Jung/Song/Ahn(2021)

signals regarding the future of the scheme. This resulted in uncertainty for KETS participants, which led them to be more inclined to hold rather than trade any surplus allowances,[32]

A carbon market with a relatively low number of participants and which receive a very high share of free allowances will be a low liquidity market. Although few transactions occur, the dominance of compliance-focused transactions can lead to unwarranted end-of-year price spikes.

The introduction of designated market makers in Korea's low liquidity market managed to increased liquidity and reduce the bid-call spread in daily trades: the market makers accounted for approximately 30% of trades in the second half of 2019.[33]

Overall, the price performance of the K-ETS was satisfactory, prices showed a steady slow upward trend and despite characteristics that are very different from the EU-ETS, a price level similar to the price in the ETS at the end of its phase 3 in 2020.

The K-ETS will not drive switching fuel away from coal without a mechanism to reflect carbon costs in power stations' dispatch decisions and retail electricity prices. An alleviating option is the introduction of an environmental dispatch mechanism, which could add an allowance shadow price, reflecting the price of KAUs on the market, to the generators' operational costs.[34]

Borrowing of allowances should be allowed only within an ETS Phase. Unless narrow limits are set for annual borrowing and banking by individual entities, the option risks to reinforce market instability.

I.3 China-ETS applying caps on the emission intensity of outputs

History and distinguishing characteristics

The NDC pledges China's CO_2 emissions to peak before 2030 and to reduce CO_2 emissions per unit of GDP by over 65 % from 2005 levels; China is to achieve carbon neutrality by 2060.

The decision to build a national carbon market was taken in 2011 and started with the launch of seven regional ETS pilots in 2013. The implementation of a national ETS market started with a first phase in 2017, which focused on building the market infrastructure. The second phase, a trial run for the power sector to test out the ETS, started its first official trading in July 2021. It covers 2,162 enterprises with emissions of 4.5 billion tCO_2 (44% of China's total) making it the largest ETS in the world. By 2025, the national ETS is expected to include industry sectors and more than 70% of China's total carbon emissions.[35] Until then, the pilots will continue to operate in parallel, covering sectors and entities not included in the national market.

[32] Source: ADB(2018)
[33] Source: Howie/Gupta/Park/Akmetov (2020)
[34] Source: German Environment Agency (2021)
[35] Source: IEA(2020)

Special characteristics. Dispatch in the power sector is governed by the socalled "three equals system" that allocates each plant a defined full load hours by technology. [36] Generation volumes and prices are set in negotiation with the government and are roughly the same across all units of a similar type. The solution chosen for China-ETS, therefore, is intensity-based system, which allocates allowances (CAUs), based on the plant's expected generation output, with a different benchmark for each fuel and technology. Ex-post adjustments to the allowance cap are made based on actual production levels.

Scope of the ETS

The C-ETS covers CO_2 emissions only, Provincial pilots include also CH4, N_2O, HFCs, PFCs, SF6.

The present phase of the C-ETS covers coal- and gas-fired power plants with annual emissions over 26,000 tCO_2 (a unit of 6 MW running at 2018 average full load hours reaches the threshold); regulating more than 2,000 companies from the power sector (including combined heat and power), as well as captive power plants in other sectors.

It is set to expand in the next phase to seven other sectors: petrochemicals, chemicals, building materials, iron and steel, non-ferrous metals, paper and domestic aviation. Indirect emissions from power consumption will then be included as well.

ETS governance and administration

Ministry of Ecology and Environment (MEE) is the authority in charge. MEE subsidiaries at the provincial level oversee the implementation of ETS rules; and municipal-level authorities take on some management duties locally.

MEE entrusts specialised sector agencies, e.g. the Building Materials Federation, to facilitate the GHG data collection and benchmarks calculation.

Provincial-level ecological and environmental authorities are in charge of organizing the verification of GHG reports. They may commission technical service agencies to provide verification services.

Beijing Green Exchange operates the CCER registry.

Carbon emissions allowances can be traded on a dedicated trading platform managed by the Shanghai Environment and Energy Exchange. Nine regional carbon exchanges in China are dedicated CCER trading platforms.

Trading on the spot market - there is no futures and derivatives market - is mainly for emitters. But financial companies and individuals fulfilling defined criteria, such as the Shanghai Environment and Energy Exchange, are allowed to participate.

[36] Source: IEA(2020)

The China Securities Regulatory Commission (CSRC) is the authority responsible for approving services related to derivatives trading as well as new financial products. CSRC approval of the creation of a futures exchange in Guangzhou has opened a door for carbon derivative trading.[37]

Cap setting and allocation of free allowances

The policy goal for 2025, defined in 14th Five-Year Plan, is a reduction in carbon emissions per unit of GDP of 18 % compared to 2020 levels.

Allocation is done bottom-up with a different benchmark for each fuel and technology. The CO_2 fuel factor (the amount of CO_2 emitted per unit of fuel) is expressed in tCO_2/MWh for power generation and in tCO_2/gigajoules (GJ) for heat generation. There are 11 benchmarks for the power sector, nine of which were for coal-fired plants and the rest for gas-powered technologies. The average CO_2 intensity of coal plants at 900 gCO_2/kWh, and that of the most efficient ultra-supercritical units at 740 gCO_2/kWh (at full capacity factor levels); the main benchmark is 0,877 tCO_2/MWh.[38]

The MEE allocates allowances (CAUs), based on the plant's fuel factors and expected generation output; ex-post adjustments to the cap are made based on actual production levels.

The power sector receives 100% free allowances. Auctioning of some allowances may be introduced before 2025.

Due to high gas prices and China's political will to increase the share of gas in power and heat generation, gasfired power generation will not have to procure additional allowances if in deficit; but can sell surplus allowances.[39]

In the draft ETS Trading Regulation from March 2021, the fines for failing to submit a report range from CNY 50,000 – 200,000, the fines for failures in compliance obligations from CNY 100,000 – 500,000 and up to CNY 10 million for severe misconduct such as market manipulation.

Flexibility mechanisms

Detailed rules on banking and borrowing are not yet specified. The system is expected to allow for banking but not for borrowing.

Covered entities can use domestic project based carbon offset credits - China Certified Emissions Reductions (CCERs) - for up to 5 % of their verified emissions. (RE, carbon sinks, methane recovery).

In May 2021, the MEE announced the option of establishing a market-regulating and protection mechanism to respond to abnormal fluctuations in trading prices. For instance, through buy-back, auctioning or adjusting the rules related to CCER use.[40]

[37] Source: ICAP/World Bank(2022)
[38] Source:
[39] Source: IEA(2020)
[40] Source: ICAP (2022)

Use of carbon revenue

The Draft Interim Regulations propose to set up a national ETS fund, funded by auction revenues. It will support the development of the national carbon market and key GHG reduction projects.

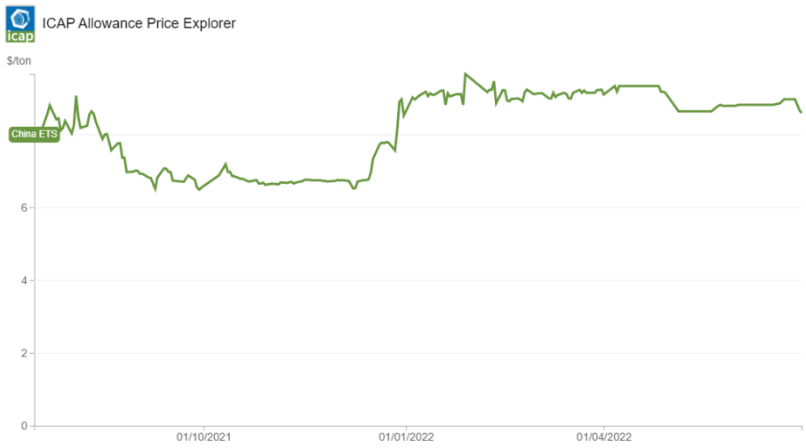
Companion policies

Companion policies include, inter alia, promoting coal substitution, energy conservation standards, air pollution standards, power market reform (improving market pricing mechanisms for electricity), capacity retirement plans and promotion of RE.

Carbon prices and consumer reaction in a regulated power market

The first year trading volume is expected to reach 200 million tons by mid-2022. [41] This amounts to a modest 4% of the annual allowances, reflecting the fact that emission allowances were rather lax and allocated free of charge. Prices of CEAs during second half of 2021 were in the $6-7 range; during the first half of 2022 around $8.

Figure 8: Carbon price in China ETS 2021-2022



Source: ICAP website

The financial volume of trading is, therefore, far below the volume on the EU-ETS carbon market.

Impact on emissions and international economic competitiveness

The operational experience of the C-ETS is too short for drawing conclusions about its emission reduction impact. Its effectiveness will depend on sufficiently ambitious benchmark emission levels per unit of production. Since the benchmarks are differentiated by fuel type, the C-ETS will not incentivise fuel switching in the power sector to lower carbon fuels.

[41] Source: Mak(2022)

Lessons learned from C-ETS and the Provincial pilot schemes

The experience from the C-ETS is too short. Yet, the experience of the Provincial pilots gives reasons to conclude that the C-ETS will lead to a reduction in carbon emissions despite low carbon prices and infrequent trading.

Allowance trading in the Provincial pilots is infrequent. The turnover rate of carbon allowance, measured by the ratio of exchanged allowances to total allowances, was 0.018 on average in the same period. [42] Trading occurs mainly at the end of the compliance period due to the fact that total allowances are not known until the final output is determined under the rate-based allowance allocation rule.

The daily carbon price of the regional ETS pilots ranged from $1.38 to $20.88/t CO_2 e between 2013 and 2015, with the average carbon price at $5.6/t CO_2e. [43]

Yet, the regional ETS pilots were effective in reducing firm emissions, leading to a 16.7% reduction in total emissions and a 9.7% reduction in emission intensity. The firms achieved emission abatement through reducing energy consumption by 13% and switching to low-carbon fuels thereby reducing emissions per unit of energy consumption by 3.7%.[44]

The regional ETS pilots adopt two types of allowance allocation rules: absolute quantity caps and output emission intensity rates. The former allocation method has shown to be more effective in reducing emissions. [45]

To maintain competitive advantages, regulated firms reduce labor inputs. [46]

[42] Source: Cuia/Wang/Zhang/Zhenge(2021)
[43] Source: Cuia/Wang/Zhang/Zhenge(2021)
[44] Source: Cuia/Wang/Zhang/Zhenge(2021)
[45] Source: Cuia/Wang/Zhang/Zhenge(2021)
[46] Source: Cuia/Wang/Zhang/Zhenge(2021)

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