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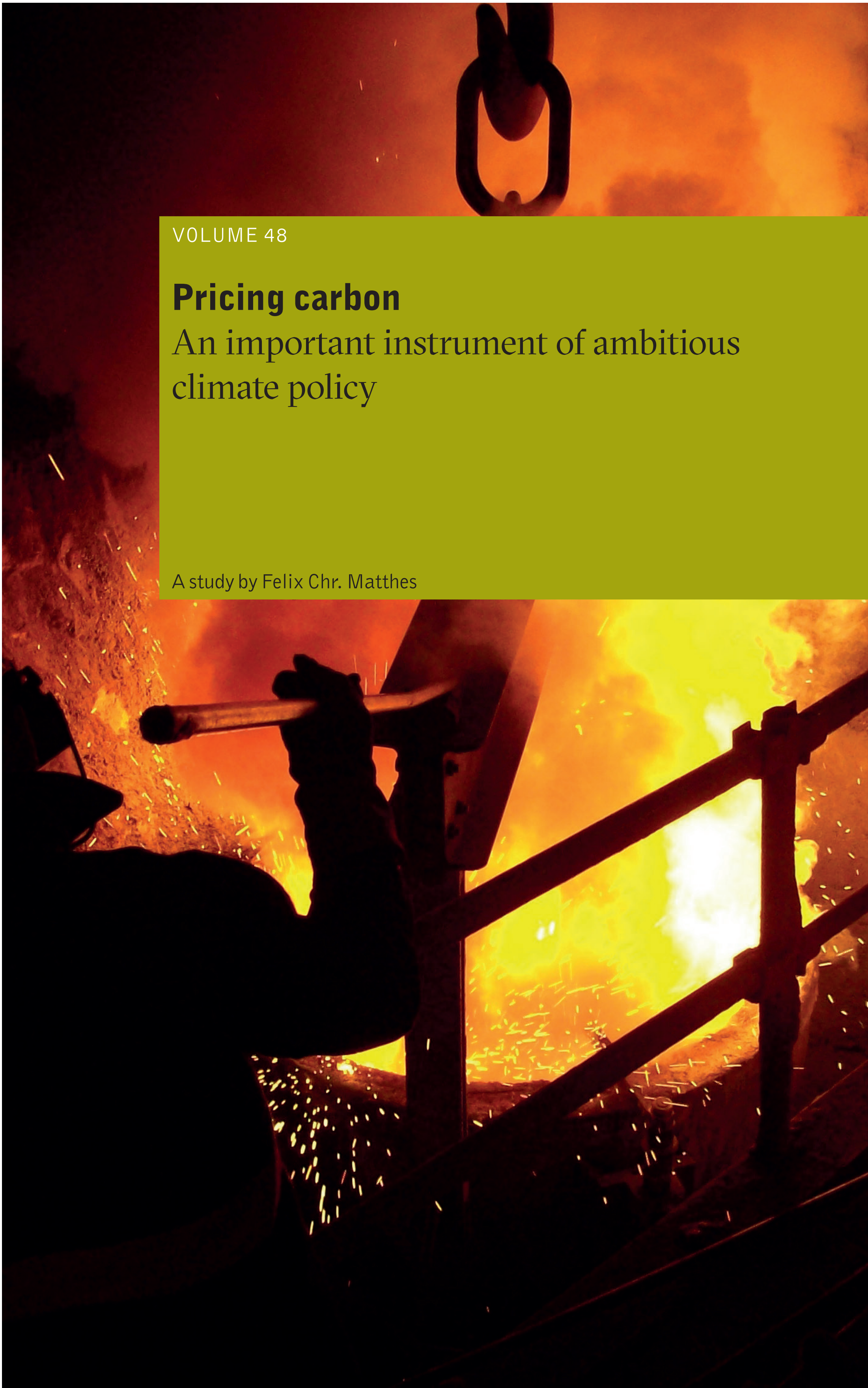

VOLUME 48

Pricing carbon
An important instrument of ambitious climate policy

A study by Felix Chr. Matthes

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PUBLICATION SERIES ECOLOGY

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Edited by the Heinrich Böll Foundation Brussels

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Volume 48 of the Publication Series Ecology
Edited by the Heinrich Böll Foundation Brussels 2020

Copy-Editing and translation: Vanessa Cook
Editorial design: feinkost Designnetzwerk, C. Mawrodiew (based on the origin layout by State Design)
Cover photo: Goodwin Steel Castings – flickr (CC-BY-SA 2.0)

This publication can be downloaded here:
Heinrich-Böll-Stiftung European Union, Rue du Luxembourg, 47–51, B-1050 Brussels
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PREFACE

Carbon pricing has featured prominently in recent public debates about the best policy tools for tackling climate change. The idea of putting a price on carbon dioxide is simple: whoever emits climate-damaging emissions into the atmosphere shall pay for it. The political approach is: climate-damaging products and behaviour will decline because they are more expensive than climate-friendly production and behaviour. It is also hoped that by introducing a carbon market mechanism, further strict political regulation will become unnecessary. However, the effects of the European Emissions Trading System (EU-ETS) so far have shown that it is not that simple.

Germany has already decided to implement a national emissions trading system for heating and mobility, namely the Fuel Emissions Trading Act. The upcoming months will show whether and in what ways this act has to be adapted for legal reasons or harmonised with the existing and new European framework.

This study analyses detailed criteria for setting up different systems of carbon pricing. Its aim is to reassess these technical aspects in order to provide decision-makers and experts with tangible findings that show the potential results of policy implementation.

The European Green Deal has entered the political arena and the momentum for change has come. Carbon emissions must decrease as quickly as possible – in all sectors. Investments need to spur climate-neutral and scalable technologies. It is and will be crucial to support and finance these technologies and infrastructure with the revenues from carbon pricing. Furthermore, both Germany and Europe must establish incentives and a legal framework for all sectors to achieve climate neutrality by 2050. To meet this target, relying exclusively on carbon pricing mechanisms is not sufficient.

At the European level, a range of economic and climate policies will be decisive for the future of carbon pricing and the path towards a carbon-neutral continent:

The *European Green Deal* has to lay the foundation for the environmental transformation of our economy and make Europe carbon-neutral by 2050. The European Climate Law is currently under negotiation and European Commission's President Ursula von der Leyen has proposed an emission reduction target of at least 55 percent by 2030 (compared to 1990 levels). While this is a step in the right direction, climate scientists concur that much more is necessary.

A *reform of the European Emission Trading System* (EU ETS) is necessary to ensure that more sectors are included, the surplus of allowances is reduced and the price for emitting CO_2 increases.

The *EU Energy Taxation Directive* (ETD) has to be revised in order to stop tax exemptions for diesel fuel, heating oil and other tax loopholes.

We would like to thank Felix Matthes for writing this study and for the excellent cooperation. We hope that this publication will contribute to the current debate about carbon pricing instruments and help decision-makers to evaluate the challenges and prospects of carbon pricing.

Brussels, September 2020

Dr. Ellen Ueberschär
Co-President,
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EXECUTIVE SUMMARY

The topic of carbon pricing is experiencing a renaissance in German, European and international energy and climate policy. Although there is broad agreement about the necessity of carbon pricing on an abstract level, there are striking differences in evaluations of concrete proposals for its implementation. A first reason for these different evaluations – above all concerning the uniformity of a carbon price signal and the ability of markets to generate long-term price signals – derives from different core (economic) beliefs which cannot, in the final analysis, be resolved on a basic level. Another reason is that the evaluations reflect the existing carbon pricing landscape which has multiple serious distortions, especially with a view to current energy taxes. Thirdly, the classification of carbon pricing differs depending on the level of ambition of the emission reductions aimed at overall. Fourthly, there are different views about the appropriate redistribution of revenues from carbon pricing. Fifthly, there are some substantial differences regarding the prioritization of administrative effort, flexibility and predictability.

Some of the basic issues relating to carbon pricing must be decided urgently and unambiguously on a political level so that practical implementation models can be created. Other basic issues can be tackled based on pragmatic solutions such as smart hybrid systems based on emission trading and carbon pricing.

It is crucial that beyond all (important) technical details of carbon pricing systems, the issues relevant on a basic level must be discussed comprehensively and clearly decided upon with sufficient advance notice. Otherwise, overhasty ad hoc decisions could lead to consequences and implications that are partly unclear, resulting in less robust carbon pricing systems (such as the national emission trading system [nETS] adopted in Germany).

Particularly with a view to the far-reaching changes in EU law on carbon pricing and energy taxation within the framework of the European Green Deal, careful handling of the above-mentioned issues will be of great importance in the years ahead, with cross-border cooperation and EU-wide implementation playing special roles.

There is a high probability that, by the mid-2020s at the latest, Germany will once again have to make basic revisions to its carbon pricing system, not only due to changes in the EU framework but also because of the specific challenges facing Germany. The necessary preparatory processes should be planned in the short term in parallel with implementation of the nETS.

1. Introduction and background

In Germany and internationally, the debate about the pricing of greenhouse gas emissions (hereafter referred to as «carbon pricing» for the sake of simplicity) is experiencing a largely unexpected renaissance. The reasons for this are as varied as the number and range of corresponding proposals and implementation plans. This creates the paradoxical situation that there is growing consensus about carbon pricing needing to play an important role in future energy and climate policy, but the concrete proposals and the scope for carbon pricing for different stakeholders are more varied than ever. These debates are being conducted with increasing sharpness and acrimony.

This is hardly surprising given the very different basic (economic) beliefs at work. What is surprising, however, is that many discussions are being held at a level of abstraction on which the overarching goal of carbon pricing gets lost – namely, climate neutrality for Germany and Europe (as well as other highly developed industrialized countries) by the middle of the century.

Discussions about carbon pricing strategies should always bear in mind that new carbon pricing instruments will always emerge in the context of a wide range of existing climate protection instruments including implicit carbon pricing mechanisms (e.g. energy taxes) and in which greenfield implementation will not be possible. Exceptional situations that previously applied for a variety of very specific reasons (e.g. for the introduction of the EU Emissions Trading System, EU ETS) will not exist for the upcoming carbon pricing measures.

Against this background, a sophisticated and reality-based discussion is needed about the means and ways of facilitating a stronger role for carbon pricing in the climate policy mix. The wide range of analyses and proposals put forward in the last two to three years includes an even wider range of elements that need to be assessed in a differentiated way. With this in mind, the present analysis aims to examine systematically the different elements of a carbon pricing strategy and provide a clearer overview of the individual elements and their possible combinations.

Alongside the fundamental question of the level on which carbon pricing should occur, an array of individual questions that are also central. Some of these questions concern the main elements of carbon pricing and some concern implementation issues which may enable or block carbon pricing pathways.

2. Positioning carbon pricing in the policy mix

What we can – and cannot (really) – expect of carbon pricing

Carbon pricing – considered as a strategy and in the implementation of concrete policy instruments – can only meaningfully be discussed and classified in the context of the specific climate targets that are to be met (Matthes 2019b).

For Germany, the EU and other industrialized countries, the objectives of the Paris Agreement set out a path for reducing emissions in which the transition to a climate-neutral economy is to be achieved within three decades (at most):

- Given the considerable inertia of various technical and economic systems (lifetime of the capital stock, renovation cycles, lead times for infrastructure and innovation etc.) and social framework conditions (e.g. regional adaptation processes), parallel transformation processes are inevitable to a certain degree. The necessity of transformative and parallel processes of transition is a first restriction on intertemporal flexibility (i.e. the decentralized decisions of economic subjects to bring forward or postpone investment and operational decisions). Such flexibility is a crucial feature and a major advantage of carbon pricing instruments. On the path to climate neutrality, there will thus be limited scope within comparatively short periods of time for a sequential approach to mitigation cost curves, i.e. tapping the cheap emission reductions first and the cost-intensive ones last. This is also true of the international distribution of emission reductions and the efficiency gains to be achieved through international cooperation. In view of the tight time-frame for transforming national economies, the dynamic efficiency of the adaptation processes compared with those considered static (i.e. occurring at specific points in time) becomes even more important.
- In different sectors (electricity, industrial, heat, transport, agriculture, etc.) and in different jurisdictions internationally (e.g. legal arrangements for the electricity industry), issues such as different profitability considerations and economic rationalities, infrastructural requirements, regulatory framework conditions, etc. have a decisive influence on the effectiveness of pricing strategies and what effectiveness and efficiency advantages can ultimately result from them.

This is even more so the case when the different modes of action for reducing emissions are taken into account. Ideally, carbon pricing could serve as a central feature of each of the four areas of action discussed below and trigger optimization processes among them. A closer look, however, reveals a much more differentiated picture:

- The *first* important lever for reducing emissions concerns operational decisions (power plant dispatch in the electricity market, vehicle use based on operating costs, adjusting the heating and air conditioning temperatures in buildings, etc.). These are mainly of a short-term nature, are especially relevant for very price-sensitive sectors (power generation etc.) and involve a substantial emission reduction potential, especially in sectors with a high share of carbon-intensive power plants, appliances or vehicles. Pricing instruments are of stellar importance in the implementation of these emission reductions and there is often no alternative. Any volatilities in carbon prices is more of an asset than a problem for this sector as long as they arise predominantly from short-term changes in framework conditions. This lever also avoids or alleviates rebound effects, i.e. changed power plant operation resulting from other emission reduction measures (e.g. the shutdown of coal-fired power plants) that is counterproductive to climate policy.
- The *second* lever for emission reduction is the (earlier) removal of carbon-intensive power plants, appliances and vehicles from operation. Here, comprehensive carbon pricing is an important and advantageous detection and selection mechanism (e.g. in the context of carbon pricing, the profitability of coal-fired power plants can decrease and result in shutdown if personnel and repair costs can no longer be covered). It should be borne in mind that alternative instruments are also available here (especially in regulatory law for standard power plants, appliances and vehicles). The risk considerations associated with possible price volatilities tend to be an advantage rather than a disadvantage from the perspective of emissions reduction.
- The *third* lever for reducing emissions is the (earlier) investment in low-emission or zero-emission power plants, appliances and vehicles. Carbon pricing can play a significant role here, e.g. greater incentives to purchase electric vehicles with significantly higher costs for fossil fuels. However, there is a wide range of alternative instruments; these instruments may also prove useful beyond the effectiveness and efficiency of climate policy. These alternative instruments range from focused investment financing to regulatory law and are particularly relevant for typical applications with high transaction costs or low price sensitivities. Carbon pricing can also prove useful in these cases if investment decisions can be postponed or (legal) legitimation for increasing the intervention intensities of other instruments is possible. The role of carbon pricing would, however, be limited to that of an accompanying instrument. Any price volatilities lead to risk charges on the capital costs for investment payback; they tend, therefore, to be a cost driver, to lead to higher system costs and to reduce the efficiency of emission reduction in this context.
- The *fourth* lever for emission reductions concerns the spillover effects of carbon pricing. Changes in relative prices in the value chain can lead to substitution

effects or other changes in consumption (e.g. higher incentives for energy efficiency via higher costs of fossil fuels). They can also trigger or strengthen innovation processes (substituting carbon-intensive basic materials such as steel or cement with less carbon-intensive alternatives). Carbon pricing can be used if it is possible to pass on the carbon costs in the value chains, which is not necessarily the case (in view of international competition or the regulatory arrangements in the electricity sector). The spillover effects also include information about certain characteristics of carbon pricing instruments such as emissions trading systems with long-term caps. Here, the effect may not be caused by changes in relative prices in the time frame for economic decisions, but rather by clearly indicating the investment projects compatible with long-term climate targets. The effects of volatile carbon prices can be rather problematic for the leverage potential of spillover effects.

This discussion shows that many basic assumptions of neo-classical theory (complete information and perfect foresight, no barriers to market access, unlimited speed of adaptation, etc.) cannot or cannot fully be assumed for a target-oriented, effective, politically robust and dynamically efficient climate policy. Thus, there will inevitably be a need for comprehensive instrument packages. The challenge here is above all to design such packages rationally and transparently and avoid (political) arbitrariness.

Several challenges arise from these considerations with a view to carbon pricing debates and strategies:

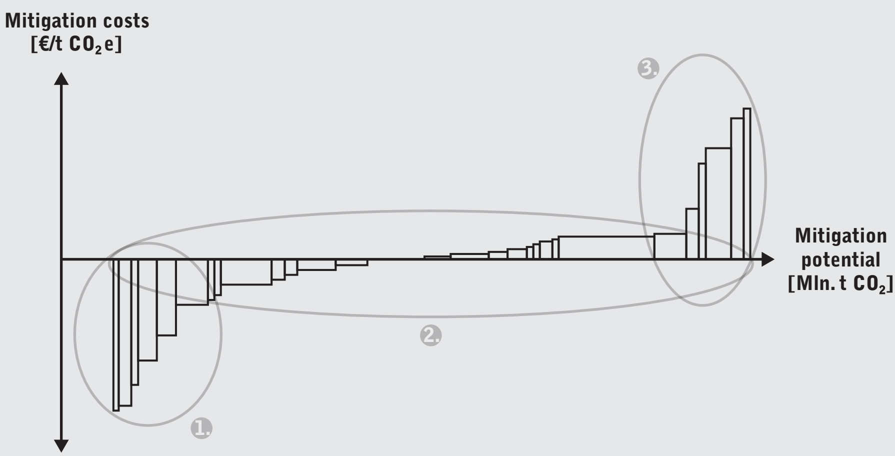
- Can uniform carbon prices (for sectors, countries, etc.) – which are often equated with (static) efficiency – be reliably pursued on a level beyond abstract economic beliefs and with the objective of achieving climate neutrality by 2050? This question applies less to formally uniform carbon prices (which are added to other implicit carbon price components) than to carbon prices that are effectively uniform, i.e. the entirety of implicit and explicit carbon pricing. Aside from efficiency issues (in a dynamic sense), distribution effects should also be considered a very important factor in the implementation of carbon pricing instruments.
- From an incentive perspective, when can carbon pricing be considered a major strategy or instrument (with other instruments playing a complementary role at most)? And when should carbon pricing assume the role of an accompanying instrument (with other instruments making the main contributions to emission reductions)? Beyond complementing carbon pricing with additional measures in infrastructure and innovation which is largely uncontentious, the role of carbon pricing strategies has to be carefully and realistically determined, especially with a view to strengthening investment-based emission reductions in other ways (promoting/financing investments, regulatory law) and to using such instruments as regulatory law to displace carbon-intensive shares of capital stock.
- A rational policy mix needs to focus on not only the relationship between carbon pricing and other instruments, but also the design of the different carbon pricing instruments. For example, hybrid approaches that combine carbon-based energy

taxes and emission trading systems could create the necessary sectoral differences in carbon pricing and ensure a minimum degree of price stability while also tapping the advantages of emission trading systems.

With these questions and challenges in mind, some systematic conclusions can be drawn on the positioning of carbon pricing in the policy mix. Figure 1 shows the typical curves of mitigation costs and potentials. Seven areas can be identified in which carbon pricing strategies can or should be positioned differently:

- The central role of carbon pricing as an incentive and discovery instrument for market potentials is largely undisputed (segment 2). The wider and flatter this section of the mitigation cost curve, the more important the role of carbon pricing in the policy mix.

Figure 1: Mitigation cost potentials grouped according to the role of carbon pricing in the policy mix



1. Locked potentials
standards, support – if necessary, complemented by carbon pricing

2. Market potentials
carbon pricing as instrument of choice (exception: high uncertainties re. emission quantities)

3. a) Learning potentials
b) with long-lived capital stock
c) locked by market design
d) high inframarginal distribution effects
standards, support/financing – if necessary complemented by carbon pricing

4. Infrastructure-based potentials (not shown in the figure)
infrastructure planning and risk protection with sufficient lead time, if necessary targeted support of options on supply and demand side

Source: Author's own based on Öko-Institut 2010 and IEA 2011; own chart.

- With regard to negative mitigation costs (segment 1), it can be assumed that carbon prices have no or only a strongly distorted influence on decision-makers, either because of structural barriers (e.g. user-investor dilemma[1]) or distorted cost-benefit perceptions[2]. Carbon pricing may be able to remedy this situation in part (in case of doubt, only with very high prices), but it is hardly a suitable major instrument.
- In the area of high mitigation costs (segment 3), carbon pricing strategies mainly reach their limits at four points:
  - In some areas, high cost reductions can be achieved in the medium term by tapping potentials at an early stage (observable in solar and wind power generation, batteries or electrolysis technologies). These so-called learning curve effects lead to cost savings in emission reductions, which can rarely be initiated by pure carbon pricing strategies due to the high initial costs. Other instruments based on subsidies or regulatory law would need to play a central role and carbon pricing a supplementary one (segment 3a).
  - Especially in the case of very ambitious climate policies, there is an unfavorable relation between the time available for transformation and the modernization cycles connected to long-lived capital stock (industrial power plants, buildings, etc.). Corresponding emission reductions can therefore only be achieved at the lowest possible cost if *business-as-usual* cycles are used to implement far-reaching emission reduction measures, even if other substantial emission reduction potentials are available at the same time at lower cost (segment 3b).
  - In some segments, market design has a significant influence on the effects of carbon pricing. When solar and wind power plants operate in a market in which prices are based on marginal costs and no other mechanisms for investment payback are available, considerable periods of time can be expected in which solar and wind power plants cannot generate any income. With large shares of wind and solar energy on the wholesale market, the electricity price is very low, zero or negative – independently of the carbon price. Due to their weather-dependent operation, much higher carbon prices would have to be charged in the remaining hours than in a market design in which (as in some non-European countries) the electricity system is market-based but fully oriented to long-term power purchasing agreements (PPA). Here, too, financial instruments will ultimately play a more important role than carbon pricing (segment 3c).
  - It should be considered whether using carbon pricing on the steep part of the mitigation cost curve makes sense even after all other mitigation potentials have been implemented if the necessary carbon prices result in huge

1 In this dilemma, the costs of emission mitigation are borne by the investor and the economic benefit is accrued solely by the user when there are limited possibilities for passing on the mitigation costs, e.g. in the rented housing sector.

2 For example, analyses of building refurbishment often apply not only the differential costs for *business-as-usual* refurbishments, but also the full costs; or, in analysis of vehicle procurement, the total costs over the vehicle lifetime are not considered (EWI & FiFo Köln 2019).

distribution effects that cannot, or can only partially, be compensated. As the income to be redistributed increases, such compensation measures typically become more differentiated and multi-faceted and their manageability becomes increasingly complicated (segment 3d).

- Finally, the mitigation potentials with high infrastructure requirements should also be noted. These are basically cheap potentials for which significant and long-term infrastructure inputs are necessary (which cannot or can only marginally be initiated via carbon prices). These infrastructure inputs will not materialize, however, unless specific consumption or production densities can be achieved with a high degree of certainty (e.g. offshore wind power in the case of consumption and electromobility in the case of feed-in). Here, technology-specific instruments or infrastructure regulations will always play a more prominent role than carbon pricing (segment 4).

The extent to which these seven (sub-)segments are a suitable approach for developing an effective and efficient policy mix thus depends on two main factors:

- *Firstly*, the curve of emission mitigation costs is of paramount importance. The flatter the curve is, the greater the likely role of carbon pricing in the policy mix. It is important to be aware of this cost curve when designing the policy mix.
- *Secondly*, many classifications depend on the extent to which and in what time frames future developments (or development opportunities) are anticipated by the decision-makers. If economic subjects tend to act in the short term (a robust assumption in many cases), carbon pricing loses importance in the policy mix. If it can be reliably assumed, however, that economic subjects act clearly and with the long term in mind (which tends to be the exception), carbon pricing assumes a more important role in the policy mix. The relevant basic beliefs and their empirical validation thus form a very important criterion in the design of rational policy mixes.

The role of carbon pricing in the policy mix is shaped not only by the incentive perspective, but also by how the income from carbon pricing instruments is used:

- *Firstly*, the effects of carbon pricing can be improved by decreasing mitigation costs (changing how the energy system is financed, removing specific barriers, developing infrastructure),
- *Secondly*, economic and social hardships can be reduced (by decreasing the burden on socially disadvantaged households and introducing measures to avoid carbon leakage),
- *Thirdly*, the income can be used to increase acceptance,
- *Fourthly*, it can be used to finance various instruments (e.g. promoting investment and innovation) and

- *Fifthly*, the revenue can also be used for overarching purposes such as decreasing the burdens of work, education and training, etc.

Each of these options can be implemented as the only instrument for redistributing revenue or they can be combined with other strategies. It is important to make the primary motivation and goals of the chosen model of revenue allocation clear and transparent.

These considerations are of paramount importance if carbon pricing is to be pursued not only nationally, but also in cooperation with other European countries, with the EU as a whole or in a broader international context. National or sectoral particularities and current policy or regulatory instruments will necessarily be central to the usefulness of uniform carbon prices and in the classification of different carbon pricing instruments.

3. Current status of direct and indirect carbon pricing

3.1 The situation in Germany

In Germany today, direct carbon pricing only occurs through the EU ETS. Additionally, there is indirect carbon pricing through (energy) taxes, levies and surcharges on energy sources. When interpreting taxes, levies and surcharges as carbon prices, two aspects must be considered:

- A portion of the energy taxes (i.e. fuel taxes) also serve to finance road infrastructure. The tax revenues attributable to financing infrastructure cannot be attributed to indirect carbon pricing.[3] The challenge here is that other transport-specific taxes and charges (vehicle tax, truck tolls, etc.) are also attributable to infrastructure financing.
- In contrast to the markets for storable fuels, the electricity market is a very clearly designed marginal cost market. The prices on the wholesale markets reflect the short-term operating costs of the power plants (i.e. mainly fuel and carbon costs). To date, the gaps for investment payback have mainly been filled with surcharge instruments such as the those of the German Renewable Energy Sources Act (EEG) and the German Combined Heat and Power Generation Act (KWKG). This means that they are classified as carbon pricing, but they also ensure full cost coverage.

Table 1 presents an overview of taxes, levies and surcharges in Germany which have been converted to carbon price equivalents. It shows that its system of energy taxes and surcharges brings about peculiar distortions:

- Among the energy sources used primarily for heat generation (natural gas, fuel oil, liquid gas, coal), carbon-intensive energy sources (fuel oil, coal) are almost always taxed at much lower rates than those with lower carbon emissions (natural gas). The differences are marked in all cases (natural gas to fuel oil EL: 7 €/t CO_2, natural gas to heavy fuel oil: 23 €/t CO_2, natural gas to coal: 26.50 €/t CO_2 etc.). This indirect carbon pricing has remained nominally constant in recent years, with the result that carbon prices have decreased in real terms.

3 In a thought experiment, these would be the portions of fuel taxation that could be abolished if all transport infrastructure were financed via *road pricing*.

Table 1: Implicit carbon taxation in Germany via the current system of energy taxes and levies, 2018

		Nominal tax rate	Implicit tax rate	w/o infrastructure costs*		w/o counter-fact. invest.**
				15 bn € p.a.	35 bn € p.a.	
		€ per unit	€ per t CO_2			
Heat generation						
Coal (heat)	EUR/GJ	0.33	3.47	–	–	–
Light fuel oil	EUR/1,000 l	61.35	23.03	–	–	–
Heavy fuel oil (heat)	EUR/t	25.00	7.87	–	–	–
Natural gas (heat)	EUR/MWh (H_0)	5.50	30.23	–	–	–
Liquid gas (heat)	EUR/100 l	6.06	20.56	–	–	–
Fuels ***						
Petrol leaded	EUR/1,000 l	721.00	315.90	279.79	134.93	–
Petrol unleaded	EUR/1,000 l	654.50	286.76	253.99	122.49	–
Diesel	EUR/1,000 l	470.40	179.06	165.55	35.23	–
Natural gas (fuel)	EUR/MWh (H_0)	13.90	76.40	–26.00	–198.20	–
Liquid gas (fuel)	EUR/100 l	18.03	61.16	–11.37	–159.73	–
Generation/demand of electricity						
Coal	EUR/GJ	0.00	0.00	–	–	–
Heavy fuel oil (elec.)	EUR/t	25.00	7.87	–	–	–
Natural gas	EUR/MWh (H_0)	0.00	0.00	–	–	–
Electricity EU ETS	EUR/EUA	15.82	15.82	–	–	–
Electricity tax	EUR/MWh	20.50	22.78	–	–	–
Surcharges on elec.	EUR/MWh	75.55	83.94	–	–	53.54
Electricity total	**EUR/MWh**	**111.87**	**122.54**	**–**	**–**	**90.56**

* Taking into account fuel-specific financing of road infrastructure through vehicle tax (€ 8.7 bn) and truck toll (€3.1 bn). The lower range of infrastructure costs denote the current annual investments; the upper range denotes the annuity of total costs of the system.
** Taking into account counterfactual investments of 36 €/MWh.
*** The implicit carbon tax rates also include other significant externalities of transport (other pollutants, noise, health effects) which are lower for other energy sources.
Source: Own calculations; state 2018.

- Regarding the fuels used primarily in the transport sector, significantly higher levels and substantial distortions can initially be observed. Even if the total costs of the transport infrastructure are deducted (including the different fuel shares in the various vehicles taxes and truck tolls), the indirect carbon pricing of diesel is approx. 90 €/t CO_2 lower than that of petrol (approx. 120 €/t CO_2). The tax on liquid and natural gas as fuels is so low that it does not cover the infrastructure costs attributable to vehicles, which results in negative carbon prices. Here, too, indirect carbon pricing has remained nominally constant in recent years, with the result that carbon prices have fallen in real terms.
- If the revenues from the renewable energy and combined heat and power surcharges (EEG and KWKG) are considered in financing the full costs of the electricity system; and the implicit carbon pricing effects of the remaining surcharges and the electricity tax are calculated[4], indirect carbon pricing in the electricity sector amounts to 76 €/t CO_2 for 2018. Given that direct carbon pricing via the EU ETS amounts to approx. 16 €/t CO_2, electricity is priced overall at 92 €/t CO_2. In recent years, direct and indirect carbon pricing of electricity has been volatile but has shown a clear upward trend overall.

Discussions about carbon pricing should carefully consider whether additional elements of carbon pricing should be added to the current system of indirect carbon pricing (especially with a view to incentive effects). This would mean that the basic distortions from current taxes and surcharges are retained. The alternative would be for carbon pricing to replace the current taxes and surcharges, which would lead to smaller differences between the carbon prices on different levels and would eliminate the distortions of the current system.

It should also be noted that extensive tax exemptions and refunds are in effect in the manufacturing and other price-sensitive sectors. Analysis of the effectiveness of carbon pricing must take these into account.

Figure 2 provides an overview of explicit and implicit carbon pricing in Germany for 2019 before the Fuel Emissions Trading Act (BEHG) entered into force. It shows that:

- approx. 417 million t CO_2 emissions are subject to direct pricing via the EU ETS and relatively low pricing via non-refunded energy taxes,[5]
- approx. 53 million t CO_2 emissions from the combustion of petrol are priced at 122 €/t CO_2 and
- a further 239 million t CO_2 emissions are subject to carbon prices of 23 to 30 €/t CO_2;
- the remaining 33 million t CO_2 emissions have an almost negligible carbon price via energy tax refunds.

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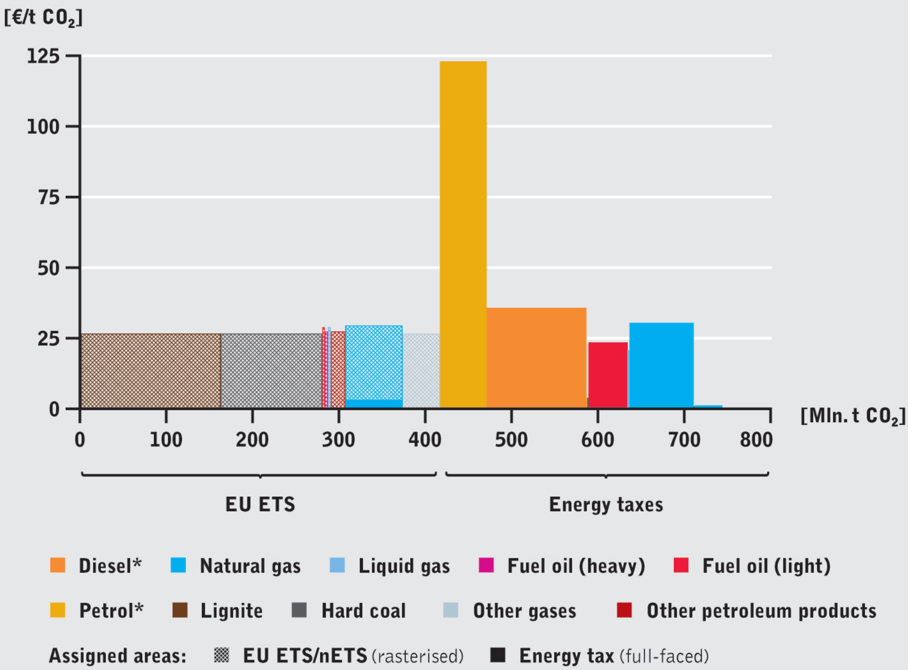
4 Determined as a thought experiment: if all other parameters are kept constant, how high does the carbon price have to be to attain electricity price effects equivalent to those of the taxes and levies.

5 From the incentive perspective, this pricing takes full effect via the opportunity costs for those segments that receive substantial free allocation of emission allowances.

With the exceptions of the tax on petrol and industrial exemptions from the energy tax for installations not covered by the EU ETS, the corridor of explicit and implicit carbon pricing in Germany is currently relatively narrow.

Figure 2: Explicit and implicit carbon taxation in Germany prior to the Fuel Emissions Trading Act (BEHG)



*adjusted for infrastructure financing
Source: Own calculations, status 2019; own chart.

3.2 Aspects of the situation in other European countries

At least a cursory glance at carbon pricing in other European countries is helpful and necessary to identify useful models and to consider cross-border strategies of carbon pricing and the cross-border rebound effects of (different) carbon pricing instruments.

By way of example, Figure 3 provides an overview of direct and indirect carbon pricing for motor fuels for EU member states and Switzerland:

- This overview shows that there is a wide range of carbon prices for motor fuels (for reasons of data availability, the portions of fuel tax used to finance infrastructure have not been deducted). These carbon prices range from 160 €/t CO_2 to 350 €/t CO_2 for premium grade petrol and from 125 to 305 €/t CO_2 for diesel. The carbon price in Germany is well above the average value for petrol (287 €/t CO_2) and slightly above the median value for diesel (179 €/t CO_2) for the countries shown (245 and 241 €/t CO_2 for petrol and 175 and 162 €/t CO_2 for diesel). Almost all economically strong countries of Western Europe are in the upper range of the carbon price.

- In almost all countries (with Switzerland the only exception), petrol is taxed more highly than diesel from the perspective of their carbon content. The range of these differences (excluding Switzerland) is substantial at 32 to 157 €/t CO_2. The difference between the tax on diesel and petrol for Germany, converted to the carbon content, is 108 €/t CO_2, which is well above the average and median value for the countries shown (70 and 63 €/t CO_2). The Scandinavian countries, Germany, the Netherlands and Greece are in the upper part of the range.
- As the only countries with carbon-based taxes (which are nevertheless implemented as energy taxes) Sweden and France are at the top end of the fuel tax range. Nevertheless, the fuel taxes for Sweden (which currently have a nominal carbon component of 114 €/t CO_2) are effectively lower than those in France (which has a nominal carbon component of 44.6 €/t CO_2) since Sweden significantly adjusted the remaining fuel taxation when introducing carbon pricing.

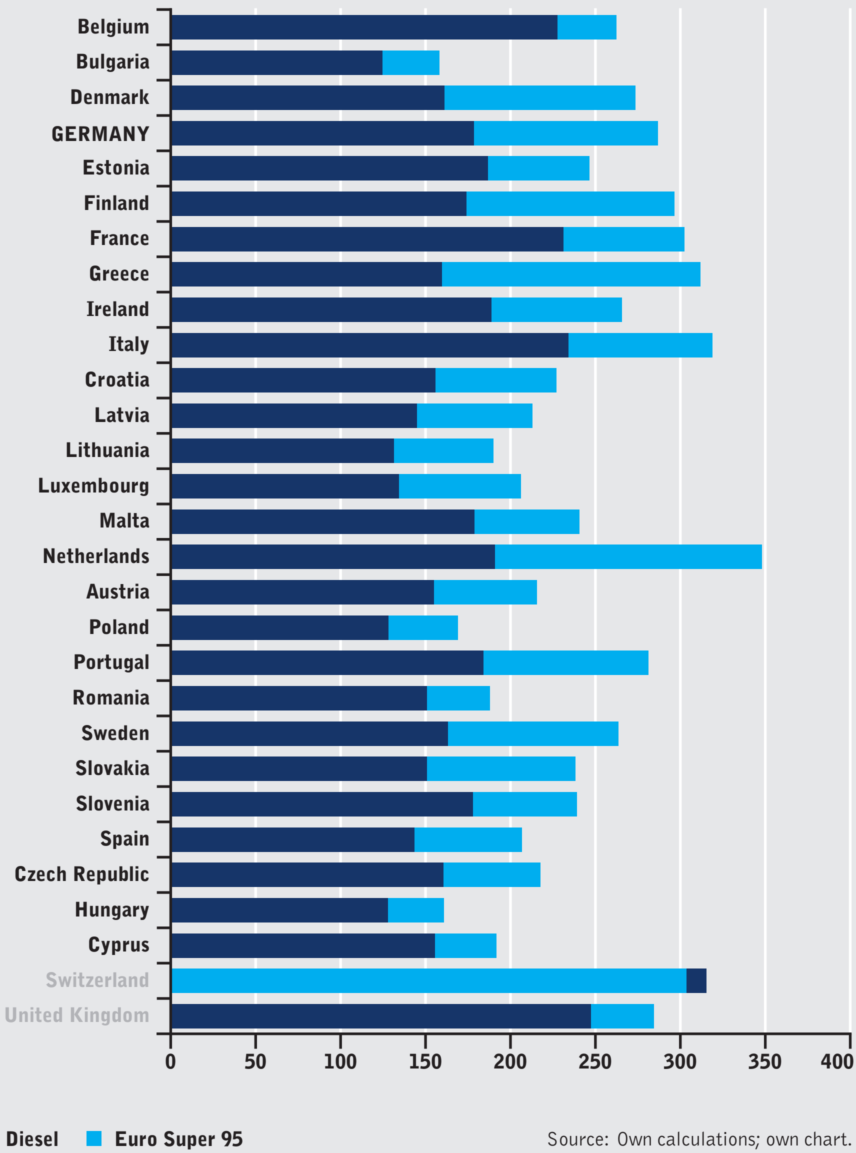
When the EU ETS was introduced as an EU-wide uniform pricing instrument, the situation was significantly different since the installations currently covered by the EU ETS were not subject or were only partly subject to direct or indirect carbon pricing mechanisms and/or these were adapted in the course of the introduction of the EU ETS.

With a view to the approaches of other European countries to carbon pricing, it is instructive to compare Sweden and Switzerland:

- In Switzerland, a carbon tax of 86 €/t CO_2 on fossil fuels is currently levied on all consumption beyond the installations covered by the EU ETS and the transport sector. The effects, e.g. in the building sector, are clearly observable but remain limited (EWI & FiFo Cologne 2019).
- Sweden currently levies a carbon tax of 114 €/t CO_2 on fossil fuel consumption beyond the installations covered by the EU ETS. The effects, e.g. in the building sector, are clearly observable and it has had a considerable impact on reducing carbon emissions (EWI & FiFo Cologne 2019). One reason for this is without a doubt the longer time frame (Sweden has applied the tax since 1991 and Switzerland since 2008); the availability of cheap alternatives in Sweden (large availability of biomass at low prices, cheap electricity prices) is also seen as an important explanatory factor.

Aside from the challenges arising with a view to indirect carbon pricing instruments already in place (above all for cross-border cooperation on carbon pricing for sectors not covered by the EU ETS), the example of Sweden shows how important a reform of taxes, levies and surcharges from carbon pricing instruments can be to the effectiveness (and also the efficiency) of these instruments. It demonstrates that discussions on cross-border cooperation must not be limited to incentives but should also include carbon pricing instruments.

Figure 3: Carbon pricing of motor fuels in the EU and Switzerland [in €/t CO_2]



Source: Own calculations; own chart.

4. What carbon prices are relevant?

Classification and evaluation of carbon pricing strategies and instruments depend largely on what carbon prices are expected or desired. There has been a plethora of analyses in this respect, the results of which span an extremely wide range. There are differences in regional and sectoral focus, in the ambition of emission reductions and in the different methodological approaches used to examine carbon price impacts.

To enable an exploratory classification of different carbon prices, some of these analyses and their results are described below. Without any claim to completeness, the aim is to outline different starting points and perspectives with regard to frameworks (global, national, sectoral, etc.) and methodological approaches (the models used, the trends viewed as *business-as-usual* developments, the integration of carbon pricing in the policy mix, discount rate strategies, etc.):

- A first group of analyses addresses global carbon prices which arise from the marginal costs of abating greenhouse gas emissions to fulfil specific global targets. As a rule, these instruments are the only or the most important control instrument and are applied to all countries and sectors. For scenarios that restrict global warming to 1.5°C above pre-industrial levels (IPCC 2018), prices for 2030 range from approx. US-$ 200 to US-$ 500 per ton of CO_2 equivalent (US-$/t CO_2e). For scenarios based on the 2°C increase limit, prices of 60 to 220 US-$/t CO_2e arise. With a view to 2050, the corresponding ranges are 450–1,000 US-$/t CO_2e or 200–800 US-$/t CO_2e. IPCC 2018 also cites modelling results in which the combination of carbon pricing with other instruments can lead to lower carbon prices and improved economic efficiency of emission reductions.
- In the Sustainable Development Scenario of the World Energy Outlook 2018 of the International Energy Agency (IEA 2018), carbon prices for the sectors in Europe covered by the EU ETS are calculated as 63 US-$/t CO_2 in 2025 and 125 US-$/t CO_2 in 2040 in order to reduce carbon emissions in the EU by approx. 60 % by 2030 compared to 1990 combined with other measures. With these prices for industrialized countries and 43 and 125 US-$/t CO_2 primarily for emerging economies, a reduction in global carbon emissions of approx. 22 % is calculated for the period of 2017 to 2030.
- Other analyses are based on the emission reduction targets relevant in the context of the Paris Agreement and use uniform carbon pricing as a key instrument. For the G20 countries, the International Monetary Fund (IMF 2019) calculates emission reductions from fossil fuel combustion compared to the *business-as-usual* (BAU) development of approx. 25–30 % by 2030 if carbon prices of 35 and 70 US-$/t CO_2 became effective for the entire economy. For Germany, these models calculate

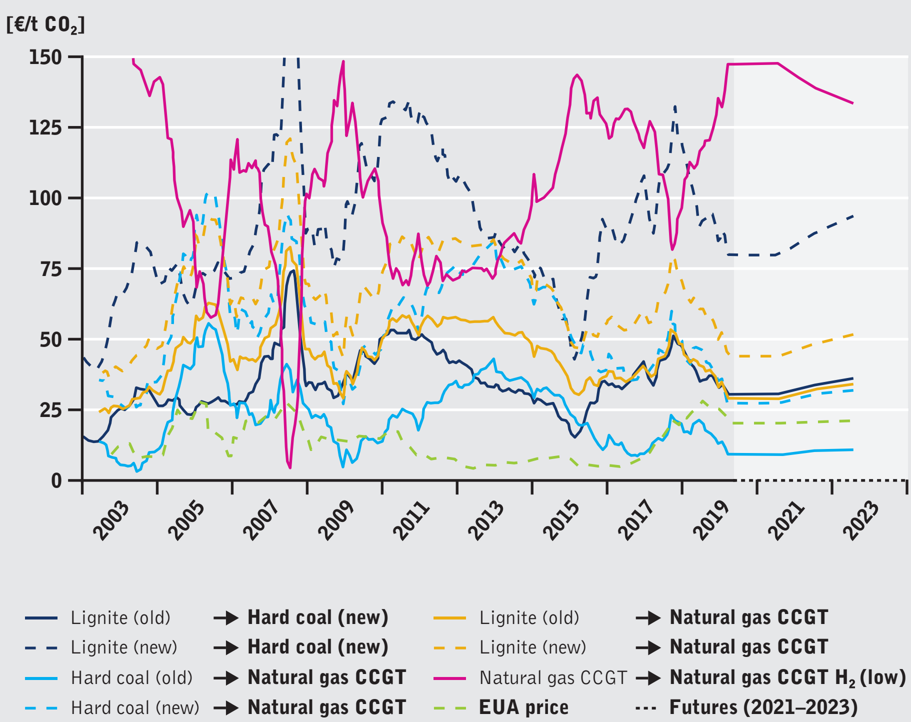
emission reductions of 16 % compared to BAU with a carbon price of 35 US-$/t CO_2 and of 25 % compared to BAU with a carbon price of 70 US-$/t CO_2.

- In the analyses on the long-term strategy of the European Union (EC 2018), emission allowance prices of 28 €/t CO_2 are applied in the sectors subject to the EU ETS to enable emission reductions of 45 % by 2030 compared to 1990. For emission reductions of about 85 % by 2050, the corresponding prices are 250 €/t CO_2; for emission reductions of more than 95 % by 2050, they are approx. 350 €/t CO_2.
- The High-Level Commission on Carbon Pricing (HLCCP 2017) recommends that carbon prices of at least 50 to 100 US-$/t CO_2 in 2030 are compatible with the objectives of the Paris Agreement. It also observes that the necessary carbon prices depend substantially on the trends assumed as BAU development and the integration of carbon pricing in the policy mix.
- With reference to Germany and the carbon emissions not covered by the EU ETS, an analysis of the German carbon pricing discussion (MCC & PIK 2019) calculates a need for carbon prices of 70 to 350 €/t CO_2 (in the base case 130 €/t CO_2) in 2030 so that the total emissions of the corresponding sectors amount to approx. 300 million t CO_2. The range results from different BAU developments and the wide spectrum of possible price sensitivities.[6] It should be pointed out that the carbon prices for the transport sector are added to the existing energy taxes, but for heating fuels (i.e. in the heat sector) they are to be replaced (for natural gas, the dominant energy source in the heat market, the carbon price surcharge in the proposal of this study is therefore about 20 €/t CO_2 in 2020 and about 100 €/t CO_2 in 2030).
- Alongside these analyses from the macro perspective, analyses have been conducted on carbon pricing from a sectoral and country-specific perspective, from the perspective of investors and depending on other framework conditions and decision-making considerations:
  - Analyses for the transport sector commissioned by the Federation of German Industry (BDI) offer interesting insights on how the 2030 targets of the German government's Climate Protection Plan 2050 (BMU 2016) can be achieved using different combinations of measures (BCG & Prognos 2019). The necessary transformation of the transport sector requires carbon prices that increase quickly and progressively from 50 €/t CO_2 to 250 €/t CO_2 for the transport sector in 2030, if no additional incentives to buy electric vehicles are created. With buying incentives decreasing over time from € 4,000 to € 1,000 per vehicle, the carbon price in the transport sector would have to increase progressively to 150 €/t CO_2 in 2030. Assuming high buying incentives that decrease from € 6,000 to € 2,000, the carbon price would have to increase from 30 €/t CO_2 in 2020 to 100 €/t CO_2 in 2030. In this analysis the carbon prices are added to the current energy taxes.

6 In methodologically diverse studies on the impact assessment of the measures of the German Climate Action Plan 2030 (Prognos et al. 2020; Öko-Institut et al. 2020), the effects of carbon pricing for similar prices in the various sectors are only a fraction of the values calculated by MCC & PIK (2019).

- A study on the refurbishment incentives of carbon taxation for Germany's building stock (EWI & FiFo Cologne 2019) shows that adding 45 €/t CO_2 in 2020, 145 €/t CO_2 in 2030 and 245 €/t CO_2 in 2040 to current energy taxes creates limited incentives for refurbishment. Only for old buildings with very poor standards are the incentives generated by these carbon prices sufficient. Even for buildings with medium energy standards, the limited incentives for energy refurbishment are not attractive if the owners base their decisions on the narrowly defined, purely energy-related additional costs and the total costs of refurbishment (with its implications for financing etc.). For buildings constructed in the last two decades, these carbon prices would not provide any incentives whatsoever to undertake the necessary long-term refurbishment measures towards a zero-emissions building.

Figure 4: Fuel switching costs on the Continental European electricity market, 2003–2023



Source: Own calculations; own chart.

- Finally, there is relatively robust empirical data available for several sectors. Figure 4 shows the fuel switching costs for standard power plants on the Continental European electricity market, i.e. the carbon price that would be necessary to bring about a shift in electricity generation to another generation technology. It shows four characteristic price levels in the current energy price environment. A carbon price of 15 to 25 €/t CO_2 (which corresponds approximately to the current allowance prices in the EU ETS) displaces old hard coal-fired power plants from the system. With carbon prices of approx. 30 to 40 €/t CO_2, old lignite and new hard coal-fired power plants are displaced. With carbon prices of approx. 50 to 60 €/t CO_2, electricity generation from new lignite-fired power plants is also displaced. Finally, with carbon prices of around 100 to 150 €/t CO_2, electricity generation from natural gas power plants would be replaced by electricity generation from climate-neutral hydrogen, if the latter became available at prices at the lower end of the supply options that are currently foreseeable (NGW et al. 2017; Equinor & OGE 2019). This option ultimately constitutes the *backstop* technology for very far-reaching emission reductions in power generation and a variety of industrial processes.

- Finally, the different assumptions of the *social costs of carbon* should be noted, which are shaped in turn by a variety of assumptions.:
  - The German Environment Agency has developed the following recommendations for calculating the environmental costs for Germany in the Methodological Convention 3.0 to be used as a basis for infrastructure projects and impact assessments (UBA 2019): 180 €/t CO_2e for 2016, 205 €/t CO_2e for 2030, and 240 €/t CO_2e for 2050.
  - The recommendations of the US government under the Obama administration (USG-IWG 2016) amounted to 50 US-$/t CO_2e for 2030 (ranging from 16 to 152 US-$/t CO_2e) and 69 US-$/t CO_2e (ranging from 26 to 212 US-$/t CO_2e) for 2050.[7]

Against this background, the following indicative conclusions can be drawn for current and future debates on carbon pricing in Germany:

- With a view to 2030, carbon prices of 40 to 60 €/t CO_2 can make a substantial contribution on the path of the electricity sector towards climate neutrality. In the longer term, prices of 100 to 150 €/t CO_2 should make it possible to achieve far-reaching climate neutrality.
- There is hardly any reliable basic data available for the carbon prices needed in the short and medium term for decarbonizing the most important industrial sectors. In the long term and with a view to the role of hydrogen as a future *backstop* technology, carbon prices are likely to range from 100 to 150 €/t CO_2 (this does not mean that much higher mitigation costs will have to be covered in individual sectors; the question is rather whether carbon pricing is useful for tapping the relevant potentials).

7 The Trump administration disbanded the Interagency Working Group on Social Cost of Greenhouse Gases (USG-IWG) on 28 March 2017 with its Executive Order 13783 and rescinded its recommendations. Some US government institutions have developed preliminary (and less ambitious) alternative principles; some continue to use the principles of 2016.

- For the emission reductions needed in the heat and building sectors in the short to medium term (with a view to refurbishment cycles etc.), carbon prices of 100 to 150 €/t CO_2 are necessary in 2030 in addition to the current energy taxes on heating fuels which should be aligned with current natural gas prices. Replacing the current energy taxes on heating fuels with carbon prices results in values of 130 to 180 €/t CO_2; in the long term, carbon prices would have to be well over 200 €/t CO_2.
- In the transport sector, the necessary carbon prices are approx. 150 €/t CO_2 in addition to current fuel taxes (for which the diesel privilege should be abolished) even with complementary measures of substantial intensity. Taking into account infrastructure financing, this would result in total carbon prices of approx. 270 €/t CO_2 (of which approx. 120 €/t CO_2 applies today). In view of the dynamic technological environment, there are still substantial uncertainties with regard to long-term prices, especially in mobility; this makes estimating the necessary carbon prices currently not very reliable.

From an incentive perspective, it is relatively clear what carbon prices play a significant role in 2030 (which still needs to be supplemented by other measures):

- for sectors currently covered by the EU ETS, the effective carbon price is calculated as 40 to 60 €/t CO_2;
- for the heat sector, an effective carbon price of at least 130 to 180 €/t CO_2 (or an addition of 100 to 150 €/t CO_2 to the energy taxes which need to be aligned with natural gas prices);
- for the transport sector, an effective carbon price (without contributions to infrastructure financing) amounts to at least 270 €/t CO_2 or an addition of 150 €/t CO_2 to the current energy taxes for petrol; the tax on diesel fuels (taking into account the higher contributions to infrastructure financing, especially with a view to the truck toll) would need to be aligned.

Analyses of the different design options for carbon pricing strategies and instruments need to consider these very different levels on which carbon prices have effects.

5. Criteria for classifying different models and design elements

To classify the different design options of carbon pricing instruments (or strategies), it is helpful and necessary to conduct a differentiated evaluation of the large range of relevant aspects. The following criteria need to be considered:

1. **Fulfilment of the German and EU climate targets**
   a. for the medium term (2030)
   b. for the long term (2050)
2. **European (and, if applicable, international) compatibility**
3. **Reliability and predictability of the price signal**
4. **Economic efficiency of emission reductions**
   a. from a static perspective
   b. from a dynamic perspective
5. **Adaptability, flexibility and challenges arising from setting the parameters inappropriately**
6. **Time needed for and administrative efforts of implementation**
7. **Distribution effects**
   a. competition effects for the economy
   b. social hardships
8. **Political implementation**
   a. legal admissibility and need for legislative changes
   b. political acceptance
   c. integration in the instrument mix

Evaluations based on these criteria naturally involve diverse challenges. These challenges stem in part from it only being possible to assess many aspects in the context of concrete options for developing parameters; these largely resist, therefore, abstract assessment. Other challenges arise from core economic and political beliefs which make evaluations subjective or categorizable according to certain schools of thought. In the following, the aim is to make these aspects transparent and accessible to political classification.

6. Central design characteristics of carbon pricing instruments

6.1 Incentives

6.1.1 Regulated sectors and uniformity of price signal

A first basic decision to be made when determining a pricing strategy for greenhouse gas emissions is what sectors should be subject to the instruments:

- without a doubt, carbon pricing is a central element for very price-sensitive sectors, e.g. the electricity sector and the energy-intensive sectors of industry;
- for the less price-sensitive sectors in which the emissions can be determined at a high quality, carbon pricing is a complementary instrument (also to limit rebound effects);
- for sectors in which the calculation of emissions involves very high uncertainties (agriculture, land use, land use change and forestry), the pricing of greenhouse gas emissions can only play a subordinate role.

The uniformity of the carbon price, i.e. whether all regulated economic subjects should be exposed to the same price signal, is a more crucial factor than the issue of what sectors are to be covered by carbon pricing strategies. This uniformity involves not only the formal uniformity of the price signal in the context of a specific pricing instrument, but also the uniformity resulting from the interaction of different carbon pricing instruments (e.g. carbon price emerging from an energy tax in addition to that of an emissions trading system).

Various designs are conceivable and have been proposed on the uniformity of carbon prices (SPC 2017; CAV 2017; r2b 2019; Agora EW 2018; RWIC 2019; MCC & PIK 2019):

- A first group of analyses proposes that a uniform price signal is created for all sectors at some point in the future; this uniform price signal would incorporate or replace all carbon pricing mechanisms (i.e. the shares from more comprehensive pricing mechanisms attributable to carbon pricing). Subsequently, all sectors would, for example, be integrated in the EU ETS and the shares of energy taxes attributable to carbon pricing would be abrogated or the current carbon pricing instruments would be replaced by a general carbon-based primary energy tax.

The most efficient solution in the medium and long term is to proceed based on the belief that a uniform carbon price signal leads to the most efficient solutions and is compatible with the objective of climate neutrality by 2050. If the belief is, in contrast, that a) emission reduction options have relatively narrow time windows in some sectors and sectoral emission reduction strategies are necessary; and b) very long-term developments are not, or only partly, considered in decisions by economic subjects, and c) there are serious behavioural or regulation-based barriers to implementing emission reduction measures, the use of an effectively uniform price signal is not advantageous from the perspective of dynamic efficiency. It would thus be unsuitable in such sectors as the central instrument of a transformation-oriented climate policy. Such a strategy would, in any case, require a great deal of time and procedural and political effort (above all with a view to the current minimum tax rates for the different energy sources), especially if the instruments are to be implemented beyond the national framework. Finally, carbon pricing instruments with cross-sectoral and effectively uniform carbon prices are likely to increase the distribution effects of carbon pricing instruments and increase the intensity of the necessary compensation measures.

- A second group of analyses proposes that effectively differentiated carbon price signals are used. One option here would be to keep the EU ETS and complement it with separate carbon pricing systems for the remaining sectors:
  - It has been proposed, for example, that the EU ETS is expanded and the current energy taxes retained (which are usually substantially different in terms of national and international carbon pricing). This kind of price differentiation (a historically determined price differentiation[8] resulting from largely arbitrary time frames) would be stronger, the weaker the current pricing instruments are supplemented by additional carbon price components. In turn, the stronger these additional carbon price components, the weaker the price differentiation resulting from continued use of the current system of energy taxes. Here, clear efficiency losses are to be expected for carbon pricing in the medium and long term. There are also crucial advantages, however: implementation takes significantly less time and involves less political effort. The problem of setting the necessary parameters inappropriately arises above all implicitly here (through price differentiation having emerged historically).
  - Historical price differentiation should be compared with strategies in which price differentiation results from sector-specific considerations (setting the time frame for emission reductions, stakeholder and barrier structures, etc.). Here, uniform carbon prices have been proposed for clusters with similar structural characteristics such as road transport, air transport and buildings (cluster-based uniform prices). This could be achieved by, for example, reducing distortions in the current system of energy taxation and supplementing

8 One example is the (ultimately arbitrary) approach tabled by various representatives in the Germany's debate that energy taxes should only be classified as implicit CO_2 pricing from 1999 when the German ecological tax reform came into force.

this system with additional carbon components (via specific mechanisms). It should be noted, however, that the time and the administrative and policy efforts needed to harmonize carbon prices are likely to be considerable; and the risk of setting the necessary parameters inappropriately is likely to be greater for differentiated carbon prices than for uniform carbon prices.

The decision about the uniformity of carbon prices and the concrete approach to price differentiation (comprehensive uniform prices or historically determined price differentiation or cluster-based uniform prices) should be substantiated and made explicit in all decisions about carbon pricing.

6.1.2 Carbon pricing instruments vs. emission trading systems

The design of carbon pricing instruments, emission trading systems and hybrid models plays an important role in debates about carbon pricing. A closer analysis enables the following approaches to be distinguished:

1. Pure carbon pricing instruments are predominantly implemented as taxes. They usually can be quite easily added to current systems of energy taxes and are therefore relatively simple to administrate. Specific forms of price control include price floors, price ceilings and fixed prices in emission trading systems (see below). A special situation arises for Germany here: the taxation of emissions, resources, and primary energy has not been possible under German constitutional law (due to how resources are distributed between the central government and the individual federal states). Fixed prices for emission allowances from emissions trading systems are also not legally admissible in Germany since a cap cannot limit the emission volume. Cross-border harmonization of a carbon-based energy tax is possible in principle (via the EU Energy Taxation Directive) but is probably quite time-consuming and requires substantial political effort. The stability and predictability of carbon prices generated with the carbon pricing system are comparatively large; however, dynamic adaptation (e.g. via paths of transparent price increases) requires a high degree of political capital and political reliability.
2. With (pure) emission trading systems (ETS), carbon price signals are generated by setting an emission cap and obliging certain economic subjects to surrender emission allowances as permission for certain activities (emissions, trade of fossil fuels, etc.) and by making it possible to trade these emission allowances. Emission trading systems are instruments of responsive carbon pricing, i.e. they generally lead to volatile prices. They are highly developed, complex and regulation-intensive instruments (which could even involve establishing a financial market authority), which require a great deal of time and administrative and political effort (Matthes 2019a). However, emission trading systems (at least in their pure form) offer a high degree of certainty that targets are met and the price increase dynamics via the cap are maintained. It should be pointed out that emission trading systems also serve as information-based instruments when they set long-term

caps: they give economic subjects a clear perspective of the future, especially in terms of the future compatibility of investment decisions.

Above all, two different variants of emission trading systems are currently being discussed in Germany:

a. A separate emissions trading system (sETS) could be created for carbon emissions from the combustion of fossil fuels not covered by the EU ETS. Here the central challenge is the time and the administrative efforts required to adapt this sETS to the EU ETS. Double regulations for installations already covered by the EU ETS have to be avoided: even if the importers and producers of fossil fuels are decided by the sETS (for which a permit requirement would have to be created and legally enforced for the wholesale trade of fuels), the fuel quantities already covered by the EU ETS can only be aligned on the final supplier level. Corresponding measurement, reporting and verification obligations would have to be created for several thousands of economic subjects. Creating a more far-reaching regulatory framework (e.g. a financial market authority) for emission allowances that are classified as securities is a substantial challenge since the rules could only be adjusted on EU level.
b. The other option is to expand the EU ETS to include additional sectors, which could be implemented either nationally or EU-wide. This approach could be implemented within the scope of the rules of the EU ETS. However, the extent to which an expansion of the EU ETS is permissible within the framework of the current EU ETS Directive – if it is to regulate not only the release of emis¬sions, but also putting fossil fuels on the market and trading them – is legally disputed. Even if it were legally permissible, there is still the question of whether the current rules of the EU ETS Directive are proving useful.[9] An expansion of the EU ETS would take considerable time and involve substantial legal, administrative and political efforts. Integrating sectors with comparatively high mitigation costs and/or low price sensitivities would also significantly increase the distribution effects of carbon pricing: according to first estimations, the price impacts of a unilateral expansion of the EU ETS are estimated at 5 to 15 €/t CO_2 in 2030; and a comprehensive expansion of the EU ETS at 45 €/t CO_2 (MCC & PIK 2019). Price impacts of the latter magnitude would make huge compensation measures necessary if distortions are to be avoided for the sectors currently covered by the EU ETS (i.e. electricity sector and energy-intensive industry) and in the relevant regions.

9 The current EU ETS Directive contains, among other things, regulations for allocating emission allowances intended for auctioning to the individual member states. If, for example, Germany were to integrate additional sectors in the EU ETS, 40 % to 80 % of the allowances auctioned (depending on the interpretation of the legal situation) would not be allocated to Germany but to other Member States along with the corresponding revenues (Matthes 2019a).

3. Hybrid systems are a possible alternative to pure carbon pricing instruments or pure emission trading systems. These can be implemented in diverse ways and can combine the corresponding advantages and disadvantages:
   a. emissions trading systems with explicit price floors and (if applicable) price ceilings (in contrast, an ETS with fixed prices would be classified as a pure pricing instrument);
   b. emissions trading systems introduced in addition to existing or adapted energy tax systems, i.e. they do not, or do not fully, replace them.

Since carbon pricing instruments and emission trading systems can, in principle, have the same effects if perfectly designed, the concrete challenges in implementation and the issues relating to uniformity of the carbon price and cross-border cooperation are especially important.

6.1.3 Harmonization with neighbouring countries and EU-wide instruments

Cross-border cooperation on carbon pricing is an important design criterion by reason of the political and economic framework of the EU and with a view to tapping efficiency gains and avoiding counterproductive rebound effects of integrated economic systems (e.g. for the electricity market).

Beyond these overarching aspects, some boundaries of action can be derived on an abstract level:

- for sectors with highly integrated markets (electricity sector, raw material industry, etc.), pure national carbon pricing instruments are highly problematic (Öko-Institut 2018 + 2019); this is especially the case for sectors and installations that are currently covered by the EU ETS;
- for sectors with potentially significant cross-border effects (e.g. so-called fuel tourism), different carbon prices are problematic at least in the medium term;
- especially for largely stationary energy consumption and emission sectors (above all the building sector), cross-border cooperation on carbon pricing is not strictly necessary.

With this differentiation in mind, approaches to cross-border cooperation can be classified as followed:

- EU-wide strategies are desirable, but take substantial time and legal, administrative and political effort to implement and manage, particularly if the carbon pricing strategy is based on effectively uniform carbon prices.
- Cross-border strategies in a «coalition of progressives» (France, the Netherlands, Scandinavia, etc.) take substantial time and legal, administrative and political effort to implement and manage, but less than for EU-wide harmonization in several sectors. Such strategies as, for example, a carbon floor price in the EU ETS seem helpful and promising. When such cooperation is not only declaimed but

is to be pursued in practice, it tends to be counterproductive to set national pricing systems strongly geared to German circumstances (e.g. a sETS).
- National carbon pricing instruments, both currently and in the future, are only useful in individual sectors (e.g. the building sector) or within certain time frames or price levels (e.g. with a view to the transport sector).

The different stages and perspectives of cross-border cooperation should therefore be a decisive criterion in all decisions to be taken on carbon pricing.

6.1.4 Need and legitimation of integrating carbon pricing in a broader policy mix

Carbon pricing can play an important role in the complex challenges of transforming national economies towards climate neutrality. Successful transformation nevertheless requires a more comprehensive policy mix:

- It is widely accepted that measures for strengthening innovation and developing infrastructure etc. are needed in any policy mix;
- The need for targeted regulatory or promotional measures (efficiency and emission standards, quotas, financing instruments, etc.) increases, a) the less price-sensitive, forward-looking or economically rational the sectors or subjects covered by carbon pricing are, b) the more uniform the carbon price signal is, and c) the greater the effect of price caps;
- The more the basic distortions in the (current) pricing systems are removed (fuel oil, coal or diesel privilege in energy taxation etc.), the less need there is for corresponding balancing mechanisms (bans or support measures relating to oil heating, etc.).

Carbon pricing instruments need to be clearly classified in this context (see also chapter 2):

- carbon pricing instruments as primary and major instruments (e.g. in the electricity and industrial sector);
- carbon pricing instruments as complementary instruments (e.g. in the building or transport sector);
- carbon pricing instruments as catch-all instruments (this also applies to hybrid carbon pricing instruments in which emissions trading ensures that the target is met but carbon pricing is the dominant strategy).

In order to have a sensible political debate about what constitutes a target-oriented and rational policy mix (i.e. beyond any decisions about instruments), the process of classifying carbon pricing instruments must be very transparent and above all explicit. This is especially true if emission trading systems are part of the policy mix and a discussion about why these systems need to interact with other instruments is necessary

(Öko-Institut 2010, IEA 2011). In the final analysis, the placement of carbon pricing strategies in the broader policy mix requires a substantial amount of political capital.

6.2 Redistributing revenue

6.2.1 Avoiding unacceptable economic hardships

Carbon pricing strategies inevitably lead to distribution effects. With very ambitious emission reduction targets, these distribution effects are larger, the more (effectively) uniform the carbon pricing. These effects include, *first* of all, aspects of competitive distortions:

- If companies of the same sector are subject to different pricing strategies (e.g. due to the size of installations or companies), competitive distortions arise. This is immediately apparent if the companies in question are subject to different pricing instruments or segments (EU ETS, sETS, carbon-based energy taxes). Uniform pricing systems can also give rise to such situations. If, for example, the EU ETS is extended to cover small industrial plants by including fuel importers or producers (who pass on the carbon costs in their selling prices), a small power plant would face the same carbon price as an installation already regulated by the EU ETS. The burden on the latter would largely be relieved through the free allocation of emission allowances; the burden of the smaller power plant, however, would not. This is where the need for compensation or adaptation measures arises.
- When carbon pricing systems have strong national characteristics, diverse compensation measures become necessary from the perspective of cross-border competition and due to the danger of displacement effects. Those affected range from energy-intensive industry to haulage companies. The compensation payments may be substantial: an analysis of the electricity price impacts of a carbon floor price introduced for electricity generation on the Central European electricity market shows that in 2030 between 16 % and 27 % of the additional revenues from the carbon floor price for electricity would have to be used to compensate electricity-intensive industries (Öko-Institut 2019).

The scope of corresponding compensation measures is limited in each case by EU laws on state aid.

A *second* category of measures to balance special economic hardships addresses social issues:

- Compensation measures geared to particularly low-income households are possible. This can be achieved either by expanding support given via the social security systems (rent subsidy, incorporation of the changes to actual electricity costs in social security systems etc.) or by using other redistribution mechanisms oriented to household income and social situation.

- Special adjustment assistance has been proposed for consumer groups subject to specific burdens, e.g. commuters and/or rural residents with limited access to infrastructure, etc. It is also possible to adjust current instruments (e.g. the commuter allowance). However, this is a highly contentious issue partly due to problematic incentive effects (e.g. urban sprawl).

The flexibility in designing measures in this area is very large, meaning that it will ultimately be a question of what the political priorities are.

6.2.2 Changing the financing structure of the energy system

A second approach to redistributing the additional revenues accrued via additional carbon pricing is to change the financing structure of the energy system:

- Several proposals use all income from carbon pricing to finance the transformation of the energy system. r2b (2019) shows that an effectively uniform carbon price of approx. 100 €/t CO_2 could assume the financing functions of the electricity and energy tax and surcharges (e.g. the surcharge applied via the German Renewable Energy Sources Act [EEG]).
- Several proposals are geared to reducing electricity costs with limited income from carbon pricing (via decreasing the electricity tax to the minimum level stipulated under EU law or by partially financing the EEG surcharge). In addition to relieving the burden on households and relevant segments of the economy (service sector and other segments that are not eligible for exemptions under tax or EEG surcharge rules), these approaches aim to promote transformation of the energy system, i.e. to improve the mitigation cost situation and thereby also increase the efficiency of transformation.

Some facets of these measures for changing how the energy system is financed can also relieve the burden on low-income households. Due to the large population of changes, however, these effects are much smaller than those achieved with targeted measures.

6.2.3 Targeted financing of climate protection measures

In the context of comprehensive packages of measures for ambitious climate protection policies, new financing instruments are becoming necessary in many areas (direct support programs, tax advantages, tax benefits etc.). For example, the income from auctioning emission allowances of the EU ETS in Germany is transferred in its entirety to the Energy and Climate Fund, which finances a wide variety and range of compensation measures for electricity intensive industry and support measures.

6.2.4 Acceptance-based approaches to redistributing revenue

With a view to the political acceptance of carbon pricing approaches, broad redistribution strategies for the total population played an important role in the discussions in Germany in 2018/2019. A central paradigm here is Switzerland's per-capita redistribution of a large portion of the income from carbon pricing. The central expectation with per-capita redistribution strategies is that they significantly increase the political acceptance of carbon pricing. Whether and to what extent this would also apply for Germany will only become clear in the course of implementation. The following aspects should nevertheless be considered in an ex-ante evaluation:

- the volumes of per-capita remuneration are limited and typically amount to approx. € 100 per resident and year;
- redistribution approaches with a per-capita basis are not suitable for compensating distribution effects that disadvantage (small) commercial enterprises; the incorporation of companies is methodologically difficult and faces substantial challenges due to EU regulations on state aid;
- in divergence from the Swiss approach, it is possible not to add the per-capita redistribution of revenues from carbon pricing to an existing administrative system (in Switzerland: general health insurance); an entirely new administrative system would have to be developed; even if technically possible, the administrative costs would be substantial – and could prove to be (highly) problematic in terms of political acceptance;
- first experiences gathered with stakeholder processes show that real-world acceptance of *flat-rate* redistribution mechanisms is by no means straightforward (IASS 2019).

Finally, acceptance-based approaches to redistributing revenue are an intrinsic consequence of core political beliefs and judgements. When making decisions about them, it should always be borne in mind that other redistribution ¬options (e.g. changing how the energy system is financed) can substantially improve the effectiveness and efficiency of carbon pricing strategies and decrease the distribution effects that come about during transformation.

7. Classifying current decisions on carbon pricing for Germany

Following intense discussions within Germany's grand coalition and between the coalition and the opposition, the climate cabinet of the German government decided on the key parameters of the Climate Action Programme 2030 on 20 September 2019. This included the proposal for a national emissions trading system (nETS). The German government approved a bill on 23 October 2019, which was adopted by the Bundestag with slight changes on 15 November 2019. The German Fuel Emissions Trading Act (BEHG), which does not require approval, formed part of the negotiations of the Mediation Committee between the Bundesrat and the Bundestag on the measures of the Climate Action Programme 2030 in tax law which require approval. As a result of these negotiations, and ultimately as a compromise between CDU/CSU, SPD and Bündnis 90/The Greens, it was agreed that the BEHG Act would have to be adapted again in spring 2020 with respect to the carbon pricing strategies. A portion of the compensation-based changes adopted by the Mediation Committee were adopted by resolutions of the Bundestag and Bundesrat on 19 and 20 December 2019 (see below).

The carbon pricing system adopted by Germany consists of the following key points:

- A national emissions trading system is to be created for carbon emissions not covered by the EU ETS. This does not regulate carbon emissions released into the atmosphere, but rather the trading of fuels whose combustion leads to such emissions. Those subject to the system are not, however, the importers or producers of fossil fuels, but rather the companies obliged to transfer the energy tax under German tax law, i.e. the final suppliers of natural gas and coal and the wholesale suppliers of petroleum products (4,000 to 6,000 companies overall). This large number of obligated companies (and the correspondingly high transaction costs) is evidently due to the system taking effect in 2021; this short time frame made it possible to avoid the necessary and time-consuming data collection by simply accessing current energy tax data (irrespective of the quality of the registration data available for energy tax).
- The system is to be introduced in 4 phases:
  - in the *first phase* (2021 and 2022), only the standard natural gas and petroleum products (petrol, fuel oil, liquid gases) are regulated and there is no trade of allowances issued at a fixed price;

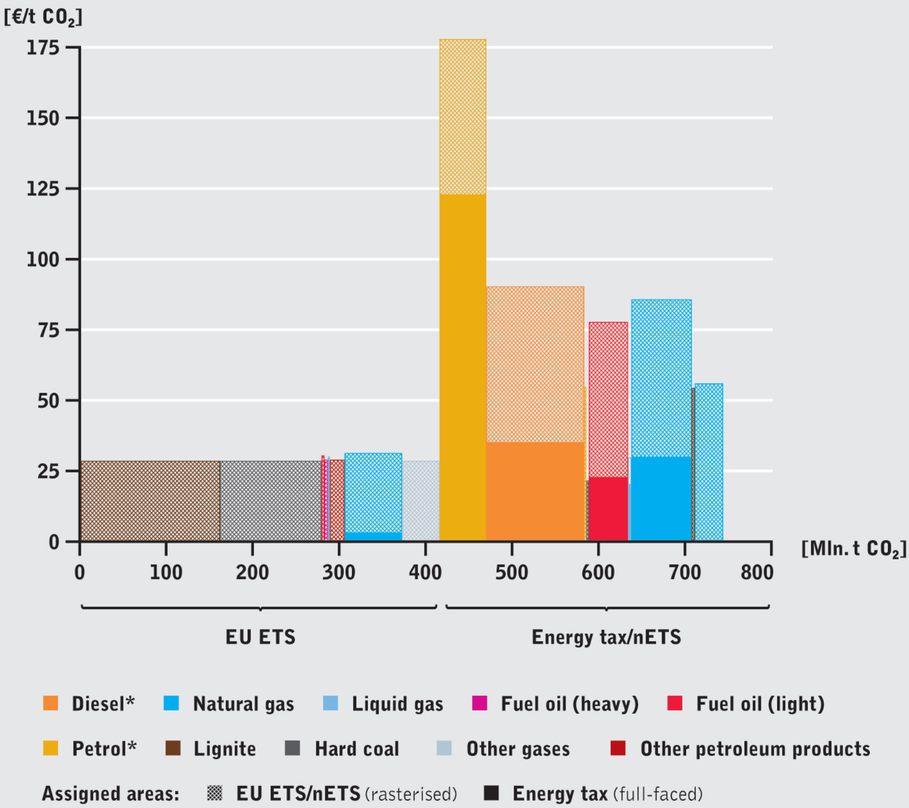
- in the *second phase* (2023–2025), other fossil fuels are included (excluding jet fuel); there continues to be no trade in allowances issued at a fixed price;
- in the *third phase* (2026) the transition to trading allowances takes place, with prices regulated by a price corridor;
- for the *fourth phase* (from 2027), it will be determined in 2025 whether a price corridor continues to apply or whether pricing is to be carried out entirely through the trade in allowances.

- For the different phases, the following price parameters have been set; the carbon prices do not replace current energy taxes (as several proposals conceived), but are in addition to them:
  - for 2021, the fixed price was originally 10 €/t CO_2 and was increased to 25 €/t CO_2 in the compromise of the Mediation Committee;
  - for 2022, the fixed price was originally 20 €/t CO_2 and was increased to 30 €/t CO_2 in the compromise of the Mediation Committee;
  - for 2023, the fixed price was originally 25 €/t CO_2 and was increased to 35 €/t CO_2 in the compromise of the Mediation Committee;
  - for 2024, the fixed price was originally 30 €/t CO_2 and was increased to 45 €/t CO_2 in the compromise of the Mediation Committee;
  - for 2025, the fixed price was originally 35 €/t CO_2 and was increased to 55 €/t CO_2 in the compromise of the Mediation Committee;
  - in 2026 originally a price corridor of 35 to 60 €/t CO_2, after the compromise in the Mediation Committee 55 to 65 €/t CO_2 (for demand conceivably to exceed supply, prices of 60 to 65 €/t CO_2 would have to apply).

Figure 5 provides an overview of direct and indirect carbon pricing in Germany for 2025:

- To ensure the availability of the allowance quantities needed in the fixed price and price corridor phase, allowance quantities are available via the EU flexible mechanisms, which predominantly means buying them from other countries;
- The allowances surrendered in 2021 to 2025 cannot be used in later years (i.e. no banking permitted).
- The boundary between nETS and EU ETS can be upheld either by reducing the obligation to surrender allowances (and the burden of proof via the trade chain) or by introducing financial compensation for companies subject to double regulation. The concrete procedures and requirements for this are still unclear and are to be specified in upcoming regulations.
- The income from the nETS is to be used to finance a wide range of measures. The following mechanisms are to be used to compensate the costs arising from nETS and to avoid related hardships:

Figure 5: Explicit and implicit carbon taxation in Germany, 2025



*adjusted for infrastructure financing
Source: Own calculations, status 2019; own chart.

- Companies with fuel costs that constitute over 20 % of the total business costs (including the costs from the nETS) or with additional costs from the nETS that amount to over 20 % of the gross value added are to receive financial compensation (the volume of these compensation payments cannot yet be specified). In order to avoid social hardships among housing benefit recipients, the housing benefit is to be increased by 10 %. Based on the housing benefit payments for 2018 which totaled € 1.045 billion (548,000 households), the increase in volume amounts to approx. € 100 million.
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- The allowance for long-distance commuters is to be increased by 5 ct/km to 35 ct/km from 2021 to 2023 for distances of 21 kilometres or more; under the compromise of the Mediation Committee, the allowance was increased by a further 3 ct/km to 38 ct/km from 2024 to 2026. Based on the current commuter allowance payments (approx. €4 billion per year), the total annual compensation amounts to €670 million for 2021 to 2023 and €1.07 billion for 2024 to 2026.
- The EEG surcharge was originally to be increased by 0.25 ct/kWh in 2021, by 0.5 ct/kWh in 2022 and 0.625 ct/kWh in 2023; in 2024 and 2025 it was to follow the path of increase for fixed prices in the nETS, i.e. 0.75 and 0.875 ct/kWh. Under the compromise of the Mediation Committee, the additional income minus the additional costs for the commuter allowance is to be used in full to decrease the EEG surcharge; as a result, by 2025 this surcharge is to be decreased by approx. 3 ct/kWh (i.e. approx. € 5 billion annually), which could reduce the EEG surcharge for non-privileged final consumers by around 40 %.

The carbon pricing system established for Germany can be classified as follows:

- In carbon pricing terms, the system cannot really be described as a major instrument of German climate policy, at least not up to 2026; instead, it can be understood as a complementary instrument geared to raising income (approx. €8 billion to €19 billion annually between 2021 and 2026) to finance different instruments;
- Due to the very late decision on whether to continue or abolish the price corridor (in 2025 for the period of 2027 onwards), robust investment security cannot be assured; investors can only use the upper price for 2026 as a basis (ca. 65 €/t CO_2);
- The system does not expunge the basic distortions of the German energy tax system. The privileges for diesel (approx. 100 €/t CO_2 compared to petrol), coal (approx. 26.50 €/t CO_2 compared to natural gas) and fuel oil (approx. 7 €/t CO_2 compared to natural gas) remain in place;
- Linkage with or a merger into the EU ETS is barely conceivable without generating distortions in the sectors currently covered by the EU ETS (possibly a huge increase in allowance prices) and in the sectors covered by the nETS (possibly a huge decrease in allowance prices); with this in mind and since the current energy tax system is being retained and the new system added to it, the implicit decision has been made to have different carbon prices;
- Since the system is to be added to the very specific German energy tax system (predominantly to enable quick implementation) and due to double regulations in relation to the EU ETS, it is highly unlikely that the nETS can be combined with cross-border cooperation (in a «coalition of progressives» or through the EU legal framework) without fundamental changes;
- Following the compromise of the Mediation Committee, approx. a third of the expected income is designated for electricity cost reductions (for households, the service sector and industrial companies not privileged under the EEG), about 7 % for the commuter allowance and about 1 % for increasing housing benefit; less

than half of the income from the nETS thus serves to compensate private consumer costs and the economy and to finance the energy system;
- Primarily due to the very long period with fixed prices and without an effective cap on emission rights, the legal admissibility of the nETS based on the German Fuel Emissions Trading Act (BEHG) has been disputed and, in view of the very large number of regulated companies, will almost certainly be subject to judicial review through the official channels.

By the mid-2020s at the latest it will be apparent whether and to what extent it is possible for the nETS to develop as an effective instrument in the long term or whether it must be fundamentally redesigned for legal reasons or to facilitate (meaningful and necessary) cross-border cooperation.

8. Synthesis, conclusions and outlook

The concrete design of carbon pricing systems is a complex and demanding task for five reasons in particular:

- it depends strongly on the level of ambition of climate protection policy (the necessity of having strong parallel transformation processes in relatively short time frames or significantly longer adaptation processes with high intertemporal flexibilities);
- it depends strongly on basic economic convictions (the appropriateness of uniform carbon prices and the maturity of market-based price signals and their anticipation);
- it depends strongly on current carbon pricing instruments, especially energy taxes (greenfield vs. brownfield introduction of a carbon pricing instrument), not only in the respective country, but also with a view to possible cross-border cooperation;
- it depends strongly on the intended role of carbon pricing in the energy and climate policy mix (major or complementary instrument or primarily as a means of raising income); this inevitably includes the necessary price levels and trends and the associated uncertainties;
- it depends strongly on what the priorities in redistributing the income from carbon pricing systems are (social acceptance, decreasing social and/or business-related hardships, changing how the energy system is financed or raising revenue for other purposes).

Finally, with a view to the architecture of carbon pricing systems, it makes more sense to have clear and transparent discussions and decisions on these basic (regulatory) issues than to start by focusing on detailed design issues and entering into the necessary political negotiations with prior arrangements (Matthes 2019b).

Table 2: Evaluation of the structural design of different carbon pricing strategies

	Pure carbon pricing			Pure ETS		Hybrid models		
	Effectively uniform prices	Historic price difference	Uniform cluster prices	Effectively uniform prices	Uniform cluster prices	Effectively uniform prices	Hist. price diff.	Uniform cluster prices
1. Achievement of DE and EU climate targets								
1a.) for medium term 2030	++	–	++	o	o	++	+	++
1b.) for long term 2050	+	o	++	++/–*	++	++	+	++
2. European (and if relevant, international) compatibility	– –	++	–	– –	– –	– –	+	o
3. Reliability and predict-ability of price signal	++	++	++	o	o	+	+	+
4. Economic efficiency of emission reduction								
4a.) from static perspective	++	o	+	++	+	+	o	+
4b.) from dynamic perspective	++/–*	+	–/++*	++/–*	–/++*	+	+	+
5. Adaptability, flexibility	++	++	++	o	o	+	+	+
6. Avoiding inappropriate setting of parameters	o	o	o	o	o	+	+	+
7. Time and administrative efforts for implementation	– –	++	o	– –	– –	–	+	o
8. Distribution effects	– –	o	+	– –	+	– –	o	+

9. Political implementation								
9a.) legal admissibility or need to make changes	–**	++	o**	–**	o**	–**	+**	o**
9b.) political acceptance	o	o	o	o	o	o	o	o
9c.) integration in instrument mix	o	–	+	o	++	+	+	++

* classification strongly dependent on basic economic beliefs,
** strongly dependent on degree of cross-border cooperation.
Source: Author's own.

Table 2 provides a summary of the evaluation of different kinds of carbon pricing systems. It shows several basic connections between the issues detailed above:

- the longer the time frame of the emission reduction targets and the greater the focus on robust target achievement (above all by means of the carbon pricing instrument), the greater the preference for emission trading systems;
- Emission trading systems require greater administrative and political efforts, which can only be adapted or updated quickly to a limited extent;
- the reliability and predictability of the price signal is and remains a central advantage of pure carbon pricing models;
- the classification of the economic efficiency of different carbon pricing strategies relies extensively on basic economic beliefs, especially when static efficiency (costs of emission reduction in a relatively narrow time frame) and dynamic efficiency (costs of emission reduction over long time frames, above all for ambitious climate protection paths) are considered;
- for all carbon pricing designs, European and international compatibility is a significant challenge; this applies to all forms of carbon pricing, from models that cover the entire economy to those for individual sectors based on uniform carbon price signals.

The overview also shows, however, that the different carbon pricing strategies are only rarely implemented in their pure form:

- This is particularly true of the uniformity of the carbon prices (the variants of «effectively uniform prices» for the economy and the variants of «uniform cluster prices» for different sectors in Table 2) if historically developed energy tax systems are not replaced or harmonized during implementation of carbon pricing («historical price differences» variants in Table 2);
- Pure emission trading systems can always only generate a uniform price; sectoral carbon prices can only arise through separate emission trading systems.

In the context of the different advantages and disadvantages of pure emission trading systems and pure carbon pricing systems, hybrid models prove to be promising:

- Hybrid models with limited flexibility (and ultimately limited probability of implementation) are emission trading systems that replace existing energy tax systems and are supplemented by price floors and in some cases also price ceilings;
- Hybrid models with high flexibility (and high probability of implementation) combine energy or carbon taxes and emission trading systems; the energy tax instruments should be harmonized at least intrasectorally from a carbon perspective; this intrasectoral harmonization can be varied over time.

Against this background, the example of the German nETS can and must serve as a negative example of the far-reaching consequences (complexity, international compatibility, investment and legal certainty) that can result from prior arrangements made largely without reflection (unilateral exclusion of a tax route for implementing carbon pricing and concurrently the commitment to very short-term implementing periods).

This is especially the case with a view to the upcoming changes of the carbon pricing landscape through the European Green Deal (EC 2019a; EC 2019b):

- in June 2021, a proposed reform of the EU Emissions Trading Directive is to be presented, which increases of the emission reduction target for 2030 to 50 %/55 % and includes the target of climate neutrality by 2050;
- in the course of 2021, a proposal for carbon border adaptation mechanisms is to be made for selected sectors (probably steel, cement, chemicals, etc.), which could have substantial implications for the design of the EU ETS (at least partial replacement of free allocation to protect raw material industries from carbon leakage); and
- a proposed reform of the EU Energy Taxation Directive is also to be presented in June 2021.

In view of these upcoming changes in EU law, the following challenges arise for carbon pricing:

- It should be a top priority to avoid that the introduction of the German nETS impedes or thwarts meaningful reform of the EU Energy Taxation Directive, which is also a central requirement for creating harmonized hybrid instruments;
- the discussion about expanding the EU ETS, its requirements and implications, and the creation of possible hybrid instruments (floor price for the current EU ETS or a combination of EU ETS and adapted or harmonized energy taxes in sectors currently not covered by the EU ETS) must be conducted very carefully and at a very early stage to avoid ad hoc decisions that are highly problematic.

A general revision of the carbon pricing system established for Germany (with a view to pricing, incentives and redistribution of revenues) makes sense from a national perspective and may become necessary for legal reasons. Its revision will also be necessary due to the changes in the framework legislation of the EU which will take effect by the mid-2020s at the latest. The debates and decisions needed in these contexts must be conducted comprehensively and at an early stage in Germany and with EU partners. If carbon pricing is to play an important role in the policy mix for achieving climate neutrality by 2050, a situation like the one in Germany must not arise in which blockades, prior arrangements, selective analyses, lack of discussion with neighbouring countries and overhasty decisions have brought about a partly problematic and in the long term probably not very robust carbon pricing mechanism like the nETS.

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ECOLOGY
VOLUME 48

Pricing carbon

An important instrument of ambitious climate policy

The topic of carbon pricing is experiencing a renaissance in Germany and internationally. A sophisticated and reality-based discussion is needed about the means and ways of enabling a stronger role for carbon pricing in climate policy.

In this study, the climate and energy expert Felix Chr. Matthes analyzes the relevant elements of a carbon pricing strategy. He provides an overview of design criteria and mechanisms.

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