Integrating agriculture into carbon pricing

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Abstract

In this working paper we examine whether it would be possible and reasonable to integrate the agricultural sector into CO_2 pricing.

CO_2 pricing has been practiced in Europe **for years**. The EU Emissions Trading System (ETS) regulates emissions from approximately 12,000 large-scale plants in the energy and energy-intensive industries, as well as emissions from intra-European aviation. The ETS thus comprises almost half of Europe's greenhouse gas emissions. The politically defined **mitigation targets are achieved in the ETS** area (albeit with the participation of various other climate policy instruments), whereas they have so far been missed in the non-ETS area.

In Autumn 2019, the German federal government presented a climate protection law that provides a comprehensive set of measures. One of the most important measures here is the **inclusion of fossil heating and fuel in emissions trading**. Initially, only a nationally-based trading system is planned for these sectors, and CO_2 prices are to be kept low in the initial phase. The long-term effect of this system change can, however, be considerable: approximately 85 percent of Germany's greenhouse gas emissions will soon be included in emission trading. This means that emissions can be gradually reduced along an initially agreed upon reduction path without the policymakers constantly having to fight for new decisions.

Besides certain emissions from industrial processes, emission trading then only **misses** the areas of **agriculture and land use**. Against this background, it is the aim of this working paper to comprehensively examine whether these areas could also be integrated.

First, based on economic theory and political experience, we show that the **advantages of CO_2 pricing** compared to other climate policy options are the following: (1) Emission reduction targets are achieved along the politically-determined savings path. (2) All companies and all consumers are supplied with scarcity signals via prices, so that all people constantly participate in the “reduction and innovation competition”. (3) Emission reductions ultimately take place where they cause the lowest economic costs. (4) The system is based on market principles and is therefore particularly well-connected to a globally coordinated climate mitigation policy.

However, **two major challenges** can be derived from the theoretical discussion, which can make it more difficult to integrate agriculture and land use into emissions trading: (1) Agricultural emissions come from many diffuse sources. It is therefore not easy to find starting points for climate mitigation measures that can be **administered legally and with reasonable effort**. (2) Agricultural and forestry products are traded internationally on a large scale. CO_2 pricing in Europe can therefore lead to emissions-intensive production branches being relocated to third countries and thus lead to higher greenhouse gas emissions elsewhere (**leakage effects**).

Theoretically, the best policy concept would be to use the "**individual greenhouse gas balance**" of each individual farm (i.e., an aggregate of all farm emissions minus the long-term carbon sequestration on its land) as a control parameter. In practice, however, it is **not possible** to determine the data required for the many farms in a justifiable and reasonable manner.

Therefore, in the further course of the article we will investigate how the different groups of greenhouse gases (nitrous oxide, methane, carbon dioxide) could be integrated into CO_2 pricing.

Nitrous oxide

The nitrous oxide emissions cannot be sanctioned directly, but only indirectly, by including the amount of reactive nitrogen compounds intoCO_2 pricing. There are **two options** for this that differ significantly in terms of "political architecture":

- The first option is to determine the **annual nitrogen surplus for each farm**. For example, this could be designed in such a way that emission certificates are issued free of charge for a small surplus per hectare. Companies that remain below this threshold can sell the certificates that are not required, and companies with particularly high nitrogen surpluses have to buy certificates. However, this policy option requires that the authorities keep an **area-wide nutrient register** and compare the information provided by the companies with information from the feed and fertilizer trade. If politicians shy away from this comprehensive control system, only the second option remains.
- With the second option, politics start with "**bottlenecks**". The case of **mineral nitrogen** offers good conditions for this: politicians could oblige the manageable number of fertilizer factories and importers who place mineral nitrogen on the market to buy emission rights for every ton of mineral fertilizer. In addition, the **feed trade** would also have to be included, since a lot of nitrogen also reaches the agricultural sector in this way. Here, however, administration is more difficult than with mineral nitrogen, because only part of the feed is sold by large companies (bottleneck problem). Alternatively, the possibility of considering the number of animals of a certain animal species (as a proxy for the nutrient consumption) as the subject of CO_2 pricing could be considered, but this option also has its weaknesses.

For CO_2 prices of 25 or 100 € / t, we examined the example of the regulation effect of CO_2 pricing. For mineral nitrogen, it can be shown that a price of 100 € / t CO_2 already has considerable climate mitigation effects. The nitrogen price doubles, which triggers a 15 percent reduction in nitrogen use in intensive wheat cultivation. This reduces yields by around 3 percent, while the nitrogen surplus is almost halved. Beyond this individual case, it should also be noted: The integration of nitrogen into CO_2 pricing mobilizes considerable efficiency reserves in nitrogen use, so that the climate policy goals can be achieved with relatively little production loss in agriculture.

Methane

Methane emissions from agriculture come mainly from enteric fermentation of ruminants and the storage of manure.

- The emissions from the **storage of manure** can be significantly reduced through technical measures. We assume that the investment support will enable farmers to be able to make investments required in the coming years and that regulatory law will gradually be adapted as the process progresses. Then, there is no need for CO_2 pricing.
- In the case of **ruminant production**, integration of CO_2 pricing is in principle possible and reasonable. For the time being, this can only be implemented by setting standard values for the emissions per animal for the individual animal species. Farmers would then have an incentive to reduce animal production and sell certificates on the carbon market.

The expected decline in ruminant husbandry in a **closed economy** would lead to rising prices for dairy products as well as beef and sheep meat and, as a result, cause the consumption of these products to decrease. This effect would be noticeable at a CO_2 price of 100 € / t, because this price increases the production costs for beef and milk at the farm gate by around 15%. With **open borders**, however, the effect is quite different: consumer prices hardly rise because imports compensate for the decline in domestic production. With prices almost unchanged, consumption hardly changes. Ultimately, the main effect is that production (and the associated emission) is relocated to countries where there is no CO_2 pricing (leakage).

What conclusion can be drawn from this for climate policy? In a **“national CO_2 pricing” scenario**, Germany should only integrate methane emissions from ruminant husbandry in the system if the EU Commission ensures that all member states comply with their reduction commitments in the non-ETS area. In this case, relocations of production can certainly take place within the EU, but they are not to be regarded as **leakage**, because those Member States that grow their cattle stock then ensure the emission reduction elsewhere in their economy. In a **scenario “EU-wide CO_2 pricing”**, leakage within the EU is excluded anyway, since all companies are faced with the same CO_2 price.

In **both scenarios**, however, the inclusion of ruminant husbandry can only have the desired climate policy impact if the **existing tariff protection for milk products and beef can be kept at a high level or if a standard CO_2 price of such import products to the EU is introduced at external borders**. This external protection ensures that (a) the increased production costs (due to the CO_2 price) are passed on to consumer prices (consequence: decrease in consumption) and (b) the domestic CO_2 price does not lead to a displacement of production abroad (consequence: no leakage).

This raises the question whether **external protection** is absolutely necessary **or** whether politicians can also achieve their climate policy goals by increasing the **consumer taxes** on milk and ruminant meat. The answer is: consumer taxes certainly work in the desired direction in terms of climate policy, but they can only partially avoid leakage (as a result of European CO_2 pricing). For example, a doubling of beef production costs (as a result of a very high CO_2 price) would largely displace beef fattening at overseas locations, while domestic beef consumption would still be considerable even if the price doubled.

Carbon Dioxide

Most of the agricultural sector's carbon dioxide emissions come from **drained peat soils**. Such soils currently make up **about 7 percent** of our agricultural area (concentrated in a few regions) and they cause 4 percent of all greenhouse gas emissions in Germany. These emissions can be integrated into a trading system by issuing emission certificates to the landowners. They can then decide whether to continue farming on their land or to rewet it. In the case of rewetting, average annual emissions of 20 t CO_2 / ha are avoided, so that with a CO_2 price of 100 € / t CO_2, the annual gross revenues are 2,000 € / ha. Even after substracting the rewetting costs, this still offers a **high incentive to promote rewetting** at many locations.

If politicians want to pursue this climate policy line further, they will have **three areas to work on**:

- Politicians will have to determine until which **target year** landowners receive **free certificates** in the event of rewetting and how this can be contractually guaranteed. An "eternal" provision of free certificates is probably out of the question, as this would contradict the polluter-pays principle. Conversely, an all too short period of time would amount to expropriation of the affected areas.
- Politicians will be faced with the question whether additional regulations are required to **balance different interests** within the regions concerned. In particular: What should be done if a large majority of the landowners want to rewet but individual landowners are against it? Do regulations need to be found to protect active tenant farmers?
- Politicians will also be faced with the question of what impacts widespread rewetting has on the regional economy and regional social structure? Since peat soils are concentrated in a few regions, but climate mitigation benefits all citizens, surely **supra-regional financial equalization** will also be discussed here.

Carbon storage in mineral soils also offers great climate protection potential, but this is very **difficult to tap** in emissions trading. For this it would be necessary to either measure the humus content of all agricultural areas in Germany at short intervals in order to have a pricing basis for each area, or to carry out a comprehensive recording of all biomass flows in an officially managed bio-mass register. Only then could the increases or decreases be sanctioned by CO_2 pricing. However, such scenarios are not realistic in the short and medium term.

As easy-to-measure **substitute parameters** for long-term carbon sequestration on mineral soils, (a) grassland use and (b) afforestation come into consideration. It can be assumed that the carbon sequestration when **converting arable land to grassland** averages 3.2 t CO_2 / ha and year (over a period of 20 years), and when **converting arable land to forest** it averages 6.4 t CO_2 / ha and year

(over a period of 75 years). Since both the annual storage capacity and the accumulation period can vary greatly from location to location, climate mitigation policy might have to use site-specific values here. In view of the above-mentioned average magnitudes, it is already becoming clear that with a CO_2 price of 100 € / t, annual climate mitigation revenues arise that offer a considerable economic incentive for afforestation, particularly in extensive agricultural regions.

This raises the question whether politicians should let **afforestation increase unlimitedly**. It should be borne in mind that the afforested area is withdrawn from food production, which, with unchanged food consumption, leads to a shift in agricultural production and the associated emissions abroad. Although this improves the German greenhouse gas balance, it does not improve the global greenhouse gas balance (leakage). Therefore, EU policy would have to supplement its CO_2 pricing with accompanying measures, as long as global CO_2 pricing has not yet been implemented:

- One option is to establish protection at the EU's external borders against biomass imports that have not been CO_2 -priced in their countries of origin. This affects both food and bioenergy sources. It is obvious that trade policy conflicts can arise here. The discourse on the “Green Deal” by the EU Commission already indicates how difficult it is for “real politics” to assign climate policy just as high importance as trade policy in case of conflicting goals.
- If trade policies cannot make imports more expensive, politicians would have to limit the afforestation incentives that result from CO_2 pricing through quantitative restrictions. For example, the integration of afforestation into CO_2 pricing could only be permitted for a (politically determined) number of hectares. The better the EU manages to limit food consumption and food losses in the EU, the higher this “afforestation rate” could be.

Overall conclusion

A cross-sectoral and cross-regional emission trading system is a suitable concept in order to (a) effectively and efficiently achieve the climate mitigation goals and (b) to quickly establish an exemplary, globally connectable “climate policy architecture” in the EU.

The integration of agriculture and land use into this emissions trading poses special challenges, but is still possible. From an agricultural perspective, early involvement would be advantageous for three reasons: (1) It can help shape the political architecture. (2) It can use the market economy concept to generate climate protection revenues or, if necessary, acquire higher emission rights. (3) There is much greater planning security. If the agricultural sector is now left out, it can be expected that it will not achieve the mitigation targets that have already been set politically. In this case, the Climate Protection Act provides that new immediate programs for the agricultural sector must be installed at short notice. It is then very likely that these programs will again contain numerous new detailed regulations. That would not be the best framework for operational farm management.

Since climate mitigation is a global challenge, cross-sector CO_2 pricing should be expanded worldwide as soon as possible. Initially, however, there will only be national or EU-wide emissions trading. With rising CO_2 prices, there is an even greater risk of leakage. In order to contain this risk, the EU's climate mitigation policy must be supplemented by external protection that makes “non- CO_2 -priced” imported goods from countries with no binding and ambitious climate targets more expensive. Otherwise, there will be production relocations on a global scale that will not produce any climate policy benefits.

The issue of “external protection” is becoming acute as a result of CO_2 pricing, regardless of whether policymakers decide for or against the integration of the agricultural sector into emission trading. The CO_2 pricing in the transport and heating sectors, which has meanwhile started, will lead to ever higher CO_2 prices, which means that EU agriculture will produce more and more bioenergy and international trade will also send ever larger amounts of bioenergy to the EU. At some point, this development overwhelms the adaptability of the global agricultural economy and is counterproductive in terms of climate policy.

When analyzing the various design options for CO_2 pricing, we were faced several times with the question whether climate policy should not also directly confront consumers of food with changed price signals. With methane emissions, for example, it is evident that the main burden of the adjustment must lie with the consumers, and it will take a long time for our suggestions to be implemented before these signals arrive there via the detour “EU-wide CO_2 pricing, external protection, price increase”. However, we recommend that the highest priority be built on the establishment of a climate policy system that consistently implements the “Paris architecture” (source group and territorial principle), which is convincing due to its market economy power, and which is therefore spread internationally as quickly as possible.

Another question arises whether it would not be appropriate to abolish, among other things, the VAT reduction for meat and milk products as part of a comprehensive ecological tax reform. That would be advantageous in terms of climate policy. In national and international communication of such a reform, however, it should be strictly ensured that this is a tax reform with positive climate policy side effects, but not the integration of systematic CO_2 pricing at the consumer level.

Keywords: Climate change mitigation, agriculture, CO_2 pricing, certificate trading, nitrogen, methane, peat soils

Content

List of figures

1 Introduction

In Autumn 2019, the German federal government and the Bundestag (German Parliament) made important climate political decisions. The intensive discussions in advance showed that Germany's climate mitigation policy is facing a fundamental political course:

- Should the reduction targets set in the 2050 Climate Protection Plan be addressed by establishing a large number of different regulatory and promotional instruments for different emissions sectors?
- Or is German politics developing a climate policy market instrument "from a single source", which gives all economic operators the same economic incentive through a uniform CO_2 price to reduce CO_2 emissions or to store carbon in the long term?

The word "CO_2 pricing" plays a central role in this fundamental debate. The term is sufficiently vague that supporters of both climate policy "architectures" can identify with it, and yet it gives a basic direction. CO_2 emissions should receive a "price" so that companies and consumers can permanently feel the climate-damaging effects of their actions and thus make their actions more climate-friendly:

- Anyone who emits CO_2 receives an economic incentive to reduce these emissions.
- Those who use products whose production has caused CO_2 emissions are given an economic incentive to redirect their consumption to more climate-friendly products.
- Anyone who stores CO_2 in the long term receives an economic incentive to expand this climate-friendly activity.

For the supporters of the market economy solution "from a single source", the term CO_2 pricing is linked to another important message. The "price" signals the scarcity of a good in the market economy. Only if all economic operators receive this one shortage signal in an unadulterated manner it will be possible to produce the scarce good at the most suitable place in the economy with the least possible effort. This ubiquitous control function of price is a major reason why the market economy is more efficient than the state planned economy. For climate policy, this means: There should be a uniform CO_2 price - possibly as part of a gradual transition process - because this is the only way to harness the full potential of the economy for climate protection and to reduce emissions with the lowest possible CO_2 mitigation costs.

The German federal government has now agreed on a compromise with the Climate Protection Act: on the one hand, it wants to implement a large number of sector-specific individual measures, and on the other hand, it is also gradually establishing a cross-sector national emissions trading system. This national trading system is intended to complement the existing EU emissions trading system ETS. In the ETS, the emissions from approx. 12,000 large-scale plants in the energy and energy-intensive industries are already regulated at the European level, as are the emissions from intra-European aviation. The supplementary national emissions trading system intends to regulate all emissions from the areas of heat and transport. There are indications that in the long term (a) the aim is to extend this system to the whole of Europe and (b) to subsequently merge the two emissions trading systems.

The hitherto plans provide for the agriculture sector not to be integrated into national emissions trading (exception: energy-related emissions), and neither for land use, land use change and forestry (LULUCF).

However, the faster the rest of the climate policy should develop in the direction of "climate policy from a single source" and "uniform CO_2 price", the more the question arises of whether the agricultural sector and LULUCF cannot also be integrated into the cross-sectoral policy concept. Around 7% of Germany's greenhouse gas emissions currently come from agriculture. A further 4% of the emissions are attributable to the agricultural use of drained peat soils. In contrast, the forest acts as a carbon store; its annual additional storage capacity was previously around 7 percent of Germany's total emissions.

The aim of this article is to examine the integration of the agricultural sector in concepts of CO_2 pricing. This is done in two steps:

- First, from an economic point of view, it is shown what advantages CO_2 pricing offers, which challenges arise in the specific design and how different solution options can be assessed. This sets up the framework in which CO_2 prices for the agricultural sector could be integrated.
- Subsequently, for the most important greenhouse gas emissions in agriculture, it is examined how they could be integrated into emissions trading or a CO_2 tax. This leads to different scenarios, and the expected economic consequences are roughly estimated for each scenario.

In order to improve the readability of the text, the term carbon pricing is used. This means the pricing of all greenhouse gases, i.e., in addition to carbon dioxide, methane (CH_4) and nitrous oxide (N_2O). These greenhouse gases are accounted using conversion factors to a uniform size (CO_2 equivalents).

2 Climate mitigation policy in the economy

2.1 Diagnosis 2019: Despite many measures, the goal is missed

Germany can now look back on **decades of experience** in its climate mitigation policy:

- In **1987**, the Enquete Commission "Precautionary measures to protect the earth's atmosphere" announced ambitious reduction targets (25% by 2005).
- In **2000**, the Bundestag passed the first climate mitigation program that contained a reduction target of 21% (based on 1990) by 2005 for the implementation of the Kyoto Agreement (1997) and also defined technology and energy carrier-related targets (renewable energies, power-heat coupling, etc.).
- In **2002**, the government parties agreed to set a 2020 reduction target of 40% (based on 1990).
- In **2010**, the federal government adopted a long-term strategy with ambitious target values of 55% (by 2030), 70% (by 2040) and 80 to 95% (by 2050), each based on 1990. These goals were reaffirmed in **2016** in the Climate Protection Plan 2050.

In fact, Germany's greenhouse gas emissions were reduced by almost 20% by 2005 (based on 1990). However, this impressive interim result was largely due to the collapse of the energy-intensive East German industry after reunification. Since 2005, the reduction in emissions has proceeded much more slowly. By 2018, only a further approx. 10 percentage points (based on 1990) had been reached, so that **the "40% by 2020" target will most likely be clearly missed**. And the "55% by 2030" goal can only be achieved if climate policy has a much stronger impact in the future than in the past 10 years.

This finding is particularly sobering because **the climate mitigation policy has been continuously expanded since 2005**:

- At the EU level, the emissions trading system (ETS) was introduced. The ETS regulates the emissions of approx. 12,000 large plants in the energy and energy-intensive industries (approx. 45 percent of Europe's greenhouse gas emissions), as well as emissions from intra-European aviation.
- In Germany, many additional regulations and funding programs have been launched or tightened, for example the Renewable Energy Sources Act (EEG), the Law on the Promotion of Combined Heat and Power (CHP), the Energy Saving Ordinance (EnEV) and the Integrated Energy and Climate Program (IEKP), which consists of a total of 29 individual measures.
- In addition, the climate protection goal was anchored as a secondary goal in the further development of almost all policy areas. This happened both at the European level (e.g., agricultural reform 2013) and at the federal, state and municipal levels, where German counties and municipalities have now established hundreds or even thousands of climate mitigation initiatives.

A closer look reveals that emissions in those economic sectors covered by the EU ETS continue to decrease significantly. According to the Federal Government's 2019 projection report (2019), GHG emissions in the ETS area decreased by almost 13% by 2016 compared to 2005. In the other “non-ETS” areas (trade, , services, buildings, transport, agriculture and waste management), emissions fell by just under 4% in the same period. The “cap and trade” mechanism of the EU-ETS is taking effect, and the EU Commission therefore assumes that the reduction targets set for 2020 will also be achieved.

Since 2013 there have been no national reduction targets in the EU ETS, rather a common EU ceiling applies to the ETS sectors of all member states together. For political reasons, Germany also wants to achieve national reduction targets in this segment of climate mitigation policy. This cannot be achieved through the ETS mechanism, but through the closure of coal-fired power plants. Emission certificates that are released as a result are to be removed from trading (Commission "Growth, Structural Change and Employment", 2019). In this way, the effectiveness of the EU ETS is maintained and at the same time it is ensured that the closure of power plants in Germany does not lead to a drop in exchange prices in the ETS and thus to additional emissions in other EU member states.

The criticism of the ineffectiveness of the EU-ETS, which has often been expressed in the press and on the part of environmental organizations, does not refer to the achievement of objectives, but to the low certificate prices. Between 2011 and 2018, these were less than EUR 10 per tonne of CO_2. However, low certificate prices are no evidence that the "cap and trade" mechanism does not work. Rather, they only reflect how unambitious the EU reduction targets have so far been given the low avoidance costs. In addition, accumulated overhangs in certificates and policies taken in parallel, e.g. to counteract the promotion of renewable energies, a shortage and increase in the price of emission certificates. By (a) reducing the certificates in the ETS insufficiently and (b) taking so many parallel climate policy activities, politicians have ensured that the certificate price in the ETS remained low.

Conclusion: As a result of the very low certificate prices, the ETS has so far provided little incentive for innovations and investments in climate-friendly technologies; however, the limitation of emissions and the safeguarding of reduction targets were successfully ensured in the ETS area. In contrast, Germany obviously has major problems in achieving the national emission reduction target for the non-ETS area of 14% by 2020 (based on 2005) set out in the EU Effort Sharing Decision No. 406/2009/EG. If the target for the German non-ETS area is missed, the Federal Government will have to buy emission credits from other EU countries in the future.

2.2 A beacon of hope: CO_2 pricing

If the German reduction target outside the ETS area is not achieved despite the many policy measures and despite double-digit billions in funding, two explanations can be considered: the amount of measures is insufficient or there is an error in the measure architecture.

After the many analyses that science has recently presented, the answer is: both explanations are correct, i.e., the architecture of measures should be reconsidered in order to give climate policy more strength overall, but it will then still be necessary to dose the level of intervention at a high level. Climate protection is not free of charge; after all, a far-reaching tranformation of the entire economy is necessary.

Consistent CO_2 pricing, such as already realized in the ETS with the trade of certificate, offers the following advantages compared to the classic environmental policy architecture:

- **Each issue receives a price tag, i.e., all people are reached.** The CO_2 pricing creates a financial incentive that is present in all economic activities of companies and consumers. This is a big difference to an environmental policy that primarily works with conditions. There are no incentives for further CO_2 reductions for people who have fulfilled a certain requirement.
- **Emissions are reduced with the greatest possible efficiency.** If all issuers receive the same price signal, emissions will be reduced where it is most cost-effective for the economy. Here, too, there is a big difference to the classic "circulation policy", because with one restriction the politicians sometimes force very expensive savings, while elsewhere in the economy cost-effective savings potential is still unused. Given the economic power, consequent CO_2 pricing can achieve more climate protection than a regulatory policy.
- **The savings target is controlled consistently and transparently.** When installing a market-compliant policy measure such as the ETS, politicians can already stipulate that the total amount of emission certificates should be gradually reduced along a time-saving path. The administration will then implement this in the following years, and the entire economy can adjust to the tightening at an early stage and adjust its investments accordingly to the long-term climate protection goal. On the other hand, new national legislative initiatives had to be started again and again in the previous national climate policy, which is very time-consuming and where every business association repeatedly tries to prevent tightening and create loopholes for its own clientele.

Climate policy is internationally connectable. Climate protection is a challenge that can ultimately only be met in an international network. If it is not possible to establish such a network, global market economy competition will constantly hinder or even counteract the climate policy efforts of individual countries by shifting emission-intensive activities to other countries (leakage, see chapter 2.4). Even after the Paris Agreement has been adopted, the path to a coherent global climate policy is still very long. The voluntary commitments made by the contracting states are strongly shaped by national and sectoral interests and together result in a “patchwork” with which a shift in emissions cannot be prevented. It is therefore extremely important for the long-term success of climate policy that Germany and Europe develop a transparent, coherent and efficient climate policy “made of a piece” and in this respect act as a role model. To do this, it is necessary to achieve this goal within the EU. The ETS, in which 45% of the emissions are recorded, offers the ideal starting point for this.

The market instruments favored by environmental economists can ensure a more cost-efficient adjustment, the larger the regulatory area in relation to the addressed emission sources and the countries involved. Emission reductions are then implemented where they can be implemented most cost-effectively. This sparked criticism that the reduction would then primarily be shifted to economically weaker countries and (as “harvesting the low-hanging fruit”) to sectors with particularly low avoidance costs. This “problem description” is true, but it is important to carefully consider whether these criticisms are really so important that they should be used to push the ETS into the margins of climate policy. The following should be considered here:

- **“Low hanging fruits”.** In the interest of far-reaching climate protection, it is generally reasonable to harvest the largest possible climate mitigation achievement with the economic power invested for climate protection, instead of using the most expensive mitigation options. However, there is concern that sectors with high abatement costs are just watching and not investing in new technologies because they trust that the other sectors will already be doing the climate policy task for the time being. The concern is justified if politicians give the impression that moderate emissions targets and low certificate prices will remain in the long term. However, if policymakers lay down a clear path for reducing emissions in the EU and leave no doubt that this will lead to a significant rise in certificate prices, all sectors will immediately have an incentive to push investment in emission-reduction processes. In addition, the state should take advantage of the extensive opportunities it has in the "research and innovation" policy area.
- **Relocation to economically weaker regions.** The "textbook answer" against this criticism is: The support of structurally weak regions should be provided with the help of regional development policy and with the help of EU-wide financial compensation, not with the help of climate protection policy. In the same way, social policy goals should not be pursued within climate policy ("rich citizens" pay higher fuel and electricity prices than "poor citizens"), but with the means of social policy. The more politicians overload climate policy with constraints from other policy areas (social policy, regional policy, etc.), the more climate policy loses its power. In this respect, it is definitely a fundamental political decision whether the state (a) focuses climate mitigation policy consistently on achieving climate policy targets and then flanks undesirable side effects with the appropriate policy instruments, or whether (b) it always takes all different policy objectives into account and tries to control them simultaneously.

2.3 Specifically: tax, premium or emissions trading?

For the implementation of CO_2 pricing outside the ETS area, the state must first decide whether it wants to use its instruments (a) directly for all consumers, (b) directly for all companies or (c) specifically for a few companies that are located at "bottlenecks" of the energy and material flows of the economy.

In the EU ETS, direct regulation starts at the level of "all companies". This is possible with reasonable effort because there are only a manageable number of large emitters in the energy and industrial sectors. In the non-ETS area, however, this procedure would involve a great deal of administrative work because there are hundreds of thousands of companies here, which would then all have to be checked legally. In this respect, everything speaks for identifying “bottlenecks” there, too. An example: If the state levies a tax on fossil fuels from those companies that place such substances on the market in Germany, it only needs to control a few companies. If it raises the tax where the emission actually occurs (e.g., in the gas heater of private households or in the tank of all car drivers), it has to check a large number of measuring points.

It would be completely hopeless to start with consumers across the full spectrum of climate protection policy. To do this, every consumer good and every service would first have to be provided with a kind of “CO_2 price tag”, and then all private households would have to submit a kind of “CO_2 tax return”, which the state would have to check and sanction in the third step.

At the "enterprise" level, there are basically three forms with which the state can implement CO_2 pricing in economic policy:

- **CO_2 tax:** The state levies a tax on every tonne of CO_2 emitted by a company not previously covered by the EU ETS.
- **Emissions trading ("cap and trade"):** The state also creates emission rights (licenses) outside the previous EU ETS and only allows companies to emit CO_2 to the extent that they have emission rights. The rights are issued and / or auctioned by the state for free, with the total amount being reduced from year to year. The rights are tradable between the companies.
- **Climate protection premium:** The state allocates non-tradable emission rights (e.g., based on historical values) to the emitters outside the EU ETS and then pays a premium for all emission rights that are not used.

The climate policy control effect is very similar for all three forms of configuration: All companies consider themselves obliged to take the " CO_2 price" into account in their calculations. If their avoidance costs are below this price, they will avoid emissions (e.g., by switching to more climate-friendly production processes). It is irrelevant for the result of this business calculation ("emit or not?") whether you (a) save the tax or (b) save the purchase price for the emission right or (c) redeem the sale price for the emission right through non-emission or (d) redeem the premium for the omitted emission.

If the companies conclude that the "CO_2 price" is not high enough to implement more climate-friendly alternatives within the company, they will continue to emit. However, as long as this is feasible in the market and is not undermined by imports, they will have the additional tax payments or the lost subsidies paid for by their customers. In this case, the processing companies and the end consumers are prompted by the increased prices to limit "climate-damaging production" or "climate-damaging consumption".

In emissions trading, the state can precisely define the emission target (and its change over time) right from the start; however, it then has to wait and see how the price develops (and with it the burden on consumers and the weakening of international competitiveness). It is exactly the other way around with the CO_2 tax and the climate protection premium: Here, the state sets the price and then has to wait and see how the emissions will work. The precise targeting of the emission reduction targets is much more difficult with the tax because the constant readjustment of the tax level requires repeated, unpopular political decisions. The reduction targets and the transformation path up to 2030 are already politically fixed for the German non-ETS area. These values could be used as the basis for a “cap and trade” system (annual reduction in the total number of rights granted in accordance with the agreed saving path).

If we disregard this "leveling advantage" of emissions trading (compared to taxes and climate protection premiums), the climate policy control effect is quite similar for all three design options. In contrast, the **financial distribution effects** of the three options are very different:

- In the case of the CO_2 tax, the state retains all emission rights and every emitter must acquire this right by paying the tax payment. This causes a strong flow of funds from companies to the state, because all emissions are taxed.
- With the climate protection premium, the state gives the emission rights to the companies free of charge, and the state must then purchase the rights (with the help of the premium payments). This causes a financial flow from the state to the companies, which can also assume a considerable volume if the climate protection goals are tightened.
- In emissions trading, the state can shape the distribution effects very differently. If it auctioned off all the rights, it came very close to a CO_2 tax; if it grants all rights free of charge, no additional money flows into the state treasury.

The state can change these distributional effects by supplementing the climate policy market measures with further measures. For example, the state can use the additional government revenue of the CO_2 tax to relieve the tax burden on citizens elsewhere or to finance additional climate protection measures (climate protection premium). A CO_2 tax high enough to have an impact on climate policy would lead to a significant increase in the government ratio; this inevitably leads to controversial discussions about tax relief elsewhere. A climate protection premium would require the mobilization of additional public finances worth billions; this also triggers difficult fiscal debates.

In contrast, emissions trading can initially be designed in such a way that the annual emission rights are issued free of charge and therefore, there is no fiscal turbulence at this point. However, this cannot be maintained in all cases. For example, in the energy industry it might happen that companies who have received the emission rights (e.g., natural gas marketers) pass on the scarcity effects in the form of higher prices to end customers. In these cases, the state will auction the rights (a) to avoid "unjust enrichment" of companies and (b) to obtain funds with which it can compensate the citizens and companies affected by price increases and support them in the adjustment. This can be designed differently according to industries or recipients, without there being any disadvantages to reaching the climate target, because the total amount of emissions rights issued follows the specified reduction path.

Another important advantage of the option "Emission rights trading" is **the international connectivity** (see Chapter 2.2). Emissions trading is already established in the ETS as an EU-wide measure, and it could be extended to other sectors at this level. In contrast, tax policy in the EU is in the responsibility of Member States. Given the great importance of fiscal policy for all governments, it could prove to be too ambitious to completely change the EU's fiscal policy architecture in addition to the climate policy architecture.

However, the expansion of the ETS will undoubtedly become a time-consuming political process. At first glance, this might suggest that CO_2 tax or the climate protection premium should be preferred in Germany. However, since this does not offer a convincing long-term perspective in terms of international connectivity, a national emissions trading system should be set up as an interim solution for the current non-ETS sectors, which will then (a) be extended to the EU level as soon as possible and (b) connected gradually with the already- established ETS. Germany could offer other EU member states to follow this path from the beginning in association with all those countries that consider this path to be correct in the long term and at the same time are able to implement it on their territory at short notice.

2.4 Wanted: administrable concepts with little leakage

For the success of climate policy, it is not only important to choose the right core instrument (restrictions, tax, emissions trading, premium), it is even more important to determine the appropriate **addressees** and the **control parameters** upon which this economic policy control is based. Above all, this is about **legally compliant, transparent and inexpensive administrability**.

The challenge can be illustrated by the climate policy sub-goal "reducing the use of fossil fuels". About 70% of global greenhouse gas emissions and 85% of German greenhouse gas emissions are caused by the combustion of fossil fuels. In order to achieve this important sub-goal, politics can start with various addressees. The following two extreme scenarios illustrate what this is about:

- **Sanctioning at the location of the raw material extraction.** Oil, natural gas and coal are extracted from the earth in relatively few locations, and this is done by a very manageable number of companies. The optimal climate policy would be that the international community agrees to price CO_2 at these few extraction sites or at these few companies. It is of secondary importance whether this is done through a CO_2 tax or through a quantitative limitation of the extraction rights. In any case, the price effects would trigger climate-friendly behavior among billions of consumers and companies worldwide. If these are not yet sufficient to achieve the climate protection targets, there is no need to introduce any further climate policy instruments, but only to increase the dose of this one instrument (higher tax, stronger quantity limitation). In this way - if the international community really wanted this - the global climate protection goal in the energy sector could be achieved very easily and with maximum effectiveness, efficiency and transparency.
- **Sanctioning end users.** People consume products and services that use fossil raw materials. This means that every person has the opportunity to contribute to climate protection by changing their consumer behavior. Hoping for people's voluntary behavior is not enough, however - despite all the debates about the shame of flying, SUVs, and meat avoidance, etc. politicians could therefore think of making the “climate policy backpack” of every citizen (i.e., their consumption-related CO_2 emissions) the subject of financial sanctions. Here, too, it would be of secondary importance whether this would then be implemented through a CO_2 tax or tradable emission rights. Rather, the crucial point is that it could not work, because the consumption-related CO_2 emissions per capita can be calculated statistically for the whole of Germany, but it is not possible to use it as a justifiable starting point for sanctioning individual behavior. On the one hand, it would be extremely complex to record the CO_2 emissions along the entire value chain for each individual consumer good, and on the other hand it would not be politically feasible for state authorities to issue the "emissions declaration" of all citizens year after year (analogous to the income tax declaration) check.

These considerations speak for starting with the administration of the CO_2 pricing at the companies and looking for so-called "**bottlenecks**". These are places in the value chain or retail chain where the flow of goods has to flow through a few large companies or a government agency. The advantage of such bottlenecks is that large quantities of goods (and their climate-relevant features) can also be legally recorded for climate policy with little additional effort.

While the bottleneck principle for a globally coordinated climate policy would be fully recommended (see the example above "raw material extraction"), for political reasons, climate policy can initially only be implemented nationally or EU-wide. This is because most companies face **international competition** and many products can be traded across borders without customs barriers. If the addressees and control parameters are chosen inappropriately, this can lead to emissions being shifted abroad (**leakage**).

Let's stay with the example of "raw material extraction" to illustrate the **direct leakage** effect. If Germany were to price CO_2 (e.g., a CO_2 tax) for companies that produce crude oil in Germany (control parameters: “production volume of fossil raw materials”), this measure would be completely ineffective in terms of climate policy. The extraction companies would try to pass the CO_2 tax on to the downstream levels (right down to the consumers). This attempt would be unsuccessful, however, since the previous customers would immediately switch to imported oil, which is not taxed. As a result, there would be no price signal among consumers, and the only consequence of the climate policy measure would be that the climate-damaging extraction activity would be relocated abroad. The leakage problem can therefore lead to a climate policy measure - from a global perspective - not making any climate policy goal contribution, but rather only improving the figures of a single nation. Since climate protection is a global environmental problem, it is ultimately not the national but the global emission reductions that are decisive for the actual success of climate policy.

In most cases, the leakage effect does not occur as directly and immediately as in the example of petroleum extraction above, but in an indirect form. This can also be clearly demonstrated using the example of the energy industry: Germany would presumably make fossil fuels more expensive if it went it alone in terms of climate policy in such a way that it choose energy suppliers as addressees (mineral oil, natural gas and coal companies). Here would be a good bottleneck. The amount of fossil fuels that the respective company places on the market in Germany would presumably be chosen as the control parameter for CO_2 pricing. This would be based on the CO_2 emissions that are usually generated when the respective fossil fuels are burned. In this scenario, no immediate leakage effect would be triggered, because energy suppliers would continue to operate in Germany with a CO_2 price. However, there would be an **indirect leakage effect**, because companies would have to add the additional costs to their product prices. This increase in energy costs weakens the competitiveness of domestic companies, which - insofar as there are no cost-efficient adjustment options - will result in production capacities sooner or later being relocated abroad, especially in the energy-intensive sectors.

An important **indirect effect of the leakage problem** is that intensive discussions about the weakening of international competitiveness and possible leakage effects already take place in the run-up to a climate policy measure. This is particularly the case if climate policy is carried out with the help of regulatory law. Each branch then points to the impending weakening of competitiveness and hopes that another branch will soon become the focus of the climate policy discussion. Overall, this results in a delayed, weakly metered and inconsistent climate policy that does not achieve the overall climate policy goal. Achieving the overall target is ensured by issuing emission certificates across sectors. Discussions about relocations are also important here in order to balance the various political goals and to achieve acceptance for climate policy measures. The leakage problem is solved relatively elegantly in the EU-ETS, since companies in those sectors that are particularly affected by the leakage problem only have to buy a small part of the emission certificates. The free allocation of certificates is not based on historical emissions, but rather technological benchmarks for low-emission production.

So far, it has apparently been possible to keep the leakage problem under control to some extent. In any case, the previous emission reductions in Germany are not due to relocations abroad. As analyses based on the environmental economic accounts show, the indirect CO_2 emissions associated with imported goods increased between 2010 and 2015, but the indirect emissions associated with export goods also increased to the same extent (DESTATIS, 2019).

A relocation of production within the EU internal market should not be seen as leakage in the climate policy sense, as long as the EU states comply with their climate protection targets set by EU law and the emissions of the EU as a whole do not increase. And if it is possible to comply with ambitious emission limits in all countries of the world, the relocation of production beyond the EU's external borders cannot be classified (or only partially) as a leakage effect. Rather, they are the result of a market-based search process in which, in addition to internal costs, external costs are taken into account in all industries and regions. This is exactly what is being targeted in the planned global emissions trading scheme.

With increasingly demanding climate protection goals, the problem of leakage will become more important. It is therefore important for Germany's future climate policy to work towards an international, binding and ambitious limitation of emissions and an international coordination of measures. Specifically, this means:

- Align national climate policy so that it is internationally connectable
- Invest a significant part of the funds in "international climate diplomacy"

2.5 Critical question: is Germany creating a "real" system change?

In spite of all the difficulties in shaping the future climate protection policy in detail, the view for the whole should not be lost: **international role models, the development of future-proof technologies and the connectivity of political solutions are of paramount importance!** Germany alone can do little with its 2% share of global greenhouse gas emissions in its own territory. It is therefore even more important to create technologies and regulations in Germany that have the highest possible "export potential". In its pioneering or role model role, however, Germany has clearly fallen behind in recent years, as the failure to achieve the emission reduction target set for 2020 shows.

This core idea suggests using the **thrust of the current political debate for a "real" system change** and relying on the fact that this consistent climate policy course will soon convince the EU and later other parts of the world. Of course, there is a lot of “principle of hope” involved, but in view of the threat posed by global climate change, there is little choice.

However, the transition to a coherent climate policy with a uniform CO_2 price will not be easy. This is mainly due to the fact that the previous tax and energy policy has created **very different starting**

conditions in the various areas of the energy industry. The implicit "CO_2 taxation", which is already effective due to the various tax regulations and the energy and climate policy, differs considerably between the sectors. The Scientific Advisory Board at the Federal Ministry for Economic Affairs and Energy (2019) estimates the size of the taxes and duties as follows:

- **Electricity: 184 € / t CO_2** (electricity tax, EEG and KWKG surcharge)
- Heating oil and **natural gas: 23 and 28 € / t CO_2** (energy tax)
- **Petrol** and **diesel**: **64 or 58 € / t CO_2** (eco-tax share of the mineral oil tax)

In addition, there are loads from the ETS for electricity that fluctuate over time and have usually been below 25 € / t CO_2.

There is a lot of room for interpretation with regard to the loads on petrol and diesel. The earlier mineral oil tax (since 2006: energy tax) set significantly higher tax rates for fuels than for heating oil, whereby the reason given was mostly that these additional funds should cover the costs of road construction and maintenance. However, there is no legal obligation here i.e. the state finances road construction from general tax revenue - regardless of the amount and composition of the energy tax revenue. In this respect, it is also permissible to interpret the entire energy tax for gasoline and diesel as an implicit “CO_2 taxation”. This is how the Institute of German Business (Bardt and Schäfer 2019) did it and calculated that **gasoline** and **diesel** would be charged at **275 € and 178 € / t, respectively**.

If the state were to abruptly implement the system change, and without additional measures and initially strive for an "average CO_2 price level", there would be sharp price increases for heating oil and natural gas and sharp price reductions for electric power. There is a two-way criticism of this scenario: from a socio-political point of view, it is criticized that many citizens cannot be expected to face an abrupt increase in heating costs (this does not offset the relief on electricity bills), and from an environmental point of view it is criticized that the price reduction leads to higher electricity consumption in the electricity sector, which is counterproductive in terms of climate policy. From a scientific point of view, these arguments can be argued very well, but this should not be done here for reasons of space.

With regard to practical policy advice, it is more important to consider how politics can prevent **abrupt economic upheavals and still take a straightforward course** in terms of climate policy. In principle there are three different options for this:

- **Permanent CO_2 tax instead of emissions trading.** If politicians carry out CO_2 pricing in the form of a CO_2 tax, they can initially stick to the currently different tax rates and then gradually adjust them over time. However, it is questionable whether the government will later find the strength to do so. If not, the current “policy change” essentially boils down to maintaining the current regulations (energy tax, electricity tax, EEG levy) and merely giving it a new name (CO_2 tax). It should be remembered here that a CO_2 tax is to be judged worse than emissions trading in terms of international connectivity, international role models and the safe achievement of emission reduction targets.

- **Long transition period with phasing-in / phasing-out.** Politicians can also avoid abrupt breaks by first introducing emissions trading in addition to the existing tax, energy and climate policy regulations meaning maintaining the other regulations. It would then issue the emission rights in such a way that the price level only gradually increases. The major disadvantage of this approach is that the state and the economy have to administer two parallel systems over a long period of time. Experience has shown that this is not a good precondition for stringent, coherent policy-making, and it also offers little planning security for the economy.
- **Fast system change with compensation payments.** If the entire climate policy instruments were to be replaced by emissions trading in one fell swoop, and emission rights were scarcely measured in accordance with the reduction targets, this would result in a high certificate price. The energy industry would pass this on to end consumers. This would primarily result in the need to financially relieve the citizens affected by the increase in heating costs. The state can raise the funds for this by auctioning off the rights in this economic sector. However, the difficult task remains to design the compensation payments in such a way that (at least in the first few years) severe over- or under-compensation is avoided. In terms of climate policy, it would make sense to combine these compensations with the promotion of adaptation (e.g., promotion of the conversion of heating systems to renewable energies, building insulation, electromobility or local public transport).

The climate policy decisions of autumn 2019 are most likely to correspond to option 2. However, initially only the non-ETS areas of transport and heating will be included in the new (national) CO_2 emissions trading, while the areas of agriculture, land use change and forestry (LULUCF) should continue to be regulated separately.

2.6 Interim conclusion with regard to the involvement of the agricultural sector

A continuation of the previous climate policy would likely miss the 2030 climate policy targets significantly, because in contrast to the EU ETS, where emissions reduction is "on track", reductions in the non-ETS area have so far lagged far behind the climate policy objectives. The extension of CO_2 pricing to the previous non-ETS areas offers the potential to make climate policy more effective for the future. For long-term success, it is particularly important to choose a political architecture that (a) is internationally connectable and (b) includes the entire economy, if possible.

The Federal Government has now decided to establish emissions trading for "heat" and "traffic" as well. This is relatively easy, because all fossil fuels in the non-ETS area can be easily grasped at "bottlenecks". Germany will initially establish a national emissions trading system as a temporary solution, which could later be expanded across the EU and merged with the EU ETS. The decisions create a multi-billion fund, and there is still an intensive discussion about how and to what extent these funds are used (a) to compensate citizens concerned and (b) to finance climate protection premiums.

Wherever possible, the agricultural sector should also be integrated into the ETS (or an interim solution) in order to complete an effective climate policy "from a single source" as soon as possible. This would make the advantages of CO_2 pricing available to all sectors of the economy, and the overall system would have the best chance of being recognized as exemplary and capable of being connected on a global scale.

From an agricultural perspective, early involvement would be beneficial for three reasons:

- It can help shape the political architecture.
- It can use the market economy concept to generate climate protection revenues or, if necessary, acquire higher emission rights.
- A considerably higher planning security is achieved. If the agricultural sector is now left out, it can be expected that it will not achieve the savings targets that have already been set politically. In this case, the Climate Protection Act provides that new immediate programs for the agricultural sector must be installed at short notice. It is then very likely that these programs will again contain numerous new detailed regulations. That would not be a good framework for operational planning.

3 Integrating the agricultural sector into CO_2 pricing

In the German economy, around **85% of all greenhouse gas emissions** (converted into CO_2 equivalents) are caused by **the use of fossil fuels** (for heat, mobility, power generation). This also includes the consumption of fossil energy by the agricultural sector, which however plays only a minor role. A further approx. 7% of national emissions are attributable to various industrial processes, and approx. 1% to waste management (see Federal Environmental Agency 2019).

About **7 percent of greenhouse gas emissions** come directly from **agriculture**. Around 3 percent is due to nitrous oxide emissions from nitrogen fertilization, crop residues, etc.; around 1 percent to emissions from livestock buildings and storage of farmyard manure and biogas production, and around 3 percent to methane emissions, especially from ruminants (Rösemann et al. 2019).

In the area of **land use and land use changes**, CO_2 emissions from agricultural **peat soils** are of particular importance. They correspond to around **4 percent** of Germany's total emissions. On the other hand, the forest can bind CO_2 in the wood in the long term. When the trees die or when the harvested wood is burned, the CO_2 is released again at some point. If wood is used in construction, this release can be delayed. The current annual increase in the carbon reserve in the **forest**, i.e. the negative emission, based on the total emissions of Germany are at approx. **7 percent**.

In the overall view, it must also be taken into account that the energetic and material use of renewable raw materials has climate policy potential. It enables the substitution of fossil fuels and emission-intensive building materials. These effects are not reflected in the emissions inventory in agriculture, but, e.g., positivly in the heat and traffic sectors.

The inclusion of agriculture in CO_2 pricing is particular challenging because the **emissions and immission processes differ markedly** from the conditions in other sectors:

- In agriculture, the greenhouse gases N_2O (laughing gas) and CH_4 (methane) dominate the emissions balance.
- For the greenhouse gas CO_2 it is not just about reducing emissions, but also about storing CO_2 as much as possible in the soil as well as in wood and wood products.
- Especially in forestry, the emissions and the C sequestration are strongly influenced by soil conditions, weather conditions, pest infestation, so that there can be strong fluctuations over time.
- Ecosystem interactions must be taken into account in emissions management, for example between the C and N content in agricultural soils. In addition to carbon sequestration and CO_2 release, the N_2O emissions must also beconsidered.
- It is not possible to measure emissions and / or storage capacity per year on the level of the individual farm.

This chapter examines how agriculture can be integrated into CO_2 pricing despite these special starting conditions. The procedure is as follows:

- In a first step (chapter 3.1) the question is discussed whether it could be possible to make the control parameter "individual greenhouse gas balance" the subject of CO_2 pricing for the addressee "agricultural enterprise".
- Since this would result in very high administrative costs and control problems that are difficult to get grips on, alternative options are then examined. The focus is on either tackling the bottlenecks of emission-relevant material flows or, if a single-company approach is essential, looking for control parameters that are easier to grasp. In this sense, chapters 3.2 ff consider the individual **emission and immission areas** of the agricultural sector one after the other (laughing gas, methane, carbon dioxide), and it is examined in each case with which **addressees** which **climate-relevant control parameters** can be measured with **legal justification**.
- For such approaches, it is then examined in more detail how the CO_2 pricing can be designed and what the consequences would be. In as far as it makes sense, the following climate policy instruments are considered: **CO_2 tax, climate protection premium, emissions trading**. In emissions trading, the options **"100% auction", "100% free allocation" and "gradual entry into an auction"** are considered.
- In order to be able to estimate the consequences of the various options for CO_2 pricing, at least in approximate order of magnitude, **assumptions about the level of the CO_2 price** must be made. Two scenarios are used here, (a) with a price of **25 € / t** (based on the current ETS stock exchange price) and (b) with a price of **100 € / t**. There is consensus in the literature that a CO_2 price that is well above 25 € / t will be required to achieve the climate policy goals. The range of prices used or demanded there is between 25 and 180 € / t CO_2 (see also chapter 2.5).
- For the evaluation of specific forms of CO_2 pricing, it is also important to ask whether the measure examined in each case should be **implemented nationally, EU-wide or worldwide**. There are forms of CO_2 pricing that work very well with a globally coherent climate policy, but are unsuitable for national solo action. This is mainly due to the **problem of leakage**. Because it can be assumed that climate policy can implement CO_2 pricing much more easily and quickly on a national basis than at EU level or even in a global network, this aspect must also be included in the analysis.

This analysis initially excludes the question of how the examined CO_2 pricing arrangements correspond to the further development of the Common Agricultural Policy (CAP). The policy options are initially designed and analyzed independently of the CAP. For reasons of readability, the following text continues to refer to CO_2 emissions, CO_2 taxes, etc., although in fact they are CO_2 -equivalent emissions, CO_2 -equivalent taxes, etc. The values for nitrous oxide and methane are converted into CO_2 equivalents using the conversion factors currently used in greenhouse gas reporting for the global warming potential (nitrous oxide 298, methane 25).

3.1 Farm level greenhouse gas balance

It would be advantageous for the effectiveness of climate policy if the control parameter “annual greenhouse gas balance” were to be used for all addressed agricultural farms. This balance should be calculated for all farms and illustrate all greenhouse gas emissions caused in the course of the farm’s existence, including the consequent CO_2 sequestration in soils and wood (negative CO_2 emissions). The balance sheet values determined by individual farms could then become the subject of the CO_2 pricing. Specifically: With a CO_2 tax, farms would have to pay the tax for every tonne of CO_2 emission. With a climate protection premium, the companies receive the premium for every tonne of CO_2 emission avoided. And in the case of emissions trading, companies that reduce their production or bind more carbon in the ground could sell emission rights that are no longer required on the stock exchange.

The **great advantage of the control parameter "farm level greenhouse gas balance"** is that climate policy would then cause every farm in Germany to (a) take into account the totality of its emissions and (b) simultaneously optimize farm management taking into account the respective CO_2 emissions. This simultaneous optimization would be important because there are various interactions in agricultural holdings. If politics requests a farmer to optimize operations only for a single greenhouse gas (e.g., methane), it may trigger additional emissions from another greenhouse gas (e.g., carbon dioxide).

At first glance, one might think that determining the farm's greenhouse gas balance should not be an unconquerable hurdle. After all, “climate calculators” are already being used in agricultural advice today, and the Thünen Institute determines and reports greenhouse gas emissions annually for the entire German agricultural sector as part of international emissions reporting.

On closer inspection, however, you can see that the calculation of sector balance sheets and the use of individual company advisory tools are tasks that are fundamentally different from the task of creating a **judicial assessment basis** for a tax or a subsidy payment. When farmers enter their operational data into a counseling tool, they do so knowing that the result of the calculation has no financial consequences. But if the result has an immediate effect on income because it depends on the amount of a tax payment, they will consider how they can make this result as cheap as possible. Every kilogram of CO_2 emission is worth money!

Since the companies compete with each other on the local lease markets, they cannot afford to miss out on income opportunities. That is why more and more farmers will write beautiful numbers "on paper" (e.g. in the CO_2 tax return) - unless the state consistently prevents this. In other words, by opting for the control parameter "individual greenhouse gas balance", politicians also assume the responsibility of having to set up **a comprehensive control system** for this.

Given the complexity of practical agriculture, this would lead to **immense administrative effort** and to political and legal **controversy over trifles**. The total effort caused in this way would be disproportionate to the desired climate policy benefits. To illustrate the nature of the problems to be expected, only three of the many controversies should be selected as examples:

- Cattle and urine excretions in cattle farms lead to ammonia emissions, which in turn cause nitrous oxide emissions in various ecosystems. There are, however, large inter-company differences between cattle-keeping companies, influenced, among other things, by the stalls, storage and spreading technology, the soil conditions, the stall occupancy and the frequency of removing dung. These details of the production process would have to be checked in order to create an accurate and fair assessment basis for CO_2 pricing.
- If hedges or woody strips are planted for reasons of insect or erosion protection, this leads to an enrichment of carbon in the soil, which is desirable in terms of climate policy. The extent depends, however, strongly on the site conditions, but also on the plant composition as well as its care and use. It is not clear how these differences can be captured technically for all regions in Germany, and with little administrative effort at the same time.
- Given the high administrative costs, the state could consider taking small farms out of carbon pricing. That way it would create loopholes. For example, it would then be lucrative for small farms to sell organic material to large farms, because it can be recorded in the local humus balance as a monetary value. And as the price of CO_2 rises, the temptation increases that large farms "obtain" part of their mineral fertilizer from non-controlled small farms. This purchase of resources could still be recorded through the control of the upstream areas of agriculture, but this would not be possible with in-house substances such as straw or manure.

This list of "difficult case constellations" could be expanded almost arbitrarily. The “trials” are ultimately due to the fact that every kilogram of CO_2 emissions is monetary, but cannot be measured judicially. One way to address these issues would be to work with ratings and flat rates. The rougher such classifications are, the less they will do justice to the respective operational situation.

Furthermore, one could consider not putting every kilogram of monetary value in agriculture's CO_2 prices, but only the CO_2 emissions above a certain (declared as permissible) margin. A large part of the companies would then end up somewhere in the tolerance margin, so that there would be no incentive for any trickery and mockery. The control authorities would therefore only have to concentrate on the “critical cases”.

However, this apparent "solution" would not work. The main idea behind CO_2 pricing is to provide an economic incentive for economy and innovation **for every kilogram of CO_2 emissions**. However, if the regulation is designed in such a way that most companies do not feel any incentives and sanctions because they are comfortably within the tolerance margin, the goal of CO_2 pricing will not be achieved. Instead, only extensive accounting expenses are triggered, and as a result of this bookkeeping, many companies will become aware that they are well below the critical limit and, therefore, “still have room”. They can use this “air” economically to offer themselves to those companies that are considered “critical cases” for a fee as cooperation partners. If things go well, the "cooperation company" will also land with its CO_2 emissions within the permissible margin, so that no further adjustments to production are necessary.

Interim conclusion: With the current state of the art and the monitoring of agriculture, it is **not recommended** to integrate the agricultural sector in CO_2 pricing at the individual farm level based on the control parameter "annual greenhouse gas balance". Individual greenhouse gas balances can be a valuable element of advisory approaches and can be used in innovation networks and in environmental investments. However, they are unsuitable for comprehensive CO_2 pricing until further notice. Therefore, it is examined in the following whether (for example through the use of "bottlenecks") legally administrable partial solutions for the individual greenhouse gases can be found.

3.2 Nitrous oxide

Nitrous oxide emissions arise in agriculture primarily when converting reactive nitrogen compounds in agricultural soils and when storing manure. The nitrous oxide emissions from soils can vary greatly in the short term. Current soil and weather conditions play an important role here.

Due to these strong fluctuations and the high cost of the measurement, it is **not possible to make nitrous oxide emissions the subject of an immediate control measure**. For the time being, politicians therefore only have the option of indirect control: if they manage to reduce the total amount of reactive nitrogen compounds in the agricultural sector by granting emission rights and gradually reducing them, then they can assume that nitrous oxide emissions will approximate decrease to the same extent.

This indirect control (by **limiting the total input of reactive nitrogen**) has the positive side effect that it not only reduces nitrous oxide emissions from the agricultural sector (climate protection), but also emissions of other nitrogen compounds (nitrate, ammonia) that are undesirable from an environmental policy perspective (water protection, biotope protection).

In principle, politicians can pursue the goal of recording and reducing the total amount of reactive nitrogen in the agricultural sector in **two ways**:

- Either it integrates each individual farm into the CO_2 pricing in accordance with its nitrogen input quantity or its nitrogen balance surplus.
- Or it regulates the sectoral entry routes of nitrogen at the "bottlenecks", i.e., at those companies that place mineral nitrogen and animal feed on the market.

3.2.1 Farm level nitrogen balance

The first approach **(addressee: agricultural company, control parameters: N-amount or N-surplus)** brings with it the immense challenge of having to build a watertight and legally secure control system for hundreds of thousands of farmers.

While a judicial regulation of the entire individual greenhouse gas balance does not appear to be feasible at the moment (cf. chapter 3.1), there are definitely opportunities for the individual nitrogen balance to be implemented. Because “only” one group of substances (nitrogen compounds) is the focus here, most farms should in any case be obliged to report on these substances in their material flow balance.

The calculation methods for the material flow balance have been available since the end of 2018. The challenge is that when the material flow balance is used to implement the Fertilizer Act and the Material Flow Balance Ordinance, the incentive to “fine-tune” calculations is much lower than using the CO_2 pricing. So far, the Material Flow Balance Ordinance provides the proof that the operation is below certain limit values, and exceeding the limit value initially has no financial consequences. It is different with **CO_2 pricing**: every kilogram of nitrogen that the company reports or does not report is worth real money.

With this starting point, the authorities must be in a position **to effectively audit** the individual company information in the "**nitrogen tax return**", similar to the income tax return. This requires:

- In addition to the farms, companies in the mineral fertilizer and animal feed industries must also be integrated. All companies must disclose what quantities of substance they have obtained from which company or have delivered to which company to the control authorities.
- All farms must potentially be included in the audits, i.e., unusually high fertilizer purchases from small producers must be checked.
- The authorities must be able to compare this information not only within a federal state, but also across states and, if necessary, across the EU.
- The sanctions for legal violations must be sufficiently high.

Whether politicians can bring themselves to make the farm “transparent,” consistent with the general norm in the agricultural sector, seems questionable after the experience in connection with the introduction of the fertilizer ordinance. If politicians do not want this, they would be well-advised not to make the control parameter “individual nitrogen balance” part of the CO_2 pricing. Otherwise they run the risk of pushing the farmers en masse into a “normality of false declarations”. Similar questions will arise in the course of the planned further development of the Material Flow Balance Ordinance.

Should politicians decide to make the control parameter "individual nitrogen balance" the linchpin of nitrogen regulation, further details are required. In particular, it must be clarified whether the

CO_2 pricing should (a) relate to the total amount of nitrogen used by the company, or (b) only to the nitrogen balance surplus (difference between nitrogen export in the products sold and the amount of nitrogen used).

- The advantages of the control parameter **“nitrogen input quantity”** are: The entire nitrogen input goes through conversion processes in the agricultural soils, and with these processes there is a certain probability that volatile nitrous oxide is produced. Therefore, the nitrogen use by the company should be kept as low as possible.
- The advantages of the control parameter **"nitrogen balance surplus"** are: The nitrogen surplus that is not transported away by the crop leads to increased nitrous oxide emissions, be it through transformation processes on the farm (in the winter months) or after relocation via water or air in other parts of the ecosystem. It should therefore be kept as low as possible.

When calculating the share of **total nitrogen** that leads to nitrous oxide emissions, the general methods of GHG reporting could initially be used. The database for the precise quantification of emissions depending on the **nitrogen balance surplus** is still very thin. For the time being, rough estimates will have to be used here as well. It can be assumed that the factors for converting the amount of nitrogen into nitrous oxide emissions will be higher when choosing the control parameter “nitrogen balance surplus” than choosing the control parameter “amount of nitrogen input”.

The decision between the two options is a political one, and the following arguments could be decisive in the weighing up:

- The decision has an impact on the distribution of income within the agricultural sector: Arable farms tend to have lower balance surpluses and are therefore less burdened if the control parameter "nitrogen balance surplus" is selected. In the case of livestock farms, it is the other way round.
- The sanctioning of the nitrogen balance surplus comes closer to the intuitive sense of justice of many people. It is easier to explain that the “excess” nitrogen causes an environmental problem, even if it does not entirely correspond to the actual findings.
- If politicians choose the parameter “nitrogen balance surplus”, they are already implicitly assigning rights. Farmers have a right to part of the nitrous oxide emissions caused by agriculture free of charge. Only that part of the total emissions that results from nitrogen surpluses is sanctioned.
- If the individual farm nitrogen balance surplus is made the subject of CO_2 pricing, then it is immediately obvious that an individual farm material flow balance is necessary for this and therefore a very high administrative effort. When sanctioning the entire amount of nitrogen, politicians are well advised to start right at the "bottlenecks" (see below).

Since both indicators can be derived from the material flow balance, politicians could also come up with the idea of choosing a mixed indicator.

Once the control parameter has been decided, politicians again have the familiar options when designing the measures:

- The state could oblige all farmers to pay the **CO_2 tax** for the nitrogen balance surplus.
- The state could reward farmers who reduce their nitrogen balance below a certain maximum limit or a historical value with a **climate protection premium**. In order to avoid subsidy fraud, however, the farmer would then have to pay a tax for all farmers who are above the maximum limit or who have a rising reading. Otherwise, the premiums would mean that farmers, i.e., those transporting liquid manure to neighboring farms and would be rewarded with the climate protection premium for their emissions reduction, while the increase in emissions in neighboring companies would remain unsanctioned.
- The state could include the individual farm nitrogen balance surplus in **emissions trading**. Here a farmer would have the choice of either auctioning all emission rights or handing over part of the emission rights to the farmers free of charge (e.g., based on historical values or using maximum limits per hectare).

In principle, all the options mentioned offer the farmers the same financial incentive to reduce their nitrogen balance surplus, so that the climate policy impact is roughly the same. The options differ mainly in terms of the financial consequences. A uniform CO_2 tax leads to a particularly high burden on farmers. In this regard, it is most likely that a relatively low tax rate (special treatment for agriculture) will be negotiated in the political discussion with this instrument. The climate policy effect would then be correspondingly smaller. Alternatively, one could consider working with the help of tax exemptions and increasing burdens on the nitrogen balance surplus, but this means a departure from the principle of uniform CO_2 pricing.

A particularly **elegant instrument** is the inclusion in the **emissions trading**. Here it is up to the state to take into account of the sense of justice when handing out the certificates and to only burden those nitrogen surpluses financially that are perceived as "too high". The advantage over tax exemptions (see above) is that there is still an incentive to save for all emissions below this threshold, because farmers have the opportunity to sell their certificates on the stock exchange.

The climate policy instruments would now have to be further specified. However, this would only make sense if politicians have decided to answer the question about the “transparent farm” raised at the beginning of this chapter with a clear “yes.” If this is not possible, the control parameter “individual nitrogen surplus” for CO_2 pricing should be discarded. It is then necessary to look for **other addressees or control parameters**. In the following, it is therefore examined what potential the bottleneck “mineral nitrogen distributor” offers and how this can be supplemented in order to also include the nitrogen flows from livestock farming.

3.2.2 Sectoral nitrogen input: Starting point for „CO_2-pricing for mineral nitrogen “

If, as an alternative to considering the individual farms, the amount of nitrogen at the **bottlenecks is to be priced**, the entire nitrogen input into the agricultural sector should be integrated if possible. On the one hand, this concerns the CO_2 pricing of mineral nitrogen, which is dealt within this sub-chapter 3.2.2. In the following subsection 3.2.3, it is then examined in more detail how the CO_2 pricing of mineral nitrogen could be supplemented to include nitrogen inputs resulting from livestock farming.

Mineral nitrogen fertilizers can be integrated into CO_2 pricing relatively easily because there is a **bottleneck** here. Only few companies manufacture or market mineral nitrogen. These few companies shall be induced by the CO_2 pricing to market the mineral nitrogen more expensive. This give hundreds of thousands of farms the economic signal to reduce their use of nitrogen and thus their nitrous oxide emissions.

This bottleneck would be particularly easy to use if it were politically feasible to include mineral nitrogen in **emissions trading across the EU**. Companies that manufacture mineral nitrogen or import it into the EU are then only allowed to market as much mineral nitrogen as they have emission rights. If they wanted to put more on the market, they would have to buy certificates on the stock exchange. The calculation methods of national emissions reporting can be used to convert “tons of mineral nitrogen” into “tons of CO_2 emissions”. In addition to the direct effects, indirect effects are also to be included (emissions from harvest residues as well as due to nitrogen losses into the air and nitrogen leaching).

The obligation of importers to participate in EU emissions trading is unobjectionable in terms of trade policy, because it does not relate unilaterally to fertilizer imports, but also to nitrogen fertilizers produced domestically in the same way. With the aim of protecting the climate, the state stipulates that every ton of mineral nitrogen that is placed on the EU market, regardless of its origin (domestic or foreign product), must have an emission right.

It is also important to emphasize that at this point we are only concerned with the surcharge that is based on the estimated greenhouse effect of nitrous oxide as a result of the use of fertilizer. The greenhouse gas effect of fertilizer production (CO_2 emissions from the Haber-Bosch process, N_2O emissions from saltpetre production) is already integrated in the ETS system or must be addressed by the climate policy of the country of origin. In this respect, mineral fertilizer is treated here in exactly the same way as, for example, gasoline: emissions from gasoline production are regulated in the country of manufacture, and emissions from gasoline use are regulated in the country of consumption.

While the EU-wide integration of mineral nitrogen into the ETS appears to be unproblematic from an administrative point of view, **greater difficulties** could arise if the regulation of mineral nitrogen is initially only to be implemented as a **national measure** of German climate policy. This applies both to the inclusion of mineral nitrogen in a national **CO_2 tax** and to the inclusion in a national **emissions trading system**.

The additional difficulties are caused by the fact that there is **free movement of goods** in the EU internal market without regular border controls. If fertilizers in Germany are made more expensive as a result of CO_2 pricing, there is a financial incentive for German farmers or traders to buy fertilizers cheaply in other EU member states and to transport them to Germany.

This problem arises in a **similar way in the transport sector**, where different national tax rates for fuels offer an incentive to buy fuels in a neighboring EU member state, where they are less taxed. Motorists make ample use of this, as can be seen at the petrol stations in the border regions (so-called “tank tourism”). Obviously, politicians have found ways to limit this type of arbitrage to the private customer area. But this is also relatively easy with fuels:

- On the one hand, for safety reasons, larger quantities of fuel may only be transported in special vehicles that are easily recognizable for everyone - and therefore also for the customs authorities.
- On the other hand, fuels are only marketed by a few groups. For a large oil company, it would be foolish to seek a small monetary benefit in "small border traffic" through fraudulent imports, because if the fraud becomes public, the long-term damage to image would be many times more significant.

In the case of mineral fertilizers, it is certainly a little more difficult for the state to completely rule out commercial arbitrage deals, but **effective control of the mineral nitrogen trade** should not be an insurmountable hurdle. Important to consider for scepticer is, if it is not even possible to effectively control the mineral nitrogen trade (with its few actors), an effective control of the individual-farm nitrogen surplus (with its many actors and complex issues) is certainly not possible (see chapter 3.2. 1). This would remove the basis for any nitrogen policy that an EU member state is supposed to pursue independently. The Member States would then only have the consequence to switch to “soft instruments” at national level (more advice, etc.) and moreover to intensify their efforts to achieve **EU-wide regulation of mineral nitrogen**.

In order to illustrate the **consequences of CO_2 pricing on the bottleneck of "manufacturers and importers of mineral nitrogen"**, we start with the following simplified example:

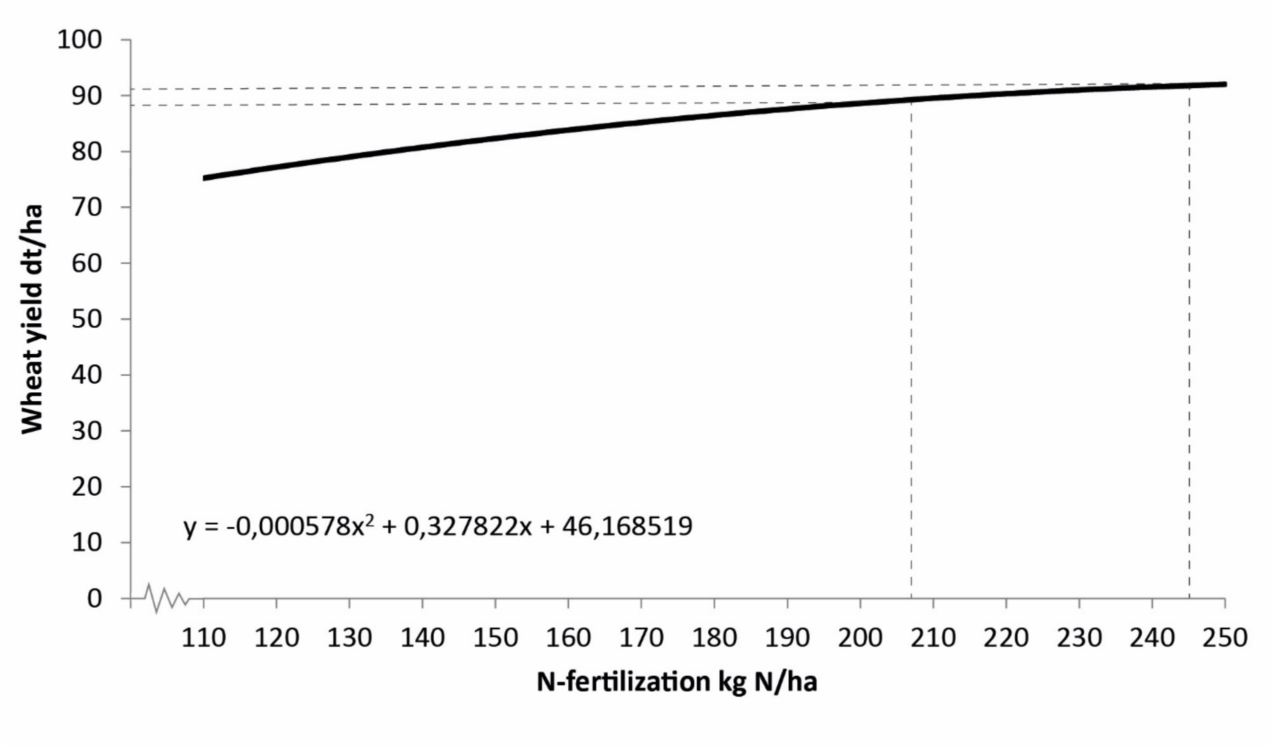
- The emission rights are completely hidden or fully covered with a CO_2 tax. Granting rights free of charge and the fertilizer manufacturers were not sinned, because the real goal of the lost ones is to pay the mineral nitrogen price and, in this way, to encourage a more economical use of mineral nitrogen. The price increase should not lead to increases in the profits of the fertilizer industry and commercial property. The settings from the auction or from the CO_2 tax are intended to increase public budget inflows, also to enable compensation, investments and innovation support services.

- The amount of the CO_2 tax is changed by the total nitrous oxide emission, which is one kilogram caused by the system. The emissions resulting from crop residues and nitrogen losses in the environment etc. also play a role in the tax on the amount of the CO_2 tax.
- If the emissions of nitrogen are included in the entire system in order to also consider the nitrous oxide emissions from harvest residues and indirect emissions into the air and water, the result is a conversion of 8 kg CO_2 equiv. / kg N. In the following, calculations are with this value.
- With the assumed CO_2 price of **25 or 100 € / t CO_2**, this scenario results in a price increase for mineral substances of **0.20 or 0.80 € / kg N**. For comparison: The current price for mineral nitrogen is **0.80 € / kg N**. The CO_2 pricing would reach the farmers as a price increase for mineral nitrogen of **25 or 100%.**

The **consequences for arable farming** should be illustrated for the 100% price increase scenario based on a typical constellation for the cultivation of winter wheat. Of particular importance is the question of how flexibly the use of nitrogen reacts to an increase in prices. There is a wide range of results here in the literature. The own price elasticities of N-mineral fertilizer demand are given in the literature as between -0.1 and -0.8, depending on the underlying assumptions (cf. Weingarten, 1996, and Ehrmann, 2017).

In order to illustrate the effect using a simple example, the following model calculation is based on an empirically determined yield function of modern winter wheat varieties. This is based on test data from Sieling et al. (2011). With the help of this yield function it will analyze, which yield effects are to be expected on different mineral fertilizer applications and how it effects a CO_2 pricing of mineral nitrogen(see Figure 1).

Figure 1: Effect of a doubling of the price for mineral nitrogen on the amount of nitrogen used in wheat production (production function of winter wheat)



Source: Own presentation in the basis of experimental data by Sieling et al. 2011.

- With an assumed wheat price of 18 € / dt and a mineral fertilizer price of 0.8 € / kg N, the optimal nitrogen fertilization is 245 kg N / ha. Farm manure is not considered here as a substitute for mineral fertilizer. [1]
- Due to the rise in the price of nitrogen by 0.8 € / kg to 1.6 € / kg N, nitrogen fertilization drops by more than 15 percent to 207 kg N / ha. Since the production function is very flat in the area of high N doses, the wheat yield only drops from 92 dt / ha to 89.5 dt / ha, i.e., by almost three percent. The costs of nitrogen fertilization increase from 196 to 331 € / ha, and the wheat revenue falls by 45 € / ha. Thus, the measure causes a financial burden on arable farming on the order of 180 € / ha, if we simplify the assumption that there are no further operational adjustments (e.g., changes to the seed, fertilization and plant protection management).
- With the assumed emission equivalent of 8 kg CO_2 / kg N, the nitrous oxide emissions drop from around 2 to 1.7 t CO_2 / ha. The economic costs are 15 € / ha (45 € / ha loss of wheat yield,

[1] On the basis of the production function, derived from test data for modern varieties by Sieling et al. 2011, we calculate the optimal use of mineral fertilizers at a wheat price of 18 dt / ha. For this purpose, the marginal yield of nitrogen is derived from the formula given in Figure 1, with a mineral fertilizer price of 0.8 € / kg N. This results in a mineral fertilizer use of 245 kg N / ha. If this is then inserted into the formula, the result is a wheat yield of 92 dt / ha. Then the marginal yield of nitrogen is calculated for a mineral fertilizer price of 1.6 € / kg N (0.8 € plus the CO_2 tax of 0.8 €). This results in an N input quantity of 207 kg N / ha, with a wheat yield of 89.5 dt / ha). This example gives a nitrogen demand elasticity of -0.16.

minus 30 € / ha saved nitrogen fertilizer). This results in CO_2 avoidance costs of 49 € / t CO_2 for this constellation. [2]

- With an N content of 1.81 kg N / dt wheat, the nitrogen excess in the initial situation was 78 kg N / ha, after the introduction of CO_2 pricing it was 45 kg / ha.

It should be emphasized that this is a model calculation, the sole purpose of which is to exemplify the essential relationships. In particular, the values for the CO_2 avoidance costs or the N surpluses can vary greatly depending on the local conditions. The calculation is also based on an example for winter wheat for trial areas in Schleswig Holstein. The decline in productivity can vary significantly in other regions and for other crops. In this simplified representation it is also not shown which cumulative effect can be expected if areas are supplied with less nitrogen over longer periods of time. Effects on the N fertilizer level in farms with heavy over-fertilization are also not considered here.

In spite of all the restrictions, an interim conclusion can be made: A CO_2 price of the mineral nitrogen in the order of 100 € / t CO_2 gives rise to clear incentives to limit overfertilization and improve N utilization.

A rise in the price of mineral nitrogen by 100 percent would also have **consequences for livestock farming**. Livestock farms usually have a much higher nitrogen surplus than arable farms. The rise in the price of mineral nitrogen means a strong incentive for them to make the liquid manure available specifically for plant growth and thus to be able to practise largely without mineral fertilizers. In addition, arable farms that do not have livestock are increasingly turning to livestock farms in order to buy farm manure and thus save mineral fertilizer costs. In this way, the rise in the price of mineral nitrogen contributes to the fact that more and more farmers **turn manure from a waste product into a valuable resource**.

How the magnitude of this indirect effect of a CO_2 pricing of mineral nitrogen (100 € / t CO_2) is to be assessed is illustrated using a few general figures for the example of **pig fattening**. With an elimination of approx. 11 kg N / fattening place and year, and a nutrient utilization of 40 percent for plant growth, a higher valuation of nitrogen by 0.80 € / kg N leads to an additional income contribution of around 3.5 € per fattening place. This corresponds to only approx. 0.7 percent of the fattening pig revenue, but at least 5 to 7.5 percent of the direct cost-free service and in many farms more than 25 percent of the profit that can be achieved from pig farming.

However, it should be added that the strong **regional concentration of livestock farming** often limits the reasonable use of liquid manure nitrogen. Long-distance transport of the manure is not economical even if the price of mineral nitrogen doubles, since the nitrogen content of the manure

[2] Costs per ha: loss of yield x price (2.5x 18 = 45 €) - N input reduction ((245-207) x 0.8) = 15 € / ha; CO_2-eq reduction: 8x38 N reduction = 0.304 t CO_2 / ha => 49 € avoidance costs per ton of CO_2 from N

is low (approx. 5 kg N / m3) and a lot of water has to be transported. In the “medium-haul range”, however, the transportability of manure increases noticeably due to a CO_2 price of 100 € / t CO_2, as the following rough calculation shows. The transport costs of 1 kg of manure-N are in the order of 0.02 € / km. If the price of mineral nitrogen increases by 0.80 € / kg N, **the distance over which liquid manure can be transported profitably increases by around 40 kilometers** compared to the previous "borderline location." In addition, technological innovations are encouraged (e.g., for thickening of liquid manure) in order to reduce the costs of nutrient transfer to the arable regions.

The illustration of the income effects for an arable farm and a processing company has shown that CO_2 pricing of mineral nitrogen leads to **very different income effects**. While a loss of well-over 100 € / ha can be triggered on a high-yielding farm in an arable farm, the neighboring processing company can possibly book an additional profit contribution through the CO_2 pricing. It is to be expected that **demands will be made for compensation for income losses**. The state generates additional income that it could use for this. However, it will not be easy to do justice to the different levels of impact of different types of farms.

The **agricultural structural effects** will be minor in the regions with high livestock numbers. On the other hand, if there is no financial compensation, there will be an increased structural change in farm size in the arable farming regions. Whole arable farming regions are not expected to fall fallow, however, because the basic rent will decrease significantly as a result of the CO_2 pricing, but it will still remain clearly in positive territory. The profitability of livestock farming in arable regions is increasing. Whether or not this leads to an expansion of animal husbandry there, it depends primarily on whether politicians in Germany succeed in achieving a social consensus on the future of livestock husbandry (see in detail: Isermeyer, 2019).

A one-sided burden on the mineral fertilizer purchases leads to incentives to expand animal husbandry and to import more nitrogen in the form of animal feed into the agricultural sector. In addition, it becomes less attractive to practice N-reduced feeding methods. Such side effects of the rise in the price of mineral nitrogen are counterproductive from a climate policy perspective. For this reason, the following chapter will examine how the nitrogen flows from animal husbandry can also be integrated into CO_2 pricing.

3.2.3 Supplement: CO_2- pricing of feed, farm animals or the consumption of animal foods

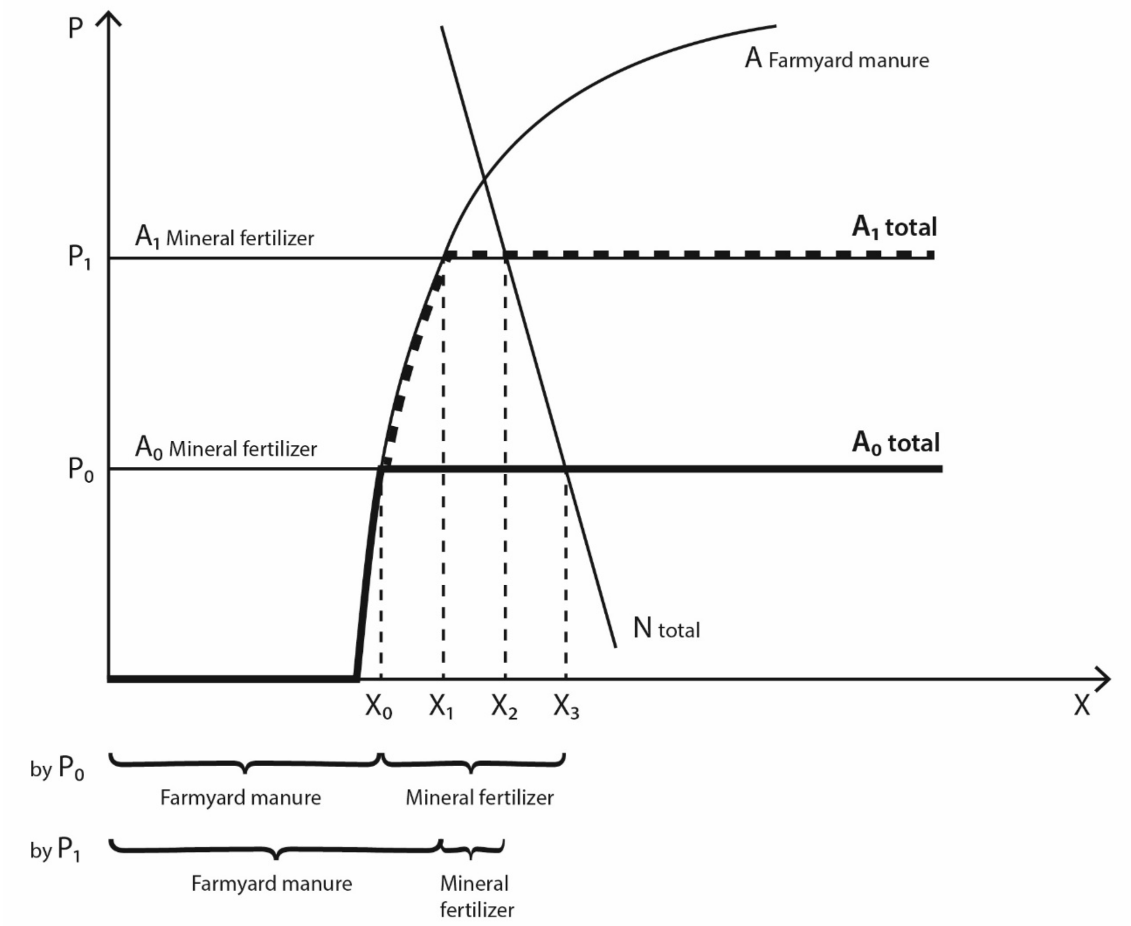
Reactive nitrogen compounds essentially enter into the German agriculture via two market channels: around **1.7 million t of N** come from the purchase of **mineral nitrogen fertilizers**, and around 1.1 million t from the purchase or own use of marketable **animal feed** (e.g., grain, rapeseed meal, soybean meal), of which **0.4 million t are from imported feed**. There are other ways (e.g., conversion of atmospheric nitrogen by grass clover), but they are of relatively little importance in terms of quantity.

3.2.3.1 Is CO_2-pricing of N fluxes in livestock husbandry even necessary?

At first glance, it does not seem necessary to charge manure nitrogen, because the price increase for the mineral nitrogen generates a **proportional increase in value** for the manure nitrogen via the market mechanism. The scarcity signal also reaches the livestock farms. Then why an **independent policy measure** to make manure nitrogen more expensive? In order to systematically clarify this question, Figure 2 first shows how nitrogen supply and nitrogen demand behave depending on the nitrogen price:

- In the initial situation, the price for mineral nitrogen is P_0. At this price, retailers offer any amount of nitrogen, so that the horizontal line can also be interpreted as a supply curve for mineral nitrogen.
- The supply curve for manure nitrogen starts far to the right and is steep at low prices. This shows that livestock husbandry and thus the production of manure generally do not depend on the nitrogen price, but on other factors (above all: the price of animal food). Farm manure occurs as a by-product and is also offered at a nitrogen price of zero. With rising nitrogen prices, **more manure is offered** for plant nutrition **without first having to expand animal husbandry**. In this area, the supply curve expresses the fact that the existing liquid manure can be used much more efficiently (liquid manure storage cover, liquid manure processing, more targeted liquid manure spreading, etc.), which, however, causes increasing marginal costs. If the nitrogen prices rise even further, the manure proceeds will become an **increasingly important by-product** of livestock farming, so that the slurry revenues will provide an **increasing incentive to expand animal husbandry** and to **worsen feeding efficiency** through N-rich feed rations. These effects are counterproductive in terms of climate policy.
- The total supply curve for nitrogen results from the horizontal addition of both curves (here: the curve marked in bold).
- The demand curve shows the usual downward trend. This expresses that the marginal productivity of nitrogen in crop production is high with small amounts of nitrogen and then decreases in accordance the higher the level of nitrogen use already is.
- In the initial situation, the price P_0 ensures that the nitrogen input from farm manure is X_0. The amount (X_3 - X_0) missing to cover the total demand X_3 is bought in as mineral fertilizer.
- If the price of mineral fertilizer doubles (P_1), the supply of manure nitrogen increases from X_0 to X_1, while the total demand for nitrogen fertilizer falls from X_3 to X_2.
- The expansion of livestock farming leads to an increase in nitrogen emissions from manure. However, this is not a problem for achieving the climate policy goal of “reducing the total amount of nitrogen in German agriculture”, since the use of mineral fertilizers is being disproportionately reduced.

Figure 2: Effect of a price increase for mineral nitrogen on the amount of mineral and farm manure used



Source: Own design.

From this analysis, however, it **cannot be concluded** that a separate policy measure for the **CO_2 pricing of manure nitrogen might be unnecessary**. There are two important points to consider here:

- **Spatial concentration of livestock farming.** In the model, the higher mineral nitrogen price pulls the value of manure nitrogen up with it, because it was assumed that livestock farming and arable farming take place in close proximity to one another. In reality, a significant part of livestock husbandry takes place in refining regions that are far removed from the arable farming regions. Due to the high transport costs for liquid manure, it is still not profitable to transport the liquid manure to the arable regions despite the doubled mineral nitrogen prices. The manure remains in the surplus regions and the arable farmers substitute less mineral nitrogen with manure nitrogen than this would be the case of a spatially balanced distribution of animal husbandry.
- **Leakage.** In the model, a sharp rise in the price of mineral nitrogen means that livestock farming is expanded in Germany and feed with higher nitrogen contents is used - ultimately in order to

mobilize additional nitrogen for plant nutrition via additional feed. The expansion of livestock farming leads to falling product prices for meat and milk and to increasing consumption of these products. In total, more feed must then be produced than before. This does not happen in Germany, however, as the nitrogen tax leads to a restriction of nitrogen fertilization, crop production and nitrous oxide emissions (see figure 2). So feed imports will increase, and with them also nitrous oxide emissions in those parts of the world in which the additional feed is produced.

Both points speak in favor of including the nitrogen flows in animal husbandry with an independent policy measure in the CO_2 pricing in order to counter the negative effects of isolated pricing of the nitrogen mineral fertilizer. The **challenge** is to find suitable **bottlenecks** for this (or other recording points at which the required economic data can be measured) **in a judicial manner and with manageable effort**).

3.2.3.2 Option 1: CO_2-pricing of animal feed

Before thinking about targeted political measures to increase feed prices, it is important to first consider whether this **price increase is not automatically an indirect effect of the mineral nitrogen tax**.

In a **closed economy without foreign trade**, this would undoubtedly be the case, as can be illustrated using the example of "100 € / t CO_2 for mineral nitrogen in wheat" (see chapter 3.2.2). The full costs of wheat production (at the farm gate) roughly correspond to the producer price for wheat, which means in the initial situation prices are 1,656 € / ha or 18 € / dt. The CO_2 price for mineral nitrogen increases the price of wheat cultivation by 184 € / ha, and the yield drops by 2.5 dt / ha. Thus, the production costs increase to almost 20 € / dt. In a closed economy, the grain producers would pass this increase in production costs of around 10% on to the downstream stages of the value chain, so that they would ultimately reach consumers (for bread, eggs, meat, etc.) as price increases.

This chain of effects does not occur with **open borders**. If Germany alone undertakes CO_2 pricing for mineral nitrogen, the grain producers cannot pass on their cost increases in the form of higher prices, since the buyers would then switch to foreign products. The national drop in yield (approx. 3% in the wheat example) would hardly be of any consequence in the EU internal market, since Germany only has a production share of just under 15%. The price increase which a national production decline of 3% could trigger, would thus remain well below 1%. In the case of EU-wide CO_2 pricing for mineral nitrogen, the effect on feed prices could be significantly higher - but only if the EU's external borders were protected by high tariff walls. This is not the case for animal feed, especially not for oilseeds (including soy). A zero duty rate is set for these products.

The interim conclusion is thus: The CO_2 pricing of mineral nitrogen has hardly any impact on the price level for marketable feed. For climate protection policy, it remains to be investigated whether politicians can find a way to intervene directly in price formation through a CO_2 tax or an emissions trading solution.

Consistency with the recording of mineral nitrogen can best be achieved if politicians choose non-agricultural companies that place feed on the market as addressees. For each feed, based on its protein content, an estimate would be made of how high the nitrous oxide emissions are likely to be at the end of the functional chain in the barn, manure store and the field, and this value would then be converted to CO_2 equivalents. In the "emissions trading" scenario, companies are then only allowed to market as much feed as they have corresponding emission rights, and in the "CO_2 tax" scenario they would have to pay the calculated tax rate for all feed sold.

Both scenarios mean that protein-containing feed in particular is becoming more expensive for farmers. This counteracts the economic incentive to expand livestock farming and to rations that are richer in nitrogen, which would arise from the CO_2 pricing of mineral nitrogen. It also provides an economic incentive to reduce nitrogen excretion from livestock husbandry (e.g., better feed conversion; multi-phase feeding; nitrogen-reduced feed).

A major challenge, however, is to correctly define the target group "those who place feed on the market". While the **CO_2 pricing of mineral nitrogen could be administered in the same way as the mineral oil tax**, only a few companies are active in the market, meaning the **CO_2 pricing of feed cannot extend to the entire feed trade**. In the case of feed there is a very heterogeneous structure of the trading companies, and a consistent inclusion of all feed flows would ultimately require that feed trade between farms also be taken into account. This is hardly possible administratively.

In order to achieve the desired concentration on "bottlenecks", politicians could consider limiting pricing to the trade in protein feed. Oil mills and importers then come into question as addressees. Together with the mineral fertilizer, this would integrate about three quarters of the nitrogen supply in the German agricultural sector. However, this does not completely close the loopholes. If the CO_2 pricing of feed leads to high feed prices in Germany, the economic incentive increases that (a) German livestock farmers procure protein feed directly from neighboring EU member states, (b) German arable farmers grow more and more protein crops, or (c) livestock farming is relocated from Germany to other member states of the EU. In the case of an EU-wide climate protection policy, the inclusion of animal feed would certainly be easier to implement, since there are fewer relocation effects in the internal market.

From an administrative point of view, it would be easiest to plan the CO_2 pricing of feed only for imported feed, because there is a bottleneck that is very easy to administer. However, this option is not feasible for reasons of trade policy, as it discriminates against imports compared to the EU's own production.

3.2.3.3 Option 2: CO_2-pricing of livestock

The second option for including manure nitrogen in the CO_2 pricing is to select **“agricultural operation” as the addressee and “number of livestock” as the control parameter**.

With this concept, the state would have to control a large number of the addressees (farms) so that one cannot speak of a “bottleneck” here. At the same time, the administration costs and the legal risks can be kept low, since the **number of livestock can be recorded relatively easily and reliably**. In any case, the cattle census takes place regularly for official statistics. In addition, animal welfare and animal disease policy are placing increasing demands on reporting on each individual animal. A database already exists here that could be used for climate policy at a reasonable cost. With the help of **species-specific flat-rate values**, each animal would be assigned an amount of nitrogen, which would then be the basis for CO_2 pricing.

For a rough impact assessment, the following nitrogen emissions can be assumed for selected typical animal husbandry methods in Germany (basis: stable space-related N excretion values of the Fertilizer Ordinance):

- Dairy farming: 14 kg N /1,000 l milk
- Laying hens: 2.5 kg N / 1,000 eggs
- Bull fattening: 140 kg N / t slaughter weight
- Pig fattening: 55 kg N / t slaughter weight
- Chicken fattening: 20 kg N / t carcass weight

"CO_2 prices" for nitrous oxide emissions can be calculated from these values by using the conversion factor of 8 kg CO_2 / kg N (see Chapter 3.2.2) and assuming the economic CO_2 price. The values for a **CO_2 price of € 100 / t** are shown below. To illustrate the order of magnitude, the calculated values are also set in relation to the producer prices of the products sold. The producer prices correspond roughly to the production costs of a product (at the farm gate).

- Dairy farming: 11 € / 1,000 l milk (corresponds to 3.4% of the producer price)
- Laying hens: 2 € / 1,000 eggs (corresponds to 1.3% of the producer price)
- Bull fattening: 112 € / t slaughter weight (corresponds to 3.3% of the producer price)
- Pig fattening: 44 € / t slaughter weight (corresponds to 12.5% of the producer price)
- Chicken fattening: 16 € / t slaughter weight (corresponds to 1.3% of the producer price)

- If the state **auctions the emission rights** or introduces **a CO_2 tax**, the financial amounts shown are direct cost increases on the farms. If the state surrenders the emission rights to the farmers **free of charge**, the farmers receive an additional asset title that they can either use to continue their animal husbandry or sell in emissions trading. If you now calculate whether you want to continue to keep livestock, you have to invoice the "livestock" production process for the lost revenue for the sale of your emission rights (opportunity costs). The same calculation is to be made for the state **climate protection premium**. Conclusion: Regardless of whether the CO_2 pricing for farmers is designed to reduce or increase income, it weakens the competitiveness of animal husbandry in Germany.

If Germany were to go it **alone at national level**, this would be directly relevant. In this case, German farmers would not be able to pass on their cost increases in the form of higher prices to the downstream stages of the market, since farmers from other EU member states can continue to produce without this cost burden and can therefore offer them at low prices. Does the CO_2 pricing lead to a competitive disadvantage for German livestock owners, which sooner or later leads to a relocation of production shares to other regions of the EU **(leakage effect)? Only at first glance**. The inclusion of livestock farming in CO_2 pricing discussed here has the purpose of compensating for the economic incentive to expand German livestock farming that would be triggered by the CO_2 pricing of mineral nitrogen (see chapter 3.2.2).

This purpose is achieved with those animal keepers who are **outside the concentration areas** of livestock husbandry. Here the competitive advantages due to the higher valuation of farmyard manure and the competitive disadvantages due to the burden on livestock farming are roughly balanced, and in the case of a CO_2 tax on farm animals, the income advantages and disadvantages would also be roughly balanced. The situation is different **within the concentration areas**, however: Here the economic incentives that emanate from CO_2 pricing for mineral nitrogen do not even arrive, because the high costs of slurry transport prevent this (see chapter 3.2.2). So there is no incentive here to expand livestock farming that would have to be compensated. Thus, the CO_2 pricing of the livestock leads to an incentive to reduce livestock farming, and a CO_2 tax or an auction of emission rights also have an undiminished effect on the income of the livestock owners.

The state could avoid this reduction in the income of livestock farmers by opting for one of the two options **"free emission rights" or "climate protection bonus"**. However, both options have a **serious disadvantage** if they are to be used permanently in the field of livestock husbandry. It must be politically determined who is allowed to benefit from these emission rights. This may still be easy in the first year because the policy can use a cut-off date regulation to orientate itself on the previous distribution of livestock husbandry. In the following years, however, this becomes more and more difficult because in the course of structural change, more and more farm managers would apply for such emission rights or premium claims: cattle farms willing to expand, young farmers, arable farmers who want to diversify, etc. So an **allocation mechanism** like ours would have to be established as well-known from previous quota systems (e.g., guaranteed milk quantity regulation). It is questionable whether political majorities can be found for this - especially since many citizens believe that this free issue of "pollution rights" would not do justice to the polluter pays principle.

These income and leakage aspects will certainly play a major role in the political discussion about CO_2 pricing for livestock. In addition, there are **three other criticisms** of this policy proposal that should be taken into account in the overall assessment:

- Within a species, each animal is "priced" with the same flat rate and not based on the actual emissions. This policy measure therefore gives farmers no incentive to innovate to reduce emissions (e.g., multi-phase feeding; change in slurry management). They can only react to the policy measure by reducing their livestock or switching to another branch of livestock farming that causes fewer emissions.
- The use of uniform flat rates per animal supports the trend towards higher and higher performance per animal, as farmers can then produce a certain amount of meat or milk with fewer animals (i.e., less CO_2 taxes). This effect of the policy measure would be questionable under animal welfare aspects.
- A differentiation of the excretion values depending on feeding and animal performance, as provided for in the Fertilizer Ordinance, would make it necessary to collect and control individual farm data.

3.2.3.4 Option 3: CO_2-pricing of the consumption of animal products

Since it is not easy to find a suitable control parameter for the CO_2 pricing of manure nitrogen at the production level, the CO_2 pricing of the consumption of animal foods should also be considered as a further option.

It would be practical here to levy a consumer tax on foods of animal origin. This would be possible with little administrative effort by designing the levy as a **surcharge on the VAT**. Such a CO_2 (or N_2O) tax is unproblematic from a trade point of view, since domestic and foreign origins are equally affected. [3]

The effect of this taxation on climate policy is that the consumption of the taxed products falls, which leads to falling product prices, falling production and falling emissions. The policy measure does not specifically affect German production sites. Whether production and the associated emissions in Germany or abroad will decline at all depends on the competitiveness of the production sites. For this reason, the emission reduction triggered by this measure is only partially reflected in German greenhouse gas reporting. This measure would not have a targeted control effect on the

[3] Banse and Sturm (2019) show that the introduction of a CO_2 consumer tax on red meat and dairy products leads to relatively high emission savings, but these emission reductions only partially take place in the EU.

production and feeding processes in animal husbandry and the introduction of emissions-reducing innovations.

The above calculations have shown that the CO_2 pricing of manure emissions at **100 € / t CO_2** - if one only considers the greenhouse gas nitrous oxide - would increase production costs at the farm level by between one and four percent. Roughly calculated, this corresponds to a **consumer price increase of between 0.5 and 2 percent**. If a **CO_2 price of 25 € / t CO_2** is calculated, the price increases at the producer and consumer level are correspondingly lower (**consistently below one percent**). Since these relatively small price changes only have a minor steering effect on consumption, it is politically hardly possible to bring about a change in VAT using the argument “laughing gas from farm manure” alone.

However, if one takes a look beyond laughing gas and includes the greenhouse gases methane and carbon dioxide in the analysis, there are also arguments in favor of changing the VAT legislation (see sections 3.3 and 3.4). It should also be borne in mind that the discussion of policy options for national animal welfare policy has led to the recommendation to introduce an animal welfare premium and possibly provide counter-financing via a changed VAT regime (cf. Isermeyer 2019). It therefore makes sense to pursue the **VAT adjustment as part of an ecological tax reform**, which then enables positive target contributions for several protected interests of politics (more animal welfare and fewer emissions of nitrous oxide, methane and carbon dioxide).

3.3 Methane

While carbon dioxide and nitrous oxide emissions still have a greenhouse gas effect many decades after their emission, methane only stays in the atmosphere for a relatively short time of 12 years. During this period the greenhouse gas potential of methane is very high: In the fifth assessment report by the IPCC, a global warming potential (GWP) of 84 was determined for a period of 20 years. In order to create a conversion option between long-lived and short-lived greenhouse gases for practical climate policy, an agreement was reached on a comparison period of 100 years. In relation to this period, methane is estimated at a GWP of 25 in the current greenhouse gas inventories, which are also used as the basis for the calculations in our work report.

In some publications in the recent past, the question has been raised whether methane should not be treated differently in climate policy than the long-lived greenhouse gases (e.g., Allen et al., 2018) due to its short life. Business associations take this up and emphasize that a reduction in methane emissions has a “cooling potential”. While a non-emission of carbon dioxide “only” leads to the greenhouse gas concentration in the atmosphere not rising any further, a non-emission of (previously regularly emitted) methane causes the greenhouse gas concentration to decrease due to the atmospheric chemical degradation of the methane already present there. In this way, the associations try to stake distribution policy claims: The climate protection policy should not punish (or tax) methane emissions, but reward omitted methane emissions as a climate protection achievement.

In principle, CO_2 pricing can deal with this. It can either work with taxes or with climate protection premiums, and in emissions trading it can either allocate the emission certificates to the companies free of charge or auction them off (see chapter 3.4). The climate policy goal is achieved in all cases: The economic actors are given an incentive to avoid methane emissions. This goal continues regardless of the current debate about the short life of methane emissions, because the reduction of methane emissions is without a doubt an important sub-goal in order to achieve the overarching 1.5-degree target. Due to the high GWP value during the first 20 years, the reduction of methane emissions plays a particularly important role in order to achieve a limiting effect on global warming in the short term.

The current debate about the short-lived nature of methane therefore has no influence on the target, but only on which tool is taken from the toolbox (tax, bonus, free allocation or auctioning of rights). At the 24th World Climate Conference in Katowice, it was decided, as part of the international set of rules for recording and reducing greenhouse gases, that the GWP 100 values from the Fifth Assessment Report of the IPCC (AR5) should be used. Methane is assigned a GWP of 28 in the AR5. In the EU, the GWP value of 25 applies for methane until further notice. Whether and when new GWP values will be set at international level (higher or lower than 28) remains to be seen.

Most of the methane emissions are caused by the ruminants, a smaller part is generated in liquid manure or digestate storage facilities that are connected to animal husbandry or biogas plants. In the following only the ruminant problem is discussed; With regard to the liquid manure and digestate storage facilities, it is assumed that sooner or later a gas-tight cover will be prescribed (possibly flanked by government investment subsidies) and that it will therefore not be necessary to integrate it into CO_2 pricing.

In the case of ruminants, climate protection policy does not have the option of precisely recording the methane emissions of each individual animal and including them in emissions trading. In this respect, the only way to determine the assessment basis for climate policy instruments (taxes, subsidies or emission certificates) is to start from **default emission values per cow, sheep or goat**. Thus, the policy measure is designed very similarly to the limitation of N emissions from farm manure explained in chapter 3.2.3.3, and the impact assessment and assessment are also very similar.

In order to be able to calculate the magnitude of the pollution, we assume the following emissions for typical constellations of dairy cattle and fattening bull farming (basis: values from national greenhouse gas reporting):

- Dairy farming: 21 kg CH_4 / 1,000 l milk
- Bull fattening: 200 kg CH_4 / t slaughter weight

With a CO_2 price of 100 € / t and a conversion factor of 25 t CO_2 / t CH_4, the following "CO_2 prices" are calculated:

- Dairy farming: 52.5 € / 1,000 l milk (corresp. 15,9% of producer price)

- Bull fattening: 500 € / t slaughter weight (corresp. 14,8% of producer price)

At a CO_2 price of 25 € / t, the values are correspondingly lower (13.1 € / 1,000 l milk and 125 € / t slaughter weight), which - in relation to the producer price - still accounts for around 3 percent. For cattle husbandry, it can be stated that the inclusion of **methane** in the CO_2 pricing has a much **greater relevance for economic efficiency** than the inclusion of nitrous oxide.

When designing climate policy, consideration should be given to not only working with a single flat rate per animal species, but also using **differentiated default values**. Here, however, the problem immediately arises again that such a differentiation should only be implemented if easily administrable, justiciable indicators are available for this. In dairy farming, this could be the herd's **average milk yield**. With increasing milk production per cow, the methane emissions per liter of milk decrease significantly. The above CO_2 price of 5.25 ct / l milk was calculated for a milk yield of approx. 8,000 l / cow; at 6,000 l / cow the result is 6.36 ct / l, at 10,000 l / cow 4.61 ct / l (own calculation based on Flachowsky and Brade, 2007).

Conflicts of goals between environmental and animal welfare can be identified here. The staggered CO_2 pricing offers a financial incentive to further increase the milk yield per cow. Since there is a positive genetic correlation between milk yield and various diseases (including hoof diseases) in dairy cows (Brade and Brade, 2014; Fleischer et al., 2001), the risk of the animals becoming ill and therefore having to be slaughtered prematurely increases. In this case, however, the fact that farmers would have to raise more heifers for remounting would have to be offset; they would then possibly come to the conclusion that the increased milk yield does not constitute a profitable adjustment to the CO_2 pricing for them.

The same relationships apply to the choice of climate policy instrument that we discussed in section 3.2.3.3 for manure pricing: If the state auctions emission rights or introduces a **CO_2 tax**, the financial amounts shown lead to an additional financial burden on the agricultural farms. You can avoid this burden by reducing the number of livestock. If the state allocates the **emission rights free of charge** or offers the farmers a **climate protection premium** for the fact of "avoiding emissions", the farms are not burdened financially, but receive an additional business option. You can take advantage of this option by reducing the number of livestock. The intra-farm **competitiveness of ruminant farming is reduced in any case** - regardless of whether the climate policy measure is designed as a CO_2 tax, an eco-premium or an inclusion in emissions trading.

With the design options “free allocation of emission rights” and “climate protection bonus”, it would also have to be regulated here which group of people should benefit from these monetary rights for which action and for which period. Since permanent free allocation is problematic in terms of distribution policy, a cut-off date solution would probably be considered.

The CO_2 pricing of methane emissions from ruminants could trigger a **strong leakage effect**, especially if a **relatively high CO_2** price emerges (cf. the figures for the scenario 100 € / t CO_2), provided that other EU countries or third countries should pursue climate protection goals less ambitiously. Ruminant farming would then gradually move to locations where it is not sanctioned. The German greenhouse gas balance would be improved by this shift, but the actual climatic benefit of the measure would be very small.

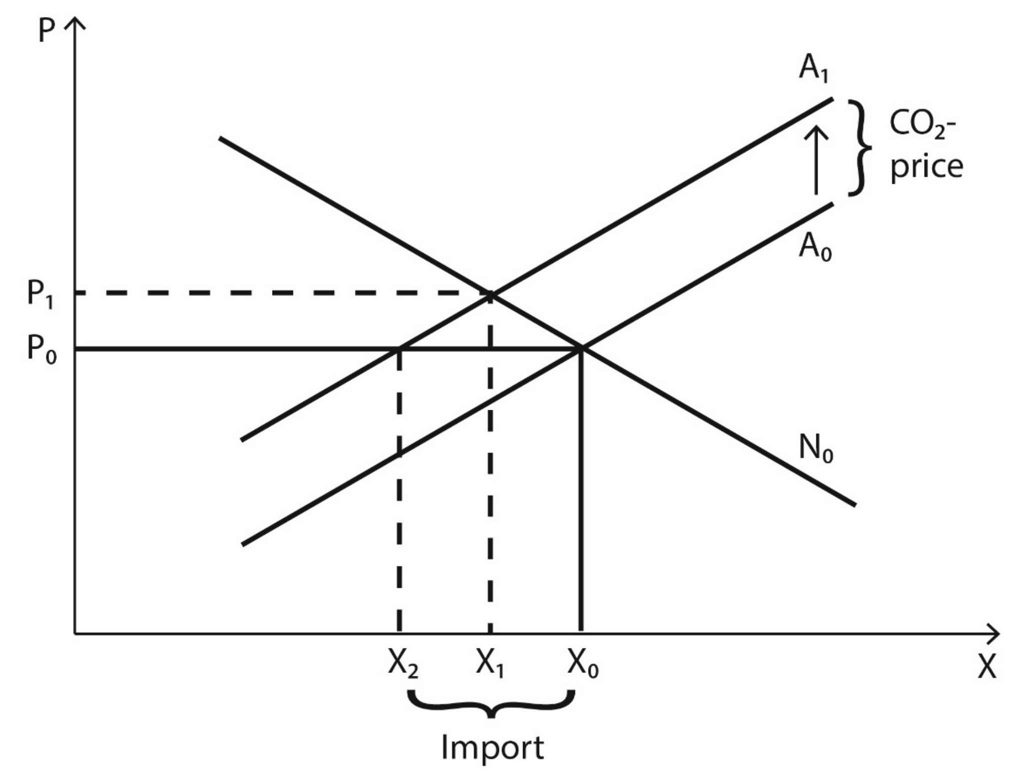
The leakage effect can be explained using a simple example with the help of Figure 3:

- The figure shows schematically how the production and consumption quantities for milk develop depending on the milk price. The supply curve (A_0) is the aggregated marginal cost curve of all EU producers; the higher the milk price, the greater the amount offered. The demand curve (N_0) is the aggregated willingness to pay curve of all consumers; the higher the milk price, the lower the amount demanded. In the initial situation, the price P_0 is set, and at this price the quantity X_0 is produced and consumed.
- To keep the presentation simple, it is assumed that (a) the equilibrium price is identical to the current world market price and (b) at this price the EU's degree of self-sufficiency is exactly 100%. In fact, it is currently around 114%. The EU is a net exporter of milk products.
- In the simplified model world, the CO_2 pricing in the EU means that the production costs of all dairy farmers increase significantly. The supply curve shifts upwards accordingly. Those farmers whose milk production was already at the limit of profitability (so-called marginal producers) will only continue their production if the milk prices rise by at least the amount of the CO_2 price.
- In a closed economy (without foreign trade), however, the price will not rise as much because demand falls when prices rise. A new market equilibrium is thus established (P_1 | X_1). The price is higher than before, the production and the consumption volume is lower than before.
- In an open economy, the rise in EU prices mobilizes milk imports from third countries. The extent of these imports depends on the nature of the world marginal cost curve. In the short term, the elasticity of supply is naturally limited, but as the adjustment period increases, the global supply can prove to be very elastic. Let us consider the extreme case in which the global milk volume can be expanded over the long term at constant marginal costs: In this case, the EU price remains at its previous level P_0, so that the consumption level does not change either (X_0). Domestic production is based on quantity X_2, and the difference to previous production is covered by imports (X_2 - X_0).
- In this constellation, i.e., with a very elastic world market supply, the CO_2 pricing in the EU remains ineffective in terms of climate policy. It essentially only leads to a relocation of an emission-intensive branch of production to another location.

The leakage effect would not occur or would only be greatly reduced if CO_2 pricing were already widespread worldwide, because then methane emissions from cattle would not only have an impact in the EU, but everywhere, increasing costs (see section 2.2). As long as this is not the case, Germany and the EU must think about **alternative ways** to enable the desired climate protection effect, but at the same time **avoid "senseless" adaptation reactions**.

In the constellation on which Figure 3 is based, the EU could counteract the relocation of production shares by levying a **climate protection tax on imported dairy products**. The imports would then not disturb the development of the new internal EU market equilibrium (P_1 | X_1). The rise in prices means that EU production falls by the amount X_2 - X_1 and the total emissions of world milk production decrease accordingly. This measure would likely lead to trade disputes, but the EU could take the position that domestic milk production is also burdened by the CO_2 pricing of methane emissions and that there is no discrimination against imported products.

Figure 3: Effect of CO_2 pricing for production (a) in a closed economy and (b) with foreign trade with a completely elastic world market supply



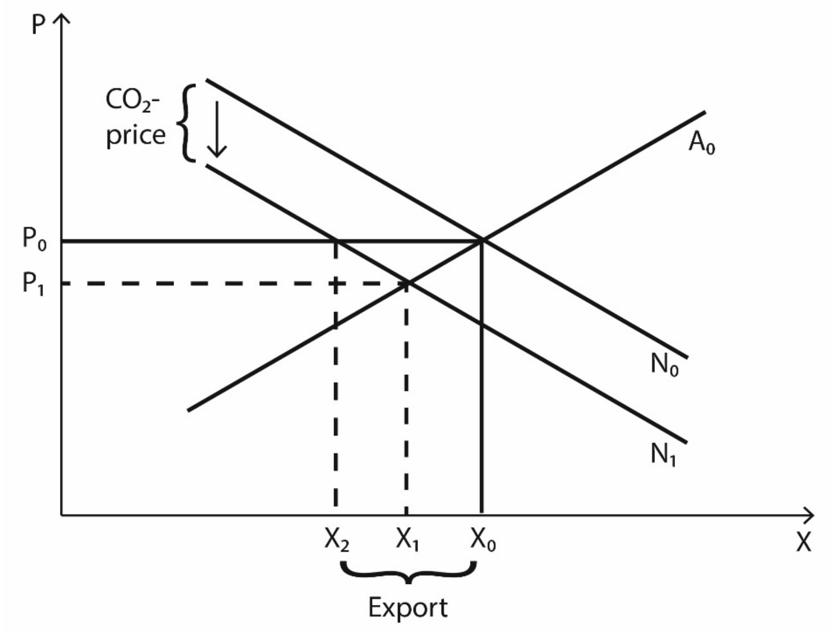
Source: Own design.

The **current market reality** deviates from the "model world" in Figure 3 because the EU is a **net exporter of dairy products**. There are no imports of any significant level, and therefore a climate protection tax on imports cannot (yet) have any effect. The EU produces at **world market price level**; otherwise it would not be able to export its products, because the earlier export subsidies have long since been abolished. In this constellation, CO_2 pricing for methane emissions in the EU would initially result in EU producers suffering cost disadvantages and therefore production shares being relocated from the EU to third countries in which methane emissions are not sanctioned by climate policy. During this shift, the EU price will initially remain at the low world market price level. The **CO_2 pricing in the EU is ineffective**, as consumption in the EU remains high and the methane emissions, which are restricted in the EU, now take place in third countries. This situation will only change fundamentally when milk production in the EU has decreased by more than 14%. Then the

EU will become a net importer of milk products, and the climate protection levy on imported milk products can set EU price levels apart from the world market. These comments apply accordingly to beef, although the EU is already a net importer here.

An **alternative solution** option consists in not adding a CO_2 price to methane emissions in agricultural production, but instead **making the consumption of products more expensive**, the production of which has led to methane emissions (milk and meat from ruminants). As already explained in chapter 3.2.3.4, the easiest way to do this is to change the VAT rates. Such a CO_2 (or CH_4) tax would be unproblematic from a trade point of view, since domestic and foreign origins would be equally affected. It could also be carried out as a **national solo effort** without a regional relocation of cattle farming within the EU internal market.

Figure 4: Effect of a taxation of consumption (a) in a closed economy and (b) with foreign trade with a completely elastic world market supply



Source: Own design.

How an EU-wide consumer tax on dairy products would work is shown in Figure 4. The same simplifying assumptions apply here as in Figure 3. The demand curve (originally N_0) is shifted down, since consumers also have to pay the CO_2 tax in addition to the milk price. In a closed economy this would lead to a decline in producer prices, domestic demand and domestic production; the new market equilibrium is P_1 | X_1 instead of P_0 | X_0. With open borders, however, the decline in production will be less or entirely obsolete, since production is not burdened.

The extreme case of a completely elastic world market is shown in the figure: The price relevant for the producers remains at P_0, because the producers are not directly affected by the CO_2 tax and can continue to export at world market conditions. So they continue to produce the amount X_0.

Domestic consumption falls to X_2 due to the CO_2 tax (demand curve N_1, price P_0), so that the amount X_2 - X_1 is exported. Production at third country locations is reduced by this amount due to the completely elastic supply (assumed here for the sake of simplicity), with corresponding advantages for climate protection.

This example makes it clear: CO_2 pricing at the consumer level is definitely beneficial for **global climate protection**, but this advantage is not, or only partially, reflected in the **German national greenhouse gas balance**. In the example shown, the German greenhouse gas balance does not improve at all because the extreme situation of a completely elastic third country supply was assumed. In this constellation, the German CO_2 consumption tax induces a negative leakage effect, i.e., the local climate policy does not lead to an increase in third country emissions, but to a decrease. This positive effect cannot be reported in the system of the Paris Agreement, since the Paris Agreement was sensibly based on territorial emission inventories (source categories).

Now that the leakage problem has been explained in detail, the question arises what consequences German climate policy should draw from it. The following **interim conclusion** for the subject of "methane" can be made here:

- The ideal situation is that an **ambitious climate policy** is implemented **worldwide** as quickly as possible. The leakage problem then does not occur at all. The conclusion for German climate policy is therefore: Highest priority for a climate protection policy that is internationally compatible and exemplary in design, and more investment in climate protection diplomacy.
- As long as there are countries that are important for the global economy, and in which no significant efforts have been made to improve climate protection, the problem of leakage is virulent. This problem can be effectively countered by **customs protection**. The EU still has a high level of customs protection for milk and beef. From a climate policy point of view, it is recommended that the **EU initially maintain this high level of tariff protection in order to be able to secure a resolute EU climate protection policy.**
- It would be ideal within the EU if the member states could jointly agree on an emissions trading system **(EU ETS**) that encompasses all economic sectors. If this is not (yet) possible, the **second-best solution is** that (a) Germany first introduces this system at national level and (b) the **EU Commission strictly monitors that all member states fulfill their reduction obligations in the non-ETS** sectors. Then it can happen that another Member State does not sanction ruminant farming at all and its savings obligations, e.g., mainly met in the nitrogen area. This then leads to a shift to production shares within the EU, but does not lead to **leakage**, because the other member state ensures the emission reduction (only elsewhere in its economy). This type of relocation of production as a result of climate policy can also arise in a similar way if an EU ETS is implemented that encompasses all sectors of the economy.

At the end of this sub-chapter, two references to other greenhouse gases (laughing gas, carbon dioxide) should be made. Such references are important because for a promising climate policy, the interactions between the individual sub-areas must be considered so that synergy effects can be achieved and thus prevent that success in one sub-area is (over) compensated for by negative effects in another sub-area.

- CO_2 pricing for farmers: In this sub-chapter it was shown that CO_2 pricing for methane emissions (especially in the case of a national solo effort) would lead to a gradual relocation of ruminant farming abroad. This development is, however, somewhat attenuated if at the same time a CO_2 pricing of the carbon enrichment with new sowing of grassland takes place (cf. in detail: chapter 3.4.2.2).
- CO_2 pricing for consumers: In this sub-chapter it was shown that the easiest way to price methane emissions is to adjust the VAT legislation. If politicians want to go in this direction, they should also consider the similar instructions on nitrogen emissions and animal welfare policy that were given in chapter 3.2.3.4.

These references are taken up again in the overarching analysis and consolidation of the recommendations in chapter 3.6 (conclusion).

3.4 Carbon dioxide (agriculture)

Agricultural businesses cause carbon dioxide emissions by using fossil fuels, for example to drive agricultural machinery or to heat buildings. With regard to these emissions, it is recommended that the climate policy incentives to reduce emissions in “traffic” and “heat” apply to agriculture as well as to all other economic sectors, as the federal government decided in its climate package (see chapter 2). This will not be discussed further below, and with regard to “bioenergy”, please see chapter 3.5.

The next question is how climate policy can influence the storage of carbon in agricultural soils. Our soils store large amounts of carbon, and depending on how these areas are used or managed, these stores can be released, kept constant or replenished. In this respect, this is an important approach for climate policy. With regard to the specific design options for climate policy, it makes sense to distinguish between organic and mineral soils.

3.4.1 Inclusion of organic soils in CO_2-pricing

In Germany there are around 1.8 million hectares of peat land. Of these areas, around 1.4 million hectares can be used for agriculture, which corresponds to around **7 percent of Germany's agricultural area**. Of this area, around one million hectares are currently used for agriculture (UAA). Most of the areas are in the North German Plain and in the Alpine Foreland. In order to open up the areas for agricultural use, the groundwater levels in the moor areas were lowered with hydraulic engineering measures. However, this lowering led to the fact that microorganisms now metabolize the carbon. The areas have thus become permanent emitters of CO_2, and the peat bottom subsidence progresses over time.

The CO_2 emissions are significantly higher for arable land use with deeply lowered groundwater levels than for grassland use with relatively high groundwater levels. Raising the water level is therefore a suitable means of delaying CO_2 emissions. A permanent preservation of the CO_2 storage is only possible if the **peat soils are completely rewetted**. Conventional agricultural use as arable land or grassland is then no longer possible. As a rule, raising the groundwater level cannot be brought about by individual farmers, but requires concerted action in the entire moor area. Numerous farmers and other land users, as well as residents, are affected by this.

Complete rewetting will stop the **CO_2 emission** currently taking place. The extent of the emission reduction achieved in this way depends heavily on the respective site conditions. For the further calculations, an average value of **20 t CO_2 / ha** and year is used, which is derived as the average value from the 2019 projection report of the national greenhouse gas reporting.

Including the peat soils in the CO_2 pricing would result in considerable values at the assumed CO_2 prices of 25 or 100 € / t CO_2: **500 or 2,000 € / ha and year**. In the case of a CO_2 tax, farmers would have to make these payments annually if they wanted to continue using the land for agriculture, and in the case of a climate protection premium they would receive these payments annually over a specified period (e.g., 20 or 30 years) if they cause the surface to be rewetted. These figures express the **gross economic benefit of rewetting**, whereby only the climate-political aspect is "priced" and the additional benefit in the area of biological diversity is still disregarded.

The economic benefits of rewetting must be compared with the **economic costs** that result from the fact that conventional agricultural production is no longer possible on the site. For a rough calculation, it is assumed for the sake of simplicity that the area will fall fallow after rewetting, i.e., no commercial use will take place and no costs will be incurred. As a result of rewetting, the economy then loses the basic rent that would have accrued if agricultural activity had been continued. This can either be read off from the amount of the lease price or calculated from accounting results by subtracting all costs (including wages and interest rates for staff and equity) with the exception of the lease costs from the operating income. This basic pension is (without considering the direct payments of the Common Agricultural Policy) on most locations in the order of magnitude of a maximum of 500 € / ha and year, often well below this (see the Federal Government's operating network). For the further analysis we assume an estimated value of **300 € / ha and year**.

Further costs arise from the hydraulic engineering measures that are required for rewetting. In Drösler et al. (2013), the annual costs are determined as the present value on the basis of data from nature conservation projects. From this, an average of 800 € / ha and year is calculated, whereby (a) costs for biotope maintenance are included that do not make a direct contribution to climate protection, and (b) cost savings due to the no longer required drainage are not included.

On balance, we assume an estimated value for the hydraulic engineering costs of around **500 € / ha and year** for the further analysis.

The comparison of benefits and costs thus shows that rewetting the peatlands - **at least in the long term - makes economic sense**. If we set the economic costs in this simplified approximate calculation at 800 € / ha and year and relate them to the avoided emissions of 20 t CO_2 per year, the result is **CO_2 mitigation costs of 40 € / t CO_2**.

This long-term positive assessment of rewetting changes only insignificantly if the **leakage effect** is taken into account. If all agriculturally used peatlands in Germany were rewetted, agricultural production would reduce to just under 1 million hectares. With open borders, this triggers the following chain of effects: The shortage induces a rise in agricultural prices. However, this is only small, since 1 million ha with a world arable area of 1.5 billion ha have hardly any price effect. Nevertheless, the market mechanism means that products previously produced on 1 million hectares in Germany now have to be produced somewhere else in world agriculture. This leads either to an intensification of production (more nitrogen fertilizers and thus more nitrous oxide emissions) or to land use change (cultivation of fallow land, plowing of grassland, in the worst case deforestation, thus more CO_2 emissions). These adaptation measures will be accompanied by additional greenhouse gas emissions, which must be included in the overall assessment. However, the world's agriculture has many millions of hectares at its disposal, some of which can be cultivated again without having to clear forests, and there is scope for increasing yields and reducing post-harvest losses. So if the global climate policy works halfway, the adaptation measures of the world agricultural economy will lead to additional emissions, which only account for a fraction of the avoided emissions from the local peat soils.

In Germany, in order to evaluate the “rewetting” scenario, it is necessary to examine the regional economic dimension in detail, in addition to the overall economic and climate policy assessment. “Seven percent of the agricultural area” does not sound dramatic at first, but because of the regional concentration of these areas in the north German lowlands and in the Alpine foothills, the proportion of areas to be set aside in the regions concerned is considerable. The **consequences for the regional economy** must therefore be subjected to an in-depth analysis and, if necessary, targeted public investments must be made to stabilize the regional economy. This also implies to impact on the local population, who can be affected by undesirable side effects such as wet cellars, mosquitoes, etc.

The consequences for the **income situation of farmers** concerned depend crucially on how the CO_2 pricing is actually designed. For the design of the various options, we assume that the policy measure is aimed at the **addressee “landowner”** (control parameter “agricultural use of one hectare of drained peatland”).

- **Auctioning of emission rights or CO_2 tax:** In this scenario, the landowners immediately feel the economic costs of the emissions caused by their agriculturally used peatland. They are only allowed to continue agricultural production with appropriate land drainage (or have it continued on a lease) if they purchase emission rights annually or pay a CO_2 tax. With emissions of 20 t CO_2 / ha and year and a CO_2 price of 25 € / t, the "climate costs" are no longer covered by the rental income on many areas. With a CO_2 price of 100 € / t, hardly any landowner will bid in emissions trading, and with a CO_2 tax of 100 € / t, the landowners will make every effort to get rid of the worthless area as quickly as possible. They will try to challenge the complete devaluation of their property titles in court and obtain compensation payments. Massive public protests can also be expected in the affected regions. Meanwhile, the surface continues to emit. These climate policy instruments do not offer the actors any economic incentive to carry out the rewetting desired by climate policy and to bear the rewetting costs.

- **Free issue of emission rights or climate protection premiums:** If landowners are given the opportunity to sell emission rights on the stock exchange or receive a subsidy for non-production, they will want to make use of this option when CO_2 prices are high. At 100 € / t the economic incentive is already very high. However, the landowners cannot bring about the rewetting themselves, but need (a) the common will of the owners of neighboring areas and (b) the consent and cooperation of the local authorities. In addition, they have to terminate the lease agreements for their leased land. Sooner or later, a community of interests of the regional landowners will form and jointly promote the "rewetting" project - but probably only after a few years, when it has been found that the high payments per hectare can actually be expected over a longer but limited period of time is.

These sketched estimates of consequences show: if policymakers intend to rewet moors with the help of CO_2 pricing, the instrument **“CO_2 tax” is not well targeted**. Greater success can be attained if the government sets finanical incentives for the landowners for rewetting. For this there are two possibilities either state climate protection premiums, or the inclusion of moors in the emission trade. But here, too, many landowners will first wait and see what happens so that the intended climate political impact is delayed.

The following **package of actions for the specific design** within the framework of an emissions trading system offers particularly good chances of success in getting rewetting on the way quickly:

- The state integrates all peat soils into emissions trading. It assures the landowners that they will be provided with emission rights annually free of charge for their (currently agriculturally used) peat land area up to a certain year (e.g., 2040 or 2050). You can use these rights to continue agricultural production or, in the event of rewetting, sell them annually on the stock exchange. The emission rights are issued within the framework of the cross-sectoral approach described in chapter 2.4 in order not to endanger the achievement of the climate protection targets through a possible oversupply of credits (“hot air”).
- The state guarantees the landowners to manage the total number of emission rights in the economy in such a way that a certain minimum price arises on the stock exchange every year (e.g., rising steadily from 50 € / t CO_2 in 2020 to 100 € / t in 2040). In the event that the market

price does not reach this minimum price, the state assures the landowners compensation for the difference from the general tax pool.

- The landowners are allowed to use the rewetted area economically within the framework of a (yet to be determined) “good moor use practice” (e.g., for paludiculture). This does not apply to precisely defined areas that are to be used as nature conservation areas in the future and excluded from any use.
- For the period after 2040 or 2050, politicians have announced their intention to reduce the number of emission allowances issued free of charge (along a path to be defined up to a defined level). If landowners still want to leave the peatland for conventional agricultural use, they have to buy the required emission rights on the stock exchange.
- Policymakers stipulate by ordinance how to proceed if the majority of the landowners affected agree to the rewetting and individual landowners reject it. In addition, it examines (a) which organizational and legal forms (e.g., cooperatives) are suitable for joint decision-making and for the joint activities of the landowners and (b) whether the legal bases should be adapted in order to ensure the most efficient and appropriate community activities enable.

The main advantages of this combination of measures are:

- All landowners in the bog regions **immediately receive clear messages**: It will be financially very attractive for at least 20 years for the landowners in a bog area to jointly decide to rewet. **The earlier the rewetting** takes place, **the more money** goes to the landowners.
- At the same time, all those affected, and the public, are informed that a **fair balance of interests** is necessary. In the first two to three decades, the **protection of trust** dominates for the owners concerned, whose families have in some cases invested private capital in the development of the property over generations. In the long term, however, the **polluter pays principle dominates**: Those who cause emissions should also be held financially responsible for the damage they cause.
- It is ensured that the areas remain in private ownership in the long term and that the **owners decide on management.** After all, this is about one million hectares of land. On some of these areas, the possible uses will be very limited by nature conservation objectives. How this special situation is to be regulated financially must be decided in nature conservation policy. For most areas, however, there is the possibility of using the rewetted areas within the framework of the "good moor use practice" (to be determined). Photosynthesis also takes place on wet surfaces, and depending on the local site conditions, there will be different possible uses. A collective search and development process is required to clarify which use is best suited to the location and which innovations best support this use. Experience has shown that the **private sector** finds **faster and more efficient solutions** in such constellations than a state-owned bog farm.

In principle, it would be possible to create this constellation **outside of an emissions trading system**. The state would then have to pay the landowners concerned for a period of, e.g., to guarantee a **climate protection premium** for 20 years if they rewet, and at the same time the state would have to announce that it will impose a **CO_2 tax** on the peat soils from 2040 (which increases over time), provided they are still used for agriculture with a low groundwater level.

This combined regulation of climate protection premium and CO_2 tax would be roughly “structurally identical” for landowners (with regard to rights, obligations and financial effects) with the emission rights regulation described above. Nevertheless, both regulations could trigger **different psychological effects**. In any case, farmers repeatedly state in agricultural policy discussions that they do not want to work for the state and are reluctant to rely on state premiums for ecological services or animal welfare services. Instead, they prefer constellations in which they can achieve higher revenues “on the market”.

In this respect, it could have a more motivating effect for those affected if they were given the opportunity to obtain the **revenues for their new production process “climate protection through rewetting”** on the stock exchange, instead of having to rely on state subsidies with the climate protection premium. Insiders understand that both regulations are installed by the state, trigger financial flows with the same effect and are also exposed to the same risk of policy change (through parliamentary resolution to de-install the respective regulations). The climate policy success of the regulation depends not only on the results of the internal analysis, but also on the feelings that the policy instrument triggers in the landowners.

3.4.2 Including mineral soils in CO_2 pricing

The vast majority of agricultural soils fall into the mineral soil category. Therefore - in addition to peatland protection - it is necessary to examine (a) whether these soils can also make a contribution to carbon storage and (b) how CO_2 pricing can be used to make this contribution to climate protection as high as possible.

The dead organic matter in the soil, also called humus, consists of around 58% carbon. The humus content of the agricultural mineral soils can vary widely. In Germany, most **arable soils** in the topsoil (0 to 10 cm) have a humus content between **2 and 4 percent**, but there are also arable soils with higher or lower contents. The humus content under **grassland** is mostly between **4 and 8 percent**, but soils with higher or lower contents can also be found here. In the deeper soil layers, the differences between arable land and grassland are less pronounced, but still significant.

A high humus content has always been of interest for agriculture because it promotes soil fertility (nutrient delivery, water storage, soil structure, etc.). In the course of the climate debate, the feature “carbon storage” is now being added. Farmers have various options for increasing the carbon content of their soils or counteracting degradation. The most important measure is undoubtedly the **maintenance of permanent grassland** or the **conversion of arable land into grassland**. In addition, all measures that lead to a **high input of organic carbon into the arable land** are beneficial: cultivation of intermediate crops, return of harvest residues to the field, application of manure, cultivation of perennial crops and planting of hedges. The influence of land use on the supply of organic soil carbon is determined using the soil depth of 0 - 30 cm, since land use there has a very formative influence. Among them, soil and site properties are decisive and the influence of use is rather minor. Therefore, the numbers of the C-stocks in 0 - 30 cm are used consistently in the text.

In view of the high potential for carbon storage, it appears desirable to include changes in the humus content or the soil carbon content in a cross-sectoral system of CO_2 pricing. But it can also be put more sharply: The **non-inclusion of soil carbon** harbors the risk of creating a **loophole in climate policy**:

- If the CO_2 pricing in energy and transport policy leads to higher prices for heat and fuels, the economic incentive to use residues from agriculture (e.g., straw) as a **bioenergy carriers** increases. However, this use leads to a decrease in carbon stocks in agricultural soils; the climate-political advantage (substitution of fossil fuels) is offset by a climate-political disadvantage (reduction of the carbon storage in the soil).
- By including the soil carbon content of the soils in the CO_2 pricing, this disadvantage also receives a "price". There is an economic incentive to **return the straw to the field**, which is then offset by the farmers using the economic incentive to sell straw (higher straw prices due to the CO_2 pricing in the energy sector). The balance of economic forces has been restored and the loophole in climate policy has been closed.

However, what follows will show that including soil carbon on mineral soils is easier said than done.

3.4.2.1 Measured or calculated change in soil carbon content

The straightforward way to integrate the supply of organic carbon into CO_2 pricing is to determine the supply of each agricultural area **annually** by means of **soil samples and laboratory analyzes** and then to make these values the subject of the pricing (addressee: agricultural company; criterion: annual change in carbon stocks on the individual surfaces). However, this path will **not be feasible** for the foreseeable future, as the following obstacles will mount up:

- The supply of organic carbon would have to be recorded on all farms and all agricultural areas in the country by means of sampling and laboratory analysis. Politics should not be limited to companies that want to participate voluntarily in a program. These participating companies would then possibly bring large amounts of organic material from neighboring companies that do not participate in the program onto their land, so that the supply of organic carbon increases there. This “extra performance” for climate protection would be rewarded financially, the corresponding “underperformance” on the areas of the neighboring farms would, however, remain without sanctions.
- Changes in the soil carbon stock, which can be traced back to changes in agricultural management, can only be measured and reliably determined after several years. It is difficult to recon-

cile CO_2 pricing based on the annuality principle (assessment basis for taxes, subsidies or emissions trading). Measuring carbon from year to year would result in values that would be inexplicable for farmers and subject to high fluctuations, but would still trigger payments or sanctions. Administration would be difficult even with measurements carried out at intervals of several years: in order to obtain meaningful time series and to prevent deceptive maneuvers, government agencies would have to take soil samples from identical measuring points (with exact GPS referencing), the exact location of which remains unknown to the farmers.

- With the current state of technology, the effort for a permanent, annual recording of justiciable soil carbon contents for all agricultural areas in Germany would be immense. Technological advances (e.g., sampling by robots; automated analysis processes, spectroscopic methods) can lead to significant cost reductions in the future, but there is still a long way to go before it can be used across the board in all agricultural areas in Germany.
- Politicians should ensure that the measure is maintained in the long term. The build-up of the supply of organic carbon takes place very slowly, but the breakdown is very rapid. Otherwise there would be the risk that companies would receive economic benefits for building up organic carbon over a period of several years (e.g. climate protection premiums), but would then no longer be asked to pay for any subsequent degradation.

For these reasons, it seems unlikely that politicians will be able to manage the **actually measured supply of organic carbo**n in the agricultural mineral soils in the cross-sectoral CO_2 pricing for each area in the foreseeable future.

A “stripped-down” variant of this proposal could be to forego annual measurement of the soil carbon per parcel and instead to make the **calculated farm carbon balance** (material flow balance) the subject of annual CO_2 pricing. Soil samples and laboratory analyses are then not required. With this approach, however, politics runs back into those fundamental problems that were discussed in detail in chapters 3.1 and 3.2.1.: CO_2 pricing is not about the use of any advisory tools, where the company can also roughly estimate a number if necessary (e.g., carbon imports). It is about state payments (subsidies, taxes ...), for whose administration the state has to set up a "watertight" control system for the entire sector. This leads to a very high level of bureaucratic effort and ultimately to "transparent operation", with all the advantages and disadvantages.

If politicians come to the conclusion that neither the annual plot-specific measurement of soil carbon nor the arithmetical material flow balance can be implemented or enforced in practice, the **loophole in the CO_2 pricing will remain open**. This means, for example, that when CO_2 prices rise sharply, farmers can be tempted to sell too much straw by the corresponding rise in straw prices, so that the humus balance and thus also the carbon stocks gradually decline.

To prevent this, politicians would have to look for a solution outside of CO_2 pricing and, if necessary, **adapt the specialist law**. Here it is sufficient to (a) stipulate adherence to a certain corridor for the humus values as part of good professional practice: (b) to oblige the farmers for regular analyzes of the humus content at intervals of, e.g. for five years; (c) arrange for a random check of the data by the supervisory authorities, and (d) provide for a staggered sequence of sanctions and control densities in the case of suspicious operations. This policy architecture has already proven itself in other areas of agri-environmental policy, and it could also be used with regard to the humus content.

3.4.2.2 Conversion of arable land to grassland

The control parameter “land use as grassland” appears attractive at first glance, because it shows a high correlation to soil carbon, and it can be recorded in a legally secure manner and with little administrative effort. With a CO_2 pricing of this parameter, it is relatively easy to provide a financial **incentive to maintain grassland or to convert arable land into grassland** (addressee: agricultural operation; control parameters: use of the area as permanent grassland).

The soil carbon stock of a soil builds up step-by- step over a very long period of time when grassland is used. In the greenhouse gas reporting, this build-up process is reported over a period of 20 years. We therefore refer to this period in the following, even though comparisons of locations with grassland stands of different ages suggest the hypothesis that carbon accumulation can continue over a longer period of time with continued grassland use (cf. BMEL 2018)

The general use of the control parameter “land use as grassland” is problematic in climate protection policy insofar as the humus build-up under grassland can vary considerably depending on the type of use. For example, a constant removal of the green cuttings or a drainage of the grassland would slow down the build-up of humus. Such inadequacies could only be remedied if agriculture were obliged to carry out a detailed, comprehensively controlled material flow balance across the board (see chapter 3.4.2.1). Since this is currently not feasible, climate protection policy will have to come to terms with the disadvantages of flat-rate valuations for the time being.

For average site conditions in Germany, it can be assumed that if the area is used as grassland, around **3.2 t CO_2 / ha** will be defined as soil carbon per year (see Umweltbundesamt, 2019b). With a CO_2 price of 25 € or 100 € / t CO_2, the use of grassland during the development phase can therefore be ascribed a climate policy benefit of **80 € or 320 € / ha and year**.

For further considerations regarding the design of the CO_2 pricing of grassland, we initially start from the “**climate protection premium**” scenario. For the specific design, two questions in particular need to be clarified:

- Is there an obligation associated with the premium to maintain the grassland permanently? And how is this obligation interpreted: Is grassland plowing then permanently prohibited, or would the premium have to be paid back in the event of a later grassland plowing?
- Will the premium only be offered for newly created grassland areas that were previously arable land, or also for grassland that is already established?

Since the upheaval of grassland leads to a rapid depletion of carbon stocks, it is necessary not only to unilaterally promote the sowing and maintenance of grassland, but also to provide appropriate "negative incentives" in the opposite case of converting grassland into arable land. This can also prevent farmers from plowing up their grassland with the aim of benefiting from a further premium payment after reseeding. In a climate protection policy in line with the market, it would therefore be consistent that the state (a) offers only a climate protection premium for a period of 20 years (from the time the grassland is sown, i.e. also for grassland that has already been sown) , and (b) concludes contracts with the premium recipients in which it is anchored that in the event of a later plowing of grassland, the **premium amount received up to that point must be repaid** (possibly in installments, possibly with interest).

The effect such a grassland premium would have, was analysed by Gocht et al. (2016) analyzed in a Europe-wide study with the help of models. The results show that with an average premium of 238 € / ha and year, the proportion of grassland would increase by an average of 5%. This average conceals considerable regional differences.

Against the policy option "**climate protection premium for grassland**" the argument is often put forward that "more grassland" also means **"more ruminants**" and thus **"more methane emissions"**. In the case of grassland use by dairy cows, a rough estimate of 1.5 cows per hectare can be assumed, which corresponds to over **5 t CO_2 / ha and year**. In the case of grassland use by suckler cows, more extensive systems are usually practiced, so that 1.0 suckler cows per hectare can be assumed, corresponding to methane emissions of around **1.9 t CO_2 / ha and year**.

These figures show that expanding cattle farming - triggered by a climate protection premium for grassland - can actually be counterproductive in terms of climate policy. However, we should **not conclude from this that grassland is fundamentally not a suitable criterion for CO_2 pricing**. Rather, a differentiated view is required:

- Today, dairy farming takes place to a large extent on the basis of arable forage (e.g., maize silage). If the methane emissions were to be priced with CO_2, this would result in a considerable cost disadvantage for this form of production, which sooner or later could lead to the milk production being relocated abroad (see chapter 3.3). If the carbon storage under grassland is also charged with CO_2, this creates a revenue advantage for those dairy farmers who keep pastures. This is similar to the above. At least some of the cost disadvantage. The **combined CO_2 pricing therefore tends to attract dairy farming from arable land to grassland**.
- With the above constellation (3.2 t CO_2 / ha carbon advantage vs. 4.6 t CO_2 / ha methane disadvantage), on balance, there would only be a small competitive disadvantage for German dairy farmers. This disadvantage could be reduced if (a) the farmers extensively raise their dairy cattle, e.g., fertilize less nitrogen and keep only one dairy cow per hectare and if (b) politicians would offer grassland a "**biodiversity price**" as well as CO_2 pricing. That would then be an additional premium **for extensive pasture**, which expresses the greater benefit of extensive pasture for biological diversity (e.g., compared to silage maize).

- When comparing figures, however, it should not be forgotten that the carbon accumulation in the soil under grassland only increases over a certain period of time and then reaches a new equilibrium, while methane emissions by ruminants continue every year after this point in time, as long as ruminants are kept. In this respect, the question is whether the above period of 20 years accurately depicts the actual accumulation process or whether significantly longer periods of time are not to be assumed here, relevant to climate policy. There is a need for research here.
- In the longer term, however, it would be even more important to focus public and private research more on **grassland use that is not dependent on ruminants**. With cross-sectoral CO_2 pricing, these systems would have the advantage that they receive a positive incentive through the CO_2 price for carbon storage and are not financially burdened by the sanctioning of methane emissions. There are different development possibilities for the use of grassland without ruminants, e.g. the keeping of non-ruminants (horses, donkeys, poultry), the extraction of feed protein for pigs and poultry from the grassland or the use of green waste in bioenergy systems (biogas). However, there are still many questions about the efficiency and profitability of such usage options. Hence the recommendation to invest in research and development first.

The CO_2 pricing of grassland does not necessarily have to be based on the "climate protection premium" instrument. In principle, it is also possible to integrate **grassland into emissions trading**, but there are special administrative challenges here. First, the policy would determine:

- Farmers are only allowed to convert grassland into arable land if they have emission rights. They have to buy these on the stock exchange.
- When farmers convert arable land into grassland, the state gives them emission rights that they can sell on the stock exchange.

To ensure that these market economy rules do not cause any ecological damage, additional guard rails are required: It must be specified that plowing up grassland is only permitted outside of protected areas, i.e. not within scenaries with grassland that is particularly worthy of protection (e.g., high proportion of biodiversity) or in flood protection areas.

In addition, it must be clarified which contractual provisions can be used to ensure that farmers take into account the long-term greenhouse gas effects of plowing or sowing grassland. The upheaval or sowing triggers **a long-term degradation or build-up process** in which a total of around 17.4 t of carbon per hectare is involved. In order to take these long-term developmenst and dismantling processes into account when pricing CO_2, the following **regulations could be integrated into emissions trading:**

- Farmers who plow up old grassland must undertake to purchase an annual emission allowance for the area for a period of around 20 years. This obligation expires prematurely if the area is converted back to grassland.

- Farmers who convert arable land into grassland receive a promise from the state that it will give them an annual emission allowance for the converted area free of charge for a period of 20 years (condition: grassland use). The farmers can then sell this annually on the stock exchange. The farmers are also given the promise that they can convert the grassland back into arable land if the state does not fulfill its obligations or if emissions trading is one day abolished. As long as emissions trading continues, however, farmers are only allowed to plow back their sown grassland areas if they commit to buying emissions rights annually for a period of up to 20 years (depending on the period of the previously "awarded" grassland use).

The legal safeguarding of these long-term obligations is an administrative task for which there are different solution options. No further elaboration should be made at this point, as this would go beyond the scope of this article.

At the end of this sub-chapter, the grassland topic discussed here should be classified under the aspects of **“competitiveness” and “leakage”** (see chapter 3.3.). As already shown, the CO_2 pricing of soil carbon enrichment under grassland counteracts the effect that arises from the CO_2 pricing of methane emissions from ruminants. If the policy also honors the biodiversity benefits of grassland, it can be achieved in this way that ruminant husbandry is kept in the country, but moved to grassland and also to more extensive grassland areas.

If, however, very high CO_2 prices develop on the stock exchange over time, the effect of the CO_2 pricing will be different: It will then become more and more profitable for farmers to convert arable land into grassland and use the grassland without ruminants, be it through exclusive mulching or for feeding horses or biogas plants. The production of field crops, milk, beef and sheep meat is then increasingly relocated abroad, and the products are delivered from there to the German and European food trade. This then leads to increasing leakage effects, i.e., Germany's and EU's greenhouse gas balance is improving, but the world's greenhouse gas balance is not. The conclusions to be drawn from this with regard to German climate policy were discussed in detail in chapter 3.3 using the example of methane.

3.4.2.3 Afforestation of agricultural land

In addition to the sowing of grassland, the afforestation of agricultural areas also offers a good opportunity to (a) bind large amounts of CO_2 from the atmosphere and fix it in the agro-ecosystem in the long term and (b) price this additional storage capacity with little administrative effort.

Forest areas in Germany store an average of 190 t C / ha (Wellbrock et al, 2014). The main contributors to this total are: Plant biomass 101 t C / ha, carbon in the mineral soil 68.5 t C / ha, litter layer 20.6 t C / ha. These values are national averages, behind which large regional averages are hidden. For comparison: The C content in arable soils in Germany is an average of 60 t C / ha (at a depth of 0-30 cm), although there are also large regional differences here (BMEL 2018). This means that the mean carbon stocks in the forest are around a factor of 3 higher than those in arable land. The main reason is that in the case of arable land, long-term carbon storage only takes place in the soil, while in the forest a lot of carbon is also bound in the long term above ground.

For the further discussion we assume that the carbon storage of 190 t C / ha will be reached around 75 years after afforestation. The reservoir continues to grow afterwards, but it also decreases again during the later timber harvest, is then refilled and thus oscillates around the long-term average value of 190 t C / ha. The long-term advantage over arable land is thus an average of 130 t C / ha (corresponding to 477 t CO_2 / ha), so that for the first 75 years after afforestation, an average annual storage capacity of approx. 1.7 t C results / ha and year (corresponding to **6.4 t CO_2 / ha**). With a CO_2 price of 25 or 100 € / t CO_2, the value of the annual storage capacity is around **160 or 640 € / ha and year**.

However, this annual CO_2 storage capacity is **only counted for the first 75 years**. Thereafter, in the case of sustainable forestry, no further C storage is built up in the forest. If the then harvested wood is processed into durable wood products, this storage capacity must also be estimated. If it is used energetically, it can contribute to the substitution of fossil fuels (see chapter 3.5.1).

The **administrative handling** of the climate policy measure “afforestation” can be carried out in the same way as the measure “grassland sowing”, which means that climate protection premium is just as possible here as inclusion in emissions trading (see chapter 3.4.2.2). The “afforestation” measure is economically more lucrative, especially when the prices for emission rights are high, because no emission rights are required for keeping ruminants. The excellence of the two options depends very much on whether afforestation and / or the sowing of grassland lead to state usage requirements at a later point in time. A re-conversion ban would lead to a drastic loss of value for the area. The question of whether the state guarantees farmers or landowners the **legally binding option of "reconversion"** or not is extremely important for the attractiveness of the measure.

From a climate policy perspective, **converting arable land into forest is more attractive** than converting it into grassland (with ruminant use) because (a) the annual CO_2 storage capacity per hectare is higher and (b) no emissions are caused by ruminant farming. For an overall economic assessment, however, additional aspects must be taken into account, e.g. the effects of the various land use options on regional employment and biological diversity. Regional peculiarities play an important role in these points, so that a generalized statement on the superiority or inferiority of afforestation is not possible.

In this context, the **problem of leakage** must be addressed again. With high CO_2 prices and open borders for agricultural products, national CO_2 pricing creates a massive financial incentive to reforest the agricultural areas in Germany and to provide food through imports. Although this improves Germany's greenhouse gas balance, there is no benefit for the global climate protection goal, because the relocation of food production abroad increases emissions there to about the same extent as they were reduced here.

This shift would not occur with global CO_2 pricing. In the case of EU-wide CO_2 pricing, it could be limited by trade policy measures. If you do it alone nationally, this is not possible. Here, Germany would have to structure emissions trading in such a way that **the number of emission rights that are issued for the afforestation of agricultural areas is limited quantitatively**. In this way it can be ensured that (a) the climate policy scarcity signals are also noticeable for the agricultural sector, but (b) there is no excessive relocation of production abroad and (c) the afforestation is directed to the areas that have the least value for food production.

A moderate increase in food prices in Germany, for example through a change in VAT legislation (full VAT rate for milk and meat), would complement this reforestation policy in a meaningful way from a climate policy perspective (see chapter 3.6).

3.4.2.4 Forest conservation, forest use and forest conversion

Should politicians decide to integrate the “afforestation” option into the cross-sectoral CO_2 pricing, the question arises as to whether the **existing forest areas** should not also be included in emissions trading.

On the one hand, this involves **questions of property and constitutional law**. Is it permissible for the state, with the Federal Forest Act, to impose high carbon storage per hectare on owners of already existing forest areas (prohibition of conversion), while owners of arable land have in principle the right to low carbon storage for each hectare, and then state "buys" this right from them through a reforestation premium? These legal questions cannot be discussed further in this article.

From the point of view of **climate policy**, it must first be remembered that maintaining a long-standing, sustainably operated forestry enterprise does not lead to additional carbon sequestration on the forest area. The advantage of sustainable forestry is that (a) the harvested wood continues to function as a carbon store and / or (b) the use of wood enables **substitution effects** that are advantageous in terms of climate policy (saving fossil fuels). This is reflected in the CO_2 pricing in other sectors (and can certainly lead to higher wood prices), but not in the CO_2 pricing of the forest.

If politicians want to ensure that more carbon is incorporated into the forest area per hectare and year, they would have **to replace** the (administratively easy-to-manage) **control parameter “forest yes / no” with another parameter**. For example, the control parameter "tons of carbon per hectare" would be ideal in terms of climate policy. - But only at first glance, because a closer look shows that, given the current state of science, it will hardly be possible to set this parameter every year (principle of annuality) to be recorded on all forest areas in Germany (a) legally secure and (b) reasonably inexpensive.

There are two major **research** construction sites here, where digitalization can be very useful:

- Development of cost-effective and reliable methods for the exact quantification of carbon storage in trees
- Development of a digital wood product store for the entire construction sector.

The discussion about how realistic these perspectives are and when the measurement methods may be ready for practical use would go beyond the scope of this article. At this point, however, it should also be pointed out that methodically perfected CO_2 pricing carries the risk of aligning forest management all too one-sided towards the goal of “high carbon sequestration”. The forest should meet many social requirements, and the control mechanisms must be balanced in such a way that the other ecosystem services of the forest (e.g., biological diversity) are not neglected.

On the other hand, if the annual change in the carbon content of the forest areas is not “priced” at all, these areas **represent a loophole in the cross-sectoral CO_2 pricing**. Rising CO_2 prices lead to rising prices for fossil and renewable energy sources, and thus forest managers will receive an increasing financial incentive to sell a lot of wood as fuel through the CO_2 pricing of the other branches of the economy. This can lead to these areas no longer being managed sustainably. In order to prevent this, politicians must counteract this with specialist laws (see also chapter 3.4.2.1 and chapter 3.5.1).

3.4.2.5 Peat as a growing medium and soil improver

The use of peat in **horticulture, landscaping and in the hobby area** causes CO_2 emissions. These arise both during peat extraction and during the gradual decomposition of the peat in its later uses. In the reporting, emissions of 2.1 million t CO_2 from peat extraction are shown for 2017 (see Umweltbundesamt, 2019b).

Pricing these emissions with 25 or 100 € / t CO_2 would burden peat extraction with **6.7 or 27 € per m^3 peat**. For the substrate industry, this would greatly increase production costs, possibly even doubling them. This would create **high incentives for the development of substitute products**.

The price increase, which is meaningful in terms of climate policy, will only come about if there is EU-wide CO_2 pricing. On the other hand, if Germany were to go it alone nationally, only peat extraction in Germany could be restricted and imports would increase accordingly (leakage effect). Imports of peat, especially from the Baltic States, are already playing a major role today. However, this leakage effect is limited by the fact that the LULUCF Regulation (EU) 2018/841 stipulates that emissions from peat extraction from 2026 should be offset against the EU targets in the LULUCF area. This can lead to the prevention of a further expansion of peat extraction in some Member States. A reduction in peat extraction will not yet be achieved. It should also be taken into account that peat is still used as fuel in some EU countries. The quantities used there could be diverted to the substrate area through intra-EU trade.

Against this background, from a climate policy point of view, it is recommended **to integrate peat extraction into an EU-wide CO_2 pricing**. This would give all players across Europe an economic incentive to (a) refrain from using peat and (b) develop substitute substrates and bring them onto the market.

3.5 Discussion of further starting points

In the previous chapters we examined how cross-sectoral carbon pricing can be used to reduce emissions of nitrous oxide, methane and carbon dioxide from agriculture and to increase long-term carbon sequestration.

Finally, we want to address two cross-cutting issues that often play a role in discussions about CO_2 pricing in the agricultural sector (bioenergy; organic farming). There are two questions here:

- Do these two areas have to be addressed separately in the "pricing policy"?
- How do the policy proposals developed above affect these two areas?

3.5.1 Bioenergy

The inclusion of the previous non-ETS areas of heat and transport in the CO_2 pricing will mean that companies and consumers will have to pay higher prices for fossil heating and fuel. The CO_2 emissions from the combustion of regenerative energy sources (e.g., bioenergy) are not priced here, because when they are burned, CO_2 is only released to the extent that it was previously bound from the atmosphere. This gives **regenerative energy sources a competitive advantage** over fossil energy sources.

Since the quantitative demand in the energy sector is very high and the supply of renewable energy sources is (still) very limited in comparison, the rise in the price of fossil energy sources will mean that the prices for bioenergy (biodiesel, ethanol, wood pellets, etc.) can be pulled upwards. This price increase improves the profitability of bioenergy generation in agriculture, so that the **cultivation area of the bioenergy segment increases**.

A separate "**climate protection premium**" for the **short-term sequestration of CO_2** in the bioenergy sources (e.g., biodiesel) would be **nonsense**, because this CO_2 is released again after a short time when it is used for energy purposes and then must be documented and has to be added again immediately to " CO_2 tax". In the same way, it would be nonsense in the food sector to give farmers climate protection premiums for carbon storage in sugar beet or grain, because then the use of biofuels and all food consumption would have to be subject to a "CO_2 tax". In the greenhouse gas reporting, through which the progress of the climate mitigation policy is checked, the short-term carbon fluxes from the cultivation of annual plants are not shown, since the stipulations and releases are roughly in equilibrium. Only long-term soil organic carbon sequestration and degradation is reported (see section 3.4.2). At this point, it could be argued that a longer-term definition is being made in forestry. Hence the clarification: With the “afforestation premium” (cf. chapter 3.4.2.3), the entire carbon storage up to the harvest of the tree is not “awarded”, because then one would also have to “tax” the harvest and the incineration. Rather, the subject of CO_2 pricing here is the difference between the average C storage per hectare that can be achieved with sustainable forestry and the average C storage per hectare on arable land.

Finally, it should be pointed out that **high CO_2 prices** in the bioenergy sector can result in a **serious leakage problem**. If the EU advances on its own in terms of CO_2 pricing and the EU prices for fossil fuels become increasingly different from the world market, it will become more and more attractive to (a) generate bioenergy instead of food within the EU and (b) to import bioenergy in large quantities from the world market. As a result, the greenhouse gas balance of the EU member states has improved significantly in the areas of transport and energy. The global greenhouse gas balance is in no way improving, however, because the more positive figures in the EU are “bought” in this scenario by expanding and intensifying agricultural and forestry production outside the EU.

The following figures indicate that the **import of biofuels** can be of considerable magnitude without political accompanying measures: The annual mineral oil consumption of the EU-28 is 600 million t. This corresponds to about a third of the total EU energy consumption. The net yield of biofuel production on agricultural land (after deducting the energy used for production and conversion and after including the credits for co-products) is in the order of 1 to 3 tonnes of oil units per hectare, depending on the energy line (Scientific Advisory Board, 2008). The arable land of the EU-28 is only approx. 100 million hectares. EU agriculture would therefore very quickly reach its limits if it was encouraged to do so by high CO_2 pricing in the transport and heating sectors, in addition to food production to provide for the bioenergy for the replacement of oil. As a result, there would be a rapid increase in European biofuel imports, with negative environmental consequences and increasing greenhouse gas emissions in non-European agriculture.

This development could certainly not be described as “exemplary” for a global climate protection policy. If other countries in the world were to allow more and more crude oil to be substituted by biofuels, this would further exacerbate the scarcity situation in global agriculture. The annual mineral oil consumption is currently 4 billion tons. For comparison: the arable land of world agriculture only covers about 1.4 billion hectares. This area is largely needed for the sustainable food supply of the growing world population.

3.5.2 Ecological farming

The following applies to both ecological and conventional farms: There are major differences between farms in terms of greenhouse gas emissions within each group. **On average**, however, the group of organically farmed farms has **lower greenhouse gas emissions per hectare**. This is mainly due to the lower nitrous oxide emissions and the higher humus content (Sanders et al., 2019).

In view of the lower emissions from organic farming per hectare, it seems reasonable to consider making the measured variable "organic farming yes / no" the subject of CO_2 pricing. However, this is not advisable, as numerous scientific studies have led to the result that although organic farming has an advantage in terms of emissions per hectare, there is no clear advantage in terms of **greenhouse gas emissions per product unit**. Applied to the arguments in this work report, this means:

- Inclusion of the measured variable "organic farming yes / no" in CO_2 pricing means that organic farming spreads more and more in Germany when CO_2 prices are high. This improves Germany's greenhouse gas balance.
- Since much lower production quantities per hectare are achieved in organic farming, the import of agricultural products increases with unchanged food consumption. This leads to increased production and higher emissions abroad (**leakage effect**).
- In total, there are no, or only minor, advantages for the global greenhouse gas balance.

The objection to this line of argument is that the assumption "unchanged food consumption" is not tenable, because **consumers of organic food** plan their food consumption with more vegetarian food and therefore have a **below-average climate footprint**. This objection is justified as long as it concerns the evaluation of the current organic market segment, in which low greenhouse gas emissions per hectare are combined with the climate-conscious eating habits of the buyers. However, it is questionable whether the climate-conscious eating habits of current organic consumers will be carried over to the "new" organic consumers who are attracted by the price reductions for organic products (as a result of CO_2 pricing). With this in mind, it is particularly important that:

- Politics, science and industry increase their efforts to sustainably improve the yield level in organic farming,
- the subject of "environmentally conscious eating habits" is promoted across the board of society.

In the case of very high CO_2 prices, organic farming will experience **expansion incentives** through CO_2 pricing even if the control parameter "organic farming yes / no" is not priced separately. This is particularly the case if there is a **CO_2 price for mineral nitrogen fertilizers** (see chapter 3.2.2). We assume that the leakage effects triggered by this (see above) will be classified as **politically acceptable**, at least as long as the proportion of organic farming in Germany is still below 20 percent. Politicians have set the goal of "20 percent organic farming", although they are aware of the lower yields of this production system, because they obviously rate the advantages of an increased organic farming share in Germany higher than the disadvantages that result from the (associated) increase in food imports result.

3.6 Conclusion

Greenhouse gas balance on farm level

First of all, we analyzed the obvious suggestion of having an "annual farm greenhouse gas balance" calculated for each farm and then "pricing" this individually in emissions trading.

This proposal is particularly charming insofar as it provides all farmers with the incentive to make an optimal adaptation to the climate protection goal, taking into account all internal interactions. This is not just about CO_2 emissions and sequestration of CO_2, but also about CH_4 and N_2O emissions and the demanding task of developing an optimal operational adaptation for all three greenhouse gases on the farm level. This proposal should therefore be pursued as one **component of a comprehensive climate mitigation policy** in order to be able to test and demonstrate best practice adaptations for selected farms.

For the integration of agriculture into **emissions trading**, however, the "annual farm greenhouse gas balance" is **not a suitable control parameter**, because a legally secure and cost-effective control of this parameter on all farms in Germany cannot be implemented for the time being.

Nitrous oxide emissions

An exact measurement of nitrous oxide emissions on the farms is also not feasible. It is therefore recommended that the **amount of reactive nitrogen** used or emitted by agriculture be made the subject of CO_2 pricing. A **fundamental political decision** is required for the specific design:

- Either: the **control parameter "individual nitrogen surplus"** is selected. As a result, all agricultural farms in Germany must submit a complete nitrogen accounting every year (material flow balance), which is then compiled in a central nutrient register and used by the authorities to (a) set up an overall view of all farms and (b) be compared with the data of the fertilizer and feed industry. After the experiences with the nitrogen policy of the past decades, doubts come up as to whether the policy can bring the farms themselves to pursue this option resolutely and to that extent that they make the "**transparent farm**" a reality. A complete screening (analogous to the income tax return) would be absolutely necessary with this policy option, since the state provides every kilogram of nitrogen with a direct monetary value when pricing CO_2.
- Or: climate policy starts at the "**bottlenecks" of the fertilizer and animal feed industries, both at the same time** in order to price the sectoral nitrogen use. Here it can be recorded by a manageable number of companies how much nitrogen is fed into the sector. The CO_2 pricing of **mineral nitrogen** (addressee: distributor) is relatively easy to implement in an EU-wide concept, as only a few companies need to be checked. Implementation is more difficult when going alone nationally, because farmers must be prevented from buying "CO_2 -unpriced" nitrogen in other EU countries. In principle, however, this can be regulated administratively, as the exam-

ple of the mineral oil tax has long shown. The CO_2 pricing of **feed** is administratively more difficult to implement because there are also many small companies in this sector (including individual farmers) who place feed on the market.

In emissions trading, the CO_2 pricing of **mineral nitrogen and animal feed** would have to be designed in such a way that the emission certificates for the quantities placed on the market are **auctioned**. In this way, mineral nitrogen and animal feed would become more expensive for farmers. That would put a considerable strain on farmers' incomes, so that discussions about income compensation would be pre-programmed here. With the CO_2 pricing of the **individual farm nitrogen surplus**, politicians would have better opportunities to avoid such compensation measures. You could, e.g., provide the farmers with certificates up to a certain nitrogen surplus (e.g., 20 kg N / ha) free of charge. Depending on the operational situation, farmers could either sell unneeded certificates on the stock exchange (positive income effect) or purchase additional certificates there (negative income effect).

To illustrate the effect of **CO_2 pricing on mineral nitrogen**, we have selected **wheat cultivation** at a northern German arable site as an example. A CO_2 price of 100 € / t CO_2 roughly doubles the mineral nitrogen price. In the example chosen, the use of mineral nitrogen is reduced by 15%, the nitrogen surplus by 42% and the wheat yield by 3%. An increase in the price of mineral nitrogen leads to an increase in the value of manure nitrogen and the profitability of livestock farming. It becomes more profitable to transport manure from the concentration areas over longer distances.

In parallel to the CO_2 pricing of the mineral nitrogen, a **CO_2 pricing of the organic fertilizer nitrogen** is useful so that the entire sectoral nitrogen input is recorded. This promotes N-efficiency in livestock husbandry, and it prevents the pricing of mineral nitrogen from stimulating livestock husbandry (which is counterproductive in terms of climate policy) on the basis of imported protein feed.

The direct counterpart to the CO_2 pricing of mineral nitrogen is the **CO_2 pricing of feed nitrogen**. This bottleneck is more difficult to grasp than with mineral nitrogen because there are many other players in the feed trade in addition to the large compound feed manufacturers, including trade between farms. In the case of an interim national solo effort, there is the option of choosing the sellers of protein feed as the addressees, e.g., the 20 largest oil mills. With this, more than 50% of the feed protein that reaches the German livestock sector would be adressed.

If politicians do not consider this path to be feasible, an **alternative solution** to feed nitrogen would be a flat-rate CO_2 price for **livestock**. Although there is no “bottleneck” here, the number of farm animals has to be recorded regularly in all farms for other reasons (animal diseases, animal welfare, etc.) so that this fact can be used for climate policy. At a CO_2 price of 100 € / t CO_2, the production costs would increase between 1.3% (broiler fattening) and 3.4% (milk production). Such a load would, however, have significantly less control effects to increase nitrogen use efficiency, since improved feeding would not pay off due to the flat rate, in contrast to the CO_2 pricing model for feed nitrogen.

For the **competitiveness of animal husbandry**, this increase in costs means that the competitive advantage that results from the higher valuation of manure is compensated for. However, this only applies to animal husbandry outside the concentration areas. The upgrading of manure is not effective within the concentration areas, since there is an excess of manure and the transport costs for manure to the arable regions are still too high. Thus, the economic burden of livestock husbandry dominates in the concentration areas, which tends to lead to a relocation (partly abroad, partly to other regions of Germany).

The described **extensifications and relocations** are also induced when politicians, instead of using the combination of “mineral nitrogen plus feed (or livestock)”, price the nitrogen surplus on individual farms with CO_2. Both ways are suitable for significantly reducing greenhouse gas emissions in agriculture. First and foremost, they lead to a much **more efficient use of nitrogen**; the relocation of emissions abroad only plays a subordinate role. Therefore, both measures are also suitable for a national solo effort if necessary, although EU-wide CO_2 pricing is preferable.

Methane emissions

The methane emissions mainly come from two sources, from manure storage and from ruminant husbandry.

With regard to the **storage of farm manure**, we assume that a step-by-step adaptation of regulatory law will provide a solution to the problem and that the farmers, through support measures (investment subsidies), will be able to make the necessary investments in the next few years.

The **keeping of ruminants** inevitably leads to methane emissions, which can only be changed to a limited extent by technical production measures. Since it is not possible to measure the emissions of the animals exactly as a basis for CO_2 pricing, only the control parameter “number of animals” remains (grouped according to animal species, possibly further specified).

A CO_2 price of 100 € / t would lead to an **increase in production costs in the range of 15%** in the examined methods of bull fattening and dairy cow husbandry. This can be partially compensated for in dairy farming if at the same time CO_2 pricing is applied to the establishment of grassland (carbon storage, see below). Because of this double pricing, milk production tends to be drawn to grassland.

In view of the considerable effects that CO_2 pricing would have on the competitiveness of cattle farming, this measure cannot simply be recommended for the “**national solo effort” scenario**. The decisive question here is whether the EU Commission can enforce that all member states comply with their reduction obligations in the non-ETS area as well. If this is guaranteed, relocations of production within the EU are not to be regarded as **leakage**, because the member states with growing cattle numbers will then ensure emission reductions elsewhere in their national economy.

In the "**EU-wide CO_2 pricing" scenario,** the inclusion of ruminant production can have a climate-political effect, provided that the **tariff protection for dairy products and beef** can be maintained at a high level. Without this tariff protection there would be a relocation of production to third countries (leakage) (increasing over time). Customs protection, on the other hand, creates the possibility that the increased production costs (as a result of CO_2 pricing) are passed on to consumer prices and thus lead to a **climate friendly worthwhile reduction in the consumption of dairy products as well as beef and sheep**.

This effect is delayed for dairy products, however, as the rise in consumer prices will only take place when the level of self-sufficiency (currently around 115 percent) approaches the 100 percent level. As long as EU prices remain at world market level due to the net export status, the relocation of production to third countries dominates.

This creates new challenges for trade policy: If EU climate protection policy is dependent on external protection when CO_2 prices are high, which increases the price of imports of biomass that are not priced at CO_2 in their countries of origin, then trade conflicts are inevitable. The current discourse on the EU Commission's "Green Deal" indicates how difficult it is currently for "real politics" to attach as much importance to climate policy as to trade policy in the event of conflicting goals. But this debate is only just beginning.

Carbon dioxide

The focus here is on the agriculturally used **drained peat soils**. These areas, which make up **seven percent of the total agricultural area**, currently cause four percent of all greenhouse gas emissions in Germany.

A permanent preservation of this carbon reservoir is only possible if it is **completely rewetted**. The inclusion of the peat soils in CO_2 pricing could develop a considerable boost here. With an average emission of 20 t CO_2 / ha and a CO_2 price of 100 € / t, the annual revenue is in the size of 2,000 € / ha. However, rewetting requires investments in hydraulic engineering, which can vary greatly from one location to another. We are assuming an approximate annual cost of around 500 € / ha.

The discussion of various design options leads to a **concrete proposal** as to how the rewetting of peat soils could be successfully **integrated into emissions trading**. The state would have to give the landowners a binding promise that the emission rights for peatlands would be made available to them free of charge over a longer period of time. He would also have to offer the prospect of covering losses in revenue when stock market prices are low. At the same time, it should be stipulated that the free issue of emission rights from a certain target year (e.g. 2040 or 2050) should be gradually phased out.

Carbon storage in mineral soils also offers great potential for climate mitigation. However, this is very **difficult to tap** into emissions trading (or with a CO_2 tax) because this would require a comprehensive annual measurement of the soil organic carbon content of the areas. This is not yet possible with the current state of the art and an important field of activity for research. The proposal to promote the sequestration of soil organic carbon as a voluntary agri-environmental measure **(climate mitigation premium**) is **not target-oriented** from a climate policy point of view. Farmers would then accumulate biomass on the award-winning areas, which is imported from other areas. This would be missing there, so that carbon losses occur there. For the time being, practical climate mitigation policy will probably have to come to terms with the fact that neither the measured nor the calculated soil organic carbon content is available as a control parameter for CO_2 pricing.

Substitute parameters for long-term carbon sequestration on mineral soil surfaces come into consideration: (a) grassland use and (b) afforestation. Roughly, it can be assumed that the carbon sequestration when **converting arable land to grassland** over a period of 20 years is an average of 3.2 t CO_2 / ha and year. With a **conversion of arable land to forest**, the storage capacity is even higher (average 6.4 t CO_2 / ha and year), although there are still some unanswered questions regarding the time course for both grassland and forest. Under average site conditions in Germany, the storage capacity of one hectare of forest is roughly three times as high as the storage capacity of one hectare of arable land (190 t C / ha compared to 60 t C / ha), i.e. in the long term, almost 500 t of CO_2 more are bound per hectare than with arable land.

At a CO_2 price of 100 € / t, annual climate mitigation revenues would be on the order of 320 € / ha for grassland sowing and 640 € / ha for afforestation. This could be economically attractive for farmers on locations with low agricultural productivity. From this finding, however, the recommendation to convert as much arable land as possible into grassland or forest area in Germany should not be derived. Regarding the use of grassland, it should be noted that the advantage (higher CO_2 storage) is offset by a disadvantage (methane emissions) if ruminants are kept on the area. For the forest use it has to be considered that the area is withdrawn from food production. This leads to more production and more emissions abroad, so that the German greenhouse gas balance improves, but not the global greenhouse gas balance (leakage effect).

This shows how important it is to apply CO_2 pricing comprehensively and to design it in such a way that leakage is avoided. When both soil carbon and methane are priced, farmers consider both aspects simultaneously. As a result, ruminant husbandry tends to be drawn to grassland, and it is not expanded at will. With reforestation, however, there is the problem that the domestic CO_2 pricing does honor the additional domestic carbon sequestration, but ignores the displacement of food production abroad (and the additional greenhouse gas emissions associated therewith). To get this problem under control, there are basically three options:

- **Worldwide CO_2 pricing.** This is the long-term goal. In order to achieve this as quickly as possible, Germany and the EU should initiate comprehensive CO_2 pricing as soon as possible. However, global CO_2 pricing cannot be achieved in the short and medium term. Therefore, other ways to avoid leakage must be found temporarily.

- **CO_2 pricing of imports at the EU's external borders**. The more ambitious the EU is in its pioneering role in climate mitigation, the higher the price of CO_2 will rise within the EU. This creates an even greater economic incentive to import products from other parts of the world that (a) have been produced with high greenhouse gas emissions (e.g., dairy products, beef) or (b) contain a lot of bound carbon (e.g., wood, bioenergy sources, but also all food). This additional import is counterproductive in terms of climate policy (e.g., deforestation in third countries), and it prevents consumers in the EU from receiving the “true” price signals (taking into account emissions). In order to prevent the EU's CO_2 pricing from going nowhere, in addition to internal EU policy measures, there would also have to be an increase in the price of imported goods at the EU's external borders. The problem outlined could also be partially solved by increasing consumption taxes in the EU - but only partially. Domestic consumption and leakage would decrease, but the problem of relocating production remains: the market would ensure that, with very high CO_2 prices and without external protection, at some point almost the entire EU would be reforested and food would be imported from third countries.
- **Limiting the amount of climate policy incentives in the EU**. As long as the rise in import prices cannot be politically enforced, the only way out is to limit the climate-political incentives within the EU. It would then, for example, be necessary to allow the inclusion of afforestation in the CO_2 pricing only for a (politically determined) number of hectares. This “afforestation quota” could be set all the higher, the better the EU succeeds in reducing food consumption and food losses in the EU (e.g., by increasing the tax rates for food and nutrition-related educational activities in schools).

When deciding in which region and at which locations within this region reforestation should take place, not only climate policy considerations should be decisive. Other goals such as biodiversity and landscape aesthetics also play a role. It is therefore recommended that the reforestation incentives triggered by **CO_2** pricing be accompanied by on-site policies in such a way that, in the end, a holistically optimized cultural landscape can emerge.

References

Allen MR, Shine KP, Fuglestvedt JS, Millar RJ, Cain M, Frame DJ, Macey AH (2018) A solution to the misrepresentations of CO_2-equivalent emissions of short-lived climate pollutants under ambitious mitigation. Climate and Atmospheric Science 1: 16.

Banse M, Sturm V (2019) Preissetzung auf agrarrelevante THG-Emissionen auf der Produktions- vs. Konsumseite: Was bringt mehr? SchrR Rentenbank 35:7-41

Bardt H, Schaefer (2019) Hohe Unterschiede der bestehenden CO_2-Preise. IW Kurzbericht 49/2019. Institut der deutschen Wirtschaft. https://www.iwkoeln.de/fileadmin/user_upload/Studien/Kurzberichte/PDF/2019/IW-Kurzbericht_2019_CO_2-Preise.pdf

BMEL (2018) Humus in landwirtschaftlich genutzten Böden DeutschlandsAusgewählte Ergebnisse der Bodenzustandserhebung. https://www.bmel.de/SharedDocs/Downloads/Broschueren/Bodenzustandserhebung.pdf?__blob=publicationFile (zuletzt 9.12.2019)

Bundesregierung (2019) Projektionsbericht 2019 für Deutschland gemäß Verordnung (EU) Nr. 525/2013. Im Internet:https://cdr.eionet.europa.eu/de/eu/mmr/art04-13-14_lcds_pams_projections/projections/envxnw7wq/

DESTATIS (2019) Umweltökonomische Gesamtrechnungen. Direkte und indirekte CO_2-Emissionen in Deutschland 2010 – 2015.

Drösler M, Adelmann W, Augustin J, Bergman L, Beyer C, Chojnicki B, Förster C, Freibauer A, Giebels M, Görlitz S, Höper H, Kantelhardt J, Liebersbach H, Hahn-Schöfl M, Minke M, Petschow U, Pfadenhauer J, Schaller L, Schägner JP, et al (2013) Klimaschutz durch Moorschutz : Schlussbericht des Vorhabens "Klimaschutz - Moorschutzstrategien" 2006-2010 [online]. München: Technische Universität München, 201 p

Ehrmann M (2017) Modellgestützte Analyse von Einkommens- und Umweltwirkungen auf Basis von Testbetriebsdaten. Braunschweig: Johann Heinrich von Thünen-Institut, 250 p, Thünen Rep 48,

EU-Kommission (2019) EU Emissions Trading System (EU ETS). Internet-Informationen, https://ec.europa.eu/clima/policies/ets_en

Flachowsky G, Brade W (2007) Potenziale zur Reduzierung der Methan-Emissionen bei Wiederkäuern. Züchtungskunde, 79, (6) S. 417 – 46

Don A, Flessa H, Marx K, Poeplau C, Tiemeyer B, Osterburg B (2018) Die 4-Promille-Initiative "Böden für Ernährungssicherung und Klima" - Wissenschaftliche Bewertung und Diskussion möglicher Beiträge in Deutschland. Braunschweig: Johann Heinrich von Thünen-Institut, 37 p, Thünen Working Paper 112

Gocht A, Espinosa M, Leip A, Lugato E, Schroeder LA, Doorslaer B van, Gomez y Paloma S (2016) A grassland strategy for farming systems in Europe to mitigate GHG emissions - an integrated spatially differentiated modelling approach. Land Use Pol 58:318-334

Isermeyer F (2019) Tierwohl: Freiwilliges Label, obligatorische Kennzeichnung oder staatliche Prämie? Überlegungen zur langfristigen Ausrichtung der Nutztierstrategie. Braunschweig: Johann Heinrich von Thünen-Institut, 48 p, Thünen Working Paper 124

Kommission „Wachstum, Strukturwandel und Beschäftigung“ (2019) Abschlussbericht. Januar 2019. Im Internet unter https://www.bmwi.de/Redaktion/DE/Downloads/A/abschlussbericht-kommission-wachstum-strukturwandel-und-beschaeftigung.pdf?__blob=publicationFile

Repenning J, Schumacher K, Bergmann T, Blanck R, Böttcher H, Bürger V, Cludius J, Emele L, Jörß W, Hennenberg K, Hermann H, Loreck C, Ludig S, Matthes F, Nissen C, Scheffler´M, Wiegmann K, Zell-

Ziegler C, Fleiter T, Sievers L, Pfaff M, Thamling N, Rau D, Hartwig J, Welter S, Lösch O, Wirz A (2019) Folgenabschätzung zu den ökologischen, sozialen und wirtschaftlichen Folgewirkungen der Sektorziele für 2030 des Klimaschutzplans 2050 der Bundesregierung. Öko-Institut e.V., Fraunhofer ISI, Prognos, M-Five, IREES, FiBL. Endbericht. Berlin, 3.1.2019.

Rösemann C, Haenel H-D, Dämmgen U, Döring U, Wulf S, Eurich-Menden B, Freibauer A, Döhler H, Schreiner C, Osterburg B, Fuß R (2019) Calculations of gaseous and particulate emissions from German agriculture 1990 - 2017 : report on methods and data (RMD) submission 2019. Braunschweig: Johann Heinrich von Thünen-Institut, 432 p, Thünen Rep 67

Sanders J, Brinkmann J, Haager D, March S, Treu H, Hess J, Kusche D, Hoppe J, Hupe A, Schmidtke K, Jung R, Gattinger A, Weckenbrock P, Freibauer A, Levin K, Brandhuber R, Wiesinger K, Hülsbergen KJ, Chmelikova L, Stein-Bachinger K, et al (2019) Im Dienste der Gesellschaft. Ökol Landbau(1):46-47Sieling K, Böttcher U, Kage H (2011) Ertragsentwicklung von Winterweizenbei variierter N-Düngung JOURNALFÜR KULTURPFLANZEN, 63 (6). S. 169–178

Umweltbundesamt (2019a) Nationale Trendtabellen für die deutsche Berichterstattung atmosphärischer Emissionen seit 1990, Emissionsentwicklung 1990 bis 2017 (Stand 01/2019).

Umweltbundesamt (2019b) Berichterstattung unter der Klimarahmenkonvention der Vereinten Nationen und dem Kyoto-Protokoll 2019. Nationaler Inventarbericht zum Deutschen Treibhausgasinventar 1990 – 2017. Climate Change 23/2019.

Weingarten P (1996) Grundwasserschutz und Landwirtschaft. Eine quantitative Analyse von Vorsorge-strategien zum Schutz des Grundwassers vor Nitrateinträgen. Landwirtschaft und Umwelt 13. Wissenschaftsverlag Vaug, Kiel

Weingarten P, Bauhus J, Arens-Azevedo U, Balmann A, Biesalski HK, Birner R, Bitter AW, Bokelmann W, Bolte A, Bösch M, Christen O, Dieter M, Entenmann S, Feindt M, Gauly M, Grethe H, Haller P, Nieberg H, Osterburg B, Rüter S, et al (2016) Klimaschutz in der Land- und Forstwirtschaft sowie den nachgelagerten Bereichen Ernährung und Holzverwendung : Gutachten des Wissenschaftlichen Beirats für Agrarpolitik, Ernährung und gesundheitlichen Verbraucherschutz und des Wissenschaftlichen Beirats für Waldpolitik beim Bundesministerium für Ernährung und Landwirtschaft. Berlin: Bundesministerium für Ernährung und Landwirtschaft (BMEL), 479 p, Ber Landwirtsch SH 222.

Wissenschaftlicher Beirat für Agrarpolitik beim BMELV (2007) Nutzung von Biomasse zur Energiegewinnung - Empfehlungen an die Politik. Gutachten.

Wissenschaftlicher Beirat für Agrarpolitik, Ernährung und gesundheitlichen Verbraucherschutz beim BMEL (2016) Klimaschutz in der Land- und Forstwirtschaft sowie den nachgelagerten Bereichen Ernährung und Holzverwendung. Gutachten.

Wissenschaftlicher Beirat beim Bundesministerium für Wirtschaft und Energie (2019) Energiepreise und effiziente Klimapolitik. Gutachten des Wissenschaftlichen Beirats beim Bundesministerium für Wirtschaft und Energie.

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