acatech POSITION PAPER

Executive Summary and Recommendations

CCU and CCS – Contributing to Climate Protection in Industry

Analysis, options and recommendations

acatech (Ed.)

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The Paris climate agreement came about due to the body of scientific evidence concerning the causes of climate change. Under the 2015 agreement, the German government is committed to delivering a significant reduction in Germany's greenhouse gas (GHG) emissions. This position paper was motivated by the realisation that the measures which have hitherto been implemented and the significant successes that have already been achieved in reducing GHG emissions will not be enough to meet these goals. It is expected that the present strategy will fall a long way short of delivering the agreed targets unless additional steps are taken.

While the energy sector is the biggest source of greenhouse gas emissions in Germany, the industrial sector also emits large quantities of gases that affect our climate. The German government's Climate Action Plan 2050 contains the first ever specific target for energy-intensive industries. It is thus clear that the industrial sector also has an important role to play in the development of strategies for achieving GHG neutrality. Based on our current knowledge, it appears unlikely that a systematic reduction in energy consumption throughout all sectors of industry coupled with a switch to renewable electricity wherever possible will be enough to deliver the agreed targets.

In order to achieve further reductions in industrial emissions, it will be necessary to overcome significant technical challenges. All the available options for cutting GHG emissions should be seriously considered. The three main options are as follows:

- Prevention – through improved efficiency, increased electrification and the use of alternative energy sources, processes and materials;
- Reuse – in the case of CO_2, this is referred to as Carbon Capture and Utilization (CCU);
- Permanent geological storage of any remaining CO_2 through Carbon Capture and Storage (CCS). If necessary, the stored CO_2 can be recovered for use as a raw material.

The different options should be prioritised in the above order. All appropriate solutions and their potential should be taken into consideration, and it will also be necessary to evaluate the opportunities, risks and practical limitations, as well as the regulatory and societal aspects.

At a glance

- Germany aims to reduce its greenhouse gas emissions by between 80 and 95 percent by 2050. In keeping with the Paris Agreement, German climate policy is geared towards the goal of comprehensive greenhouse gas neutrality by 2050.
- However, the currently planned and implemented measures will not be enough to deliver this ambitious target.
- Beside the energy sector, also the industrial sector in Germany emits large quantities of gases that affect our climate. The German government's Climate Action Plan 2050 contains the first ever specific target for industry.
- Achieving further reductions in industrial emissions will be extremely challenging technically. All available options should be seriously considered. In addition to the prevention of GHG emissions, these are CO_2 utilization (CCU) and CO_2 storage (CCS).
- We recommend engaging in a wide-ranging public debate in good time, so that broadly suitable technologies can continue to be developed and brought to market within the required timeframe and so that the necessary infrastructure can be planned, approved, financed and built.

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The CCU and CCS technologies addressed in detail by this paper are often mentioned in the same breath, as if their aims and impacts were largely similar. In actual fact, however, this is not the case. In Germany, CCU measures form part of the energy transition, which is focused on reducing our use of carbon-containing fossil fuels and making the switch to wind power and solar PV as the primary means of generating electricity. Several important industries in Germany still rely on carbon for a variety of purposes. Together with biomass, CO_2 can in principle provide an alternative source of carbon, although recycling CO_2 is generally an energy-intensive process in itself. Significant advances have already been made in power-to-gas technology. However, its large-scale use for climate change mitigation will not be possible in the short to medium term, since the necessary quantities of electrical energy from emission-free sources are not yet available. CCU technologies also provide the option of sequestering CO_2 on a longer-term basis, for instance in PVC products or by mineralising CO_2 to create concrete aggregate. Moreover, composite materials containing carbon fibres could be used instead of steel, aluminium and cement in many applications. In conjunction with the use of organisms, e.g. algae, to remove CO_2 from the atmosphere and the use of renewable energy for energy-intensive cracking, this could provide a pathway towards a carbon-neutral circular economy.

CCU technology can thus help to move our energy systems towards a renewable basis. To date, however, there has been hardly any public discussion of the very different specific CCU applications. It is not currently possible to say when the very large quantities of cheap renewable electrical energy will become available that would be required for CCU to make a substantial contribution to meeting the Paris climate targets.

Large-scale CCS ventures have been undertaken in other countries, while a CCS pilot project has been carried out near the German town of Ketzin. CCS allows relatively large quantities of CO_2 to be stored in rock formations deep underground, permanently removing it from the atmosphere. However, it does not contribute to the transformation of our energy systems. Public acceptance of this technology is low, in particular due to past debates concerning the use of CCS by coal-fired power stations. However, engineering and geoscience experts have several years' experience of safely storing CO_2, for instance under the North Sea, the Norwegian Sea and in Canada and the US. It will clearly only be possible to employ CCS as part of a strategy for achieving GHG neutrality if its use is widely supported among civil society, industry, government, professional associations and academia. Employment of CCS may be a realistic prospect in industries that have exhausted all the alternatives and have no other means of further reducing their CO_2 emissions. Before CCS can be used, it will be necessary to answer a number of questions: should any industrial emitters be granted privileged access to CCS technology – and if so which ones?; how long should they be allowed to use it (as a bridge technology)?; who will provide the infrastructure for transporting and storing the CO_2?; how can this be done in a cost-effective and environmentally-friendly manner while at the same time guaranteeing the highest safety standards?; what are the preferred locations and regions?; and who will pay for it? A series of challenges and research requirements exist primarily with regard to the technology's political and social acceptance.

German companies' innovative products and system solutions support climate protection all over the world, as well as creating and securing growth and jobs in machinery and plant engineering – and in electrical engineering, through the production of intelligent control technology, for example. Existing value chains and successful industry clusters should be maintained, with the relevant modifications; compatibility between GHG neutrality and industrial competitiveness should be ensured. Accordingly, federal and regional government must create conditions that foster innovation and a competitive technology environment, as well as facilitating a cost-effective reduction of overall industrial emissions. The regulatory framework and the targeted use of funding instruments will both be key to promoting these developments. Early roll-out of the necessary infrastructure will increase confidence in the sustainability and future success of industrial production lines and clusters, as well as helping to maintain Germany's position as a technological pioneer.

It is necessary to engage in a wide-ranging public debate on these issues in good time, so that broadly suitable technologies can continue to be developed and brought to market within the required timeframe and so that the necessary infrastructure can be planned, approved and built based on a pragmatic cross-company and cross-sectoral approach. Questions concerning the infrastructure's business models and funding must also be answered as soon as possible. Certain sectors (the chemical, iron and steel and cement industries) could expand appropriate existing development platforms or create pioneering new ones. Overall, however, the main challenge will be to build a public consensus regarding the extent to which CCU and CCS should form key pillars of an overarching strategy for achieving GHG neutrality.

Options and recommendations

Germany aims to reduce its GHG emissions by between 80 and 95 percent by 2050. In keeping with the Paris Agreement, German climate policy is geared towards the goal of comprehensive GHG neutrality by 2050. The federal government has set the industrial sector the target of halving its emissions by 2030, compared to 1990 levels. To achieve further reductions in GHG emissions over and above this interim target, it will be necessary to overcome significant technical challenges and to ensure early planning and investment: commercially viable technologies must be developed and the required infrastructure must be built.

- In order to ensure that the ambitious climate targets can be met, it will be necessary – during the term of the current parliament – to roll out the industrial decarbonisation strategies contained in the coalition agreement while finding solutions that can simultaneously safeguard German industry's innovativeness, productivity and competitiveness.
- In addition to ongoing efficiency improvements, increased electrification of industrial processes, the use of alternative energy sources, processes and materials, targeted support for innovative emission reduction technologies, and the use of Carbon Capture and Utilization (CCU) as a step towards the establishment of a circular economy, a GHG neutrality strategy for industry should also consider the geological storage of CO_2 process emissions that cannot be otherwise prevented (Carbon Capture and Storage, CCS).
- Utilization of CO_2 can make a contribution to GHG neutrality. Ultimately, however, CCU will only be able to play a decisive role in climate protection once very large quantities of cheap renewable energy become available. Since it is currently difficult to predict when this will happen, it is all the more important to implement alternative solutions over the coming decades.
- Once the potential for the affected industries to reduce or eliminate their process emissions has been definitively exhausted and the possibility of transitioning to new materials and technologies in order to further cut emissions has been fully explored, consideration should be given to the option of geological storage of CO_2. Large quantities of CO_2 can be stored deep under the earth's surface, both onshore and offshore, and can also be recovered if necessary.
- Given that it will take at least ten years to enable the widespread deployment of CCU and CCS, the potential of both technologies and the opportunities to create cost-effective synergies (e.g. a shared transport infrastructure) should be studied and assessed during the term of the current parliament. This is key to ensuring that CCU and CCS can be deployed on the necessary scale and within the required timeframe.
- Market-enabling institutions could be created to coordinate and implement the construction of a CCS infrastructure that would also be available for transporting CO_2 from CCU projects. These institutions would provide a central platform for coordinating carbon capture, transport and storage projects, thereby reducing the economic risks. A cluster approach could reduce costs by generating economies of scale.
- It will only be possible to employ CCS as part of a strategy for achieving GHG neutrality if its use is widely supported among civil society, industry, government, professional associations and academia. As well as addressing the technological, economic, geological, political and regulatory challenges, it will also be essential to build widespread public support and acceptance.

In view of the ambitious commitments arising from the Paris Agreement, we consider it urgently necessary to evaluate the opportunities, risks and practical limitations of CCU and CCS during the term of the current parliament, as part of a comprehensive GHG neutrality strategy. The options identified through this process should be discussed with all the stakeholders as soon as possible.

Methodological approach

This acatech POSITION PAPER is the product of two years' work by the project group, based on a series of in-depth workshops involving presentations, discussions and shaping of the content. A core of some 30 experts in the relevant fields took part in the project, including several leading figures from research institutions, public agencies and authorities, industry, environmental organisations, the trade unions, a standardisation institute and a number of consultants. The workshop participants from industry included representatives of companies and associations from the chemical, iron and steel and cement industries, as well as from a technology enterprise. The environmental organisations involved in the project were the European Climate Foundation, Bellona Foundation, Germanwatch and WWF Deutschland. The project was funded by the European Climate Foundation, BASF SE, Covestro Deutschland AG, The Linde Group and the acatech Förderverein.

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