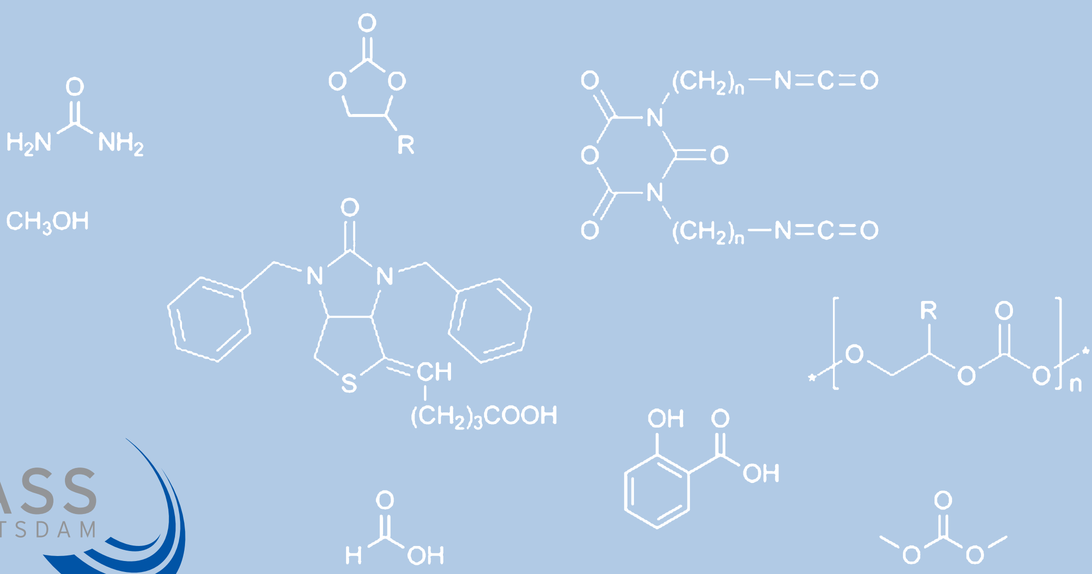
IASS WORKING PAPER

Institute for Advanced Sustainability Studies (IASS)
Potsdam, December 2015

CO_2 Recycling – An Option for Policymaking and Society?

Twelve Theses on the Societal and Political Significance of Carbon Capture and Utilisation (CCU) Technologies

Henriette Naims, Barbara Olfe-Kräutlein,
Ana Maria Lorente Lafuente, Thomas Bruhn



IASS POTSDAM

Contents

Introduction

For almost 50 years, chemistry researchers have been exploring the idea of using the molecule and greenhouse gas CO_2 as a feedstock [1]. Since the oil crises of the 1970s, and especially since climate change has become a focus of public discussion in recent years, technologies that use CO_2 as a source of carbon have been under development. These efforts are aimed at integrating the harmful gas as a feedstock in industrial processes and thus imitating a natural carbon cycle [2]. In many regions funding schemes have been introduced to support the development of such technologies [3–5]. This has led to several technological breakthroughs in recent times, and the first products are now coming on stream.

An interdisciplinary team at the IASS has been investigating the societal aspects of so-called Carbon Capture and Utilisation (CCU) technologies from the perspective of the natural sciences, engineering, economics and communication studies since 2013. The purpose of this project is to identify and evaluate the potential risks and opportunities that may arise in connection with a broad implementation of these technologies at an early stage of their development. A transdisciplinary approach is taken to this research, i.e. in dialogue with representatives of science, industry, policy and civil society. The research process also entails an intensive exchange of ideas with colleagues from other subject areas at the IASS as well as the investigation of specific disciplinary research questions. The theses on the societal and political aspects of CO_2 utilisation elaborated below were developed on the basis of this multi-layered approach.

They summarise those aspects of CO_2 utilisation that are particularly relevant to society as well as subjecting some established arguments in the CCU debate to critical scrutiny. The focus lies on the risks and potentials of CO_2 utilisation from the perspective of environmental and energy policy. Beyond that, theses and recommendations are presented on options for shaping policy that are at present mainly being discussed by the research community. Further theses deal with early critical aspects in relation to societal acceptance or a possible rejection of CCU technologies.

These theses do not represent a conclusive scientific result. They are, rather, the interim results of an initial exploration of the societal and policy dimensions of CCU and recommendations on the part of the team of authors for the dialogue on this scientific field. Prior to publication, all the participants of the Round Table on CO_2 Recycling that took place at the IASS on 9 November 2015 had the opportunity to provide their feedback on the theses. Thus the theses pick up on discussions and ideas at the round table without reflecting a consensus among the participants of that event.

I. Environmental and energy policy

1. CO_2 recycling can contribute to a circular economy and securing the raw materials base.

In the Earth's natural carbon cycle, CO_2 is not a waste product. CCU technologies imitate natural processes by attempting to integrate the CO_2 emitted through human activities as a feedstock [6]. Today, a host of applications are already technically feasible [2]. In future, a carbon cycle could arise and another carbon source could be added to the industrial raw materials base. Especially in countries with limited fossil and renewable resources, this locally available raw material could be an attractive option for industry.

2. A contribution to climate protection is possible, but shouldn't be overestimated.

Relative to the total required global emissions reductions, the anticipated contribution of CCU technologies to climate protection is rather small: even long-term scenarios based on very optimistic assumptions suggest that at most 6% of anthropogenic emissions could be used to produce materials and fuels [7, 8]. However, since CO_2 utilisation processes require energy, whose generation may result in new CO_2 emissions, their carbon footprint may be negative or positive, depending on the technology in question [9]. Moreover, in most CCU applications the length of time for which CO_2 can be stored is limited. At the end of the product's life cycle, CO_2 is once again emitted. So it is important to distinguish between the amount of CO_2 utilised and the total amount of CO_2 emissions that can be avoided as a result of this utilisation. In some CCU applications, the CO_2 saved outweighs the CO_2 used thanks to processes that are more efficient in comparison to conventional technologies [10].

3. Even when CO_2 from the combustion of renewable raw materials is used as a carbon source in CCU processes, only a limited reduction in the CO_2 content of the atmosphere is possible.

Renewable raw materials represent an alternative source of carbon and energy. They have the potential to be carbon neutral when their processing and utilisation does not cause emissions. This is possible because during their growth phase they absorb the same amount of carbon that is later emitted in combustion.

Thus, using CO_2 from the combustion of renewable raw materials in CCU-based products can lead to a reduction of CO_2 in the atmosphere because the CO_2 is taken from the atmosphere rather than from the combustion of fossil carbon. In this way, CO_2 is not permanently removed from the atmosphere, but it enters a new utilisation cycle, and the CO_2 content of the atmosphere is reduced by the total amount of CO_2 bound up in that cycle.

However, the growing demand for biomass necessitates greater land use, which could conflict with food production. Beyond that, increased biomass production can lead to deforestation and loss of biodiversity as well as driving out small farm industries [11].

4. When emissions from beyond the energy sector are used, CO_2 recycling can complement the energy transition to renewables and does not create path dependencies that perpetuate the fossil energy infrastructure. This is where CCU differs decisively from CCS.

Possible sources of CO_2 include industrial facilities and the atmosphere. The bulk of global emissions from major point sources (approx. 76%) come from the fossil energy sector (coal- and gas-fired power plants). Large industrial facilities (e.g. in the cement, iron and steel industry), which are currently responsible for 22% of global CO_2 emissions from major point sources, are also a possible source of CO_2. Only a small fraction of industrial emittents (approx. 2%) deliver highly concentrated CO_2. Even if all coal- and gas-fired power plants were decommissioned, the total CO_2 emissions from other sources (e.g. the cement, iron and steel industry or refineries) would still be large enough to cover the demand for CO_2, according to optimistic long-term scenarios for the development of CCU [12]. Thus the application of CCU to recycle industrial emissions beyond the energy sector would not create path dependencies that would perpetuate the fossil energy infrastructure.

Already much discussed, CCS (Carbon Capture and Storage) technologies aim primarily to improve the carbon footprint of the existing fossil infrastructure on a large scale, particularly that of power plants. For that reason, CCS is often seen as a bridging technology for the energy transition to renewables. Yet the investment costs associated with upgrading fossil power plants create incentives to operate them for longer and could thus lead to path dependencies that would run counter to the goal of decarbonising the energy sector.

By contrast, CCU can complement energy transition processes, as long as those emissions are used that arise outside the fossil energy sector. Apart from that, the carbon footprint of CCU processes must demonstrate an emissions saving, which is possible, for example, by substituting fossil raw materials, increasing efficiency, and using renewable energies.

5. Certain CCU applications can store energy. They are, however, not yet economically viable.

The energy transition is leading to a growing renewable energy infrastructure, which is associated with a fluctuating energy supply and therefore demands greater system flexibility, for example through energy storage. In this context, CCU technologies are proposed as an option for storing energy in so-called 'Power-to-X' applications (e.g. Power-to-Gas, -Liquid, and -Chemicals).

In the case of peaks in energy availability, surplus energy can be used in conjunction with regionally available CO_2 emissions to produce synthetic liquid or gaseous fuels [13–15]. However, this storage of energy with the help of CCU technologies does compete with other technologies, such as the direct use of hydrogen produced by renewable energy as an energy carrier, and, especially, the export of surplus energy as electricity. In general, the periods in which excess electricity is available are often too short and the amounts of renewable energy generated are not yet sufficient, given that the electricity market has to be satisfied first. Thus, broader implementation of CCU storage options will only be possible when the economic viability of these technologies can be improved.

6. The feedstock CO_2 can be a relatively inexpensive source of carbon.

The cost of pure CO_2 is the sum of the costs of capturing and, where necessary, transporting it. Transport costs can be minimised by building utilisation facilities at locations where relatively cheap CO_2 is available. The costs of capturing CO_2 depend on the source in question and the technology used and can range from only around €10 per tonne in fermentation to around €100 per tonne in refining processes [16, 17].

When CCU technologies increase the efficiency of a given process or substitute a raw material, then overall cost reductions can be expected. This is possible because another raw material, produced, for example, from high-energy carbon carriers, can be replaced. However, such a substitution is never total or in equal proportion (1:1), nor is it possible in the case of all technologies. Falling market processes for fossil raw materials are, however, reducing the incentives to develop CCU technologies further in this regard.

II. Options for shaping policy

7. CCU should continue not to be accounted for as a direct reduction of emissions in climate policy measures such as emissions trading. It is possible to account for its contribution indirectly in existing emissions reporting.

While CCS can be directly credited as a measure to reduce emissions in existing CO_2 management systems like emissions trading [18], CCU processes are not directly accounted for. This is because the emissions used are not permanently bound. Only in a small number of CCU applications where the process of conversion is often energy-intensive (e.g. the production of cement or insulating materials) can CCU delay CO_2 emissions for the longer term. Yet what's most important is that CCU can lead to emission reductions through indirect effects such as greater efficiency or the substitution of raw materials and thus have an effect on the carbon footprint of an industrial facility, just like other efficiency measures [9]. So it's not the amount of CO_2 used in CCU that should be credited as a reduction, but rather the total avoided emissions calculated for the facility in question. When such savings can be demonstrated in emissions reporting [19], it is possible to take account of CCU processes in emissions trading via existing monitoring plans and notifications of changes. In these cases, cost savings with regard to any emissions taxes or certificates that may arise can be achieved in climate policy measures such as emissions trading.

8. Portraying CO_2-based products as 'renewable-based products' may be misleading in a policymaking context.

CO_2 can be part of both a natural and a technical cycle [6]. From a technical point of view it is therefore correct to see CO_2 as a renewable resource in the context of CCU. In the policy context, however, in particular where laws, regulations and funding schemes are concerned, portraying CO_2 as a 'renewable resource', as some actors advocate, could lead to misconceptions [20]. This might imply that our understanding of the role of carbon dioxide in climate change should be completely revised. But using CO_2 generated mainly from fossil sources as a feedstock in industrial processes is not consistent with existing policy definitions of 'renewable', such as those established in the promotion of renewable energies [21]; this should be viewed and treated as a separate category in the policy context.

9. Using CO_2 from natural sources makes less sense from an ecological point of view than using CO_2 from other sources.

Capturing CO_2 involves a certain amount of effort, which varies depending on the chosen source and technology and can thus give rise to different side effects [22]. So the origins of the CO_2 used influence its ecological assessment. In many countries the current demand for CO_2 is also covered by natural sources such as rock formations; in the United States these provide approximately 45 million tonnes of CO_2 [23]. This is also because the costs of capturing CO_2 emissions from natural sources can be very low (€15–20 per tonne) due to the high purity that often characterises these natural deposits [1]. However, it should be noted that these sources often need to be developed before highly pure CO_2 can be obtained. This approach therefore contradicts the ecological goals of climate protection and the circular economy, because it releases additional CO_2 stored in nature instead of relying on available industrial emissions. It is therefore recommended to substitute CO_2 from natural sources with CO_2 from industrial emissions for CCU in order to achieve a net emissions reduction [1, 18].

10. The introduction of standards for the assessment of CCU technologies is recommended.

Techno-economic and ecological analyses are increasingly being carried out as CCU continues to grow as a field of technology. Yet, the results of these analyses depend largely on the assumptions that underlie them, the system boundaries, and the allocation methods used in the assessment, as the ISO standards for environmental management and life cycle assessment emphasise [24, 25]. Uniform standards that set out both the methodology and the criteria for the analysis are therefore essential if the results of techno-economic and ecological analyses are to be comparable. This would also enhance overall comprehension of the results and the validity of statements on the potential effects of CCU technologies. These aspects are currently being discussed in expert CCU circles, especially with regard to ecological assessments [26].

III. Societal acceptance

11. An overly optimistic communication of the ecological potentials of CCU in particular carries the risk of instrumentalisation for greenwashing.

Public pressure to legitimise technical innovations and large industrial facilities often manifests itself in a process of observation and evaluation by individuals or groups and can result in a noticeable acceptance or rejection by parts of the population [27]. So far, CCU applications have tended to be seen in a positive light in public discourse and the media [28–30]. Yet time and again, reporting on the anticipated effects of these applications, especially on their climate protection potentials, has been overly positive [31, 32]. To counter possible accusations of greenwashing, the potentials need to be communicated realistically already at the research and development stage and no false expectations should be raised.

12. CCU is not a valid argument in favour of the introduction and establishment of CCS technologies.

In Germany, CCS technologies are broadly rejected by society [33]. Despite a semantic and technical proximity at the early stages of the processes (capture), the two technological concepts – CCU and CCS – differ significantly in terms of their risks and potentials. It is therefore very important to make a clear distinction between the two technological fields in societal and political discourse. This is not only important for communicating CCU technologies in a way that does justice to its specifics, but also for contextualising the political discourse around CCU, which can and should not run parallel to that on CCS. Despite certain technical overlaps, we recommend that scientific communication highlight the very different goals and motivations behind the two concepts.

References

[1] Aresta, M. & Dibenedetto, A. (2010) 'Industrial utilization of carbon dioxide (CO_2)' in Maroto-Valer, M. M. (ed.), *Developments and innovation in carbon dioxide (CO_2) capture and storage technology: Volume 2: Carbon dioxide (CO_2) storage and utilisation*, Great Abington: Woodhead Publishing, 377–410.

[2] Peters, M., Köhler, B., Kuckshinrichs, W., Leitner, W., Markewitz, P. & Müller, T.E. (2011) 'Chemical technologies for exploiting and recycling carbon dioxide into the Value Chain', *ChemSusChem* 4(9), 1216–1240.

[3] BMBF (2013) *Technologies for sustainability and climate protection – Chemical processes and use of CO_2: Federal Ministry of Education and Research Funding Programme Information Brochure,* Bonn: BMBF.

[4] U.S. DOE (n.d.) *Innovative concepts for beneficial reuse of carbon dioxide*, Washington: U.S. Department of Energy, URL: <http://energy.gov/fe/innovative-concepts-beneficial-reuse-carbon-dioxide-0>.

[5] Climate-KIC (2014) *Climate-KIC to unveil multimillion Euro investment in four climate change innovation programmes at European Business Summit*, London: Climate-KIC, URL: <http://www.climate-kic.org/press-releases/climate-kic-to-unveil-multimillion-euro-investment-in-four-climate-change-innovation-programmes-at-european-business-summit/>.

[6] Bringezu, S. (2014) 'Carbon Recycling for Renewable Materials and Energy Supply: Recent Trends, Long-Term Options, and Challenges for Research and Development', J. *Ind. Ecol*. 18(3), 327–340.

[7] VCI & DECHEMA (2009) *Position Paper Utilization and Storage of CO_2* , Frankfurt: DECHEMA, URL: <http://www.dechema.de/dechema_media/Positionspapier_co2_englisch-p-2965.pdf>..

[8] Le Quéré, C., Moriarty, R., Andrew, R., Peters, G., Ciais, P., Friedlingstein, P., Jones, S., Sitch, S., Tans, P. & Arneth, A. (2014)'Global carbon budget 2014', *Earth System Science Data Discussions* 7(2), 521–610.

[9] von der Assen, N., Lorente Lafuente, A.M., Peters, M. & Bardow, A. (2015) 'Environmental Assessment of CO_2 Capture and Utilisation' in Armstrong, K., Styring, P. & Quadrelli, E. A. (eds), *Carbon Dioxide Utilisation*, Amsterdam: Elsevier, 45–56.

[10] von der Assen, N. & Bardow, A. (2014) 'Life cycle assessment of polyols for polyurethane production using CO_2 as feedstock: insights from an industrial case study', *Green Chem*. 16, 3272–3280.

[11] Müller, A., Weigelt, J., Götz, A., Schmidt, O., Alva, I.L., Matuschke, I., Ehling, U. & Beringer, T. (2015) 'The Role of Biomass in the Sustainable Development Goals: A Reality Check and Governance Implications', *IASS Working Paper*, Potsdam: IASS.

[12] Naims, H. (n.d.) 'Economics of carbon dioxide capture and utilization – A supply and demand perspective', *Environmental Science and Pollution Research* (under review).

[13] Varone, A. & Ferrari, M. (2015) 'Power to liquid and power to gas: An option for the German Energiewende', *Renewable and Sustainable Energy Reviews* 45, 207–218.

[14] Sternberg, A. & Bardow, A. (2015) 'Power-to-What? – Environmental assessment of energy storage systems', *Energy & Environmental Science* 8(2), 389–400.

[15] Klankermayer, J. & Leitner, W. (2015) 'Love at second sight for CO_2 and H_2 in organic synthesis', *Science* 350(6261), 629–630.

[16] Möllersten, K., Yan, J. & R. Moreira, J. (2003) ‘Potential market niches for biomass energy with CO_2 capture and storage – Opportunities for energy supply with negative CO_2 emissions’, *Biomass Bioenerg*. 25(3), 273–285.

[17] van Straelen, J., Geuzebroek, F., Goodchild, N., Protopapas, G. & Mahony, L. (2010) ‘CO_2 capture for refineries, a practical approach’, *Int. J. Greenh. Gas Con*. 4(2), 316–320.

[18] Metz, B., Davidson, O., De Coninck, H., Loos, M. & Meyer, L. (2005) *IPCC special report on carbon dioxide capture and storage*, New York: Cambridge University Press, URL: <http://www.ipcc.ch/pdf/special-reports/srccs/srccs_wholereport.pdf>.

[19] German Emissions Trading Authority (2015) *Leitfaden zur Erstellung von Überwachungsplänen und Emissionsberichten für stationäre Anlagen in der 3. Handelsperiode (2013–2020)*, Berlin: Federal Environment Agency, URL: <http://www.dehst.de/SharedDocs/Downloads/DE/Emissionsberichterstattung/stationaer/2013/Emissionsbericht_Leitfaden.pdf>.

[20] SusChem (2015) *Circular Economy: SusChem Position Paper*, URL: <http://suschem.blogspot.be/2015/10/suschem-position-paper-on-circular.html>.

[21] European Union (2009) ‘Directive 2009/28/EC of the European Parliament and the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EG und 2003/30/EG’, *Amtsblatt der Europäischen Union* 140, 16–62.

[22] Dautzenberg, G. & Bruhn, T. (2013) ‘Environmental impacts of carbon capture technologies: An overview of the state of development, potential side effects and current challenges for science and society’, *IASS Working Paper*, Potsdam: IASS.

[23] Wilcox, J. (2012) *Carbon capture*, New York: Springer.

[24] International Organization for Standardization (2006) ISO 14040: *Environmental management – Life cycle assessment - Principles and framework* (2nd ed.), Genf: ISO, URL: <http://www.iso.org/iso/catalogue_detail?csnumber=37456>.

[25] International Organization for Standardization (2006) ISO 14044: *Environmental management –Life cycle assessment – Requirements and guidelines*, Genf: ISO, URL: <http://www.iso.org/iso/catalogue_detail?csnumber=38498>.

[26] von der Assen, N., Jung, J. & Bardow, A. (2013) ‘Life-cycle assessment of carbon dioxide capture and utilization: avoiding the pitfalls’, *Energ. Environ. Sci*. 6(9), 2721–2734.

[27] Renn, O. (2005) ‘Technikakzeptanz: Lehren und Rückschlüsse der Akzeptanzforschung für die Bewältigung des technischen Wandels’, *Technikfolgenabschätzung – Theorie und Praxis* 14(3), 29–38.

[28] Schramm, S. (2014) ’Unser umtriebiges Element‘, *DIE ZEIT*, printed edition, 25.9.2014.

[29] Schrader, C. (2012) ’Klimagas in der Matratze‘, *Süddeutsche Zeitung*, printed edition, 11.12.2012.

[30] Deffke, U. (2012) ’Ressource CO_2 – Vom Klimakiller zum Rohstoff‘, *Spiegel Online*, 26.12.2012, URL: <http://www.spiegel.de/wissenschaft/technik/kohlendioxid-klimakiller-als-rohstoff-a-873928.html>.

[31] Fröndhoff, B. (2015) ’Die Welt hat kein Rohstoffproblem‘ *Handelsblatt*, printed edition, 21.10.2015.

[32] Lim, X. (2015) ‘How to make the most of carbon dioxide’, *Nature* 526, 29.10.2015, URL: <http://www.nature.com/news/how-to-make-the-most-of-carbon-dioxide-1.18653>.

[33] Pietzner, K. (2015) ’Gesellschaftliche Akzeptanz: Ganzheitliche Bewertung im Bereich von Energiewirtschaft und Industrie‘ in Fischedick, M., Görner, K. & Thomeczek, M. (eds), *CO_2: Abtrennung, Speicherung, Nutzung*, Berlin: Springer, 671–697.

IASS Working Paper
December 2015

Institute for Advanced Sustainability Studies Potsdam (IASS) e. V.

Author contact:
Henriette.Naims@iass-potsdam.de

Translated by:
Anne Boden

Address:
Berliner Strasse 130
14467 Potsdam
Germany
Phone 0049 331-28822-340
www.iass-potsdam.de

e-mail:
media@iass-potsdam.de

Management Board:
Prof. Dr. Mark G. Lawrence

DOI: 10.2312/iass.2016.004

SPONSORED BY THE
Federal Ministry
of Education
and Research

FONA
Research for Sustainable Development
BMBF

LAND
BRANDENBURG
Ministerium für Wissenschaft,
Forschung und Kultur