2021-IP15 – CSLF 2021 Technology Roadmap

This Carbon Sequestration Leadership Forum (CSLF) 2021 Technology Roadmap was published in May 2021. The Roadmap is an update of the 2017 version, complied from reported progress on carbon capture, utilisation and storage (CCUS) activities between October 2017 and February 2021. The publication is a succinct summary of the significant progress in CCUS. It includes developments in capture, storage, utilisation, transportation, initiation of hubs and an outline of national policies. This information paper briefly highlights key points and recommendations proposed by the CSLF.

In the 2021 Technology Roadmap, the time horizons for medium- and long-term targets have changed from 2025 and 2035 to 2030 and 2050, following the international trend for climate ambitions. This Roadmap includes new scenario projections from the IEA based on the IEA Sustainable Development Scenario (SDS)[1][2][3][4] in contrast to the previous IEA 2C scenario used in 2017. There are updated sections on power, industry, R,D&D and expanded sections on hydrogen with CCUS, CO_2 hubs, industrial CCUS, and CO_2 utilisation. A new section on negative emission technologies (NETs) has been included.

One of the headline points of the Roadmap is that many countries have ambitious targets to achieve net-zero emissions by mid 21st century, however analyses by the UN in February 2021 shows that the world is not on track to reach targets set by the Paris Agreement of keeping with the 2°C temperature rise and preferably close to 1.5°C by the end of the century.

Despite the impact of the COVID-19 pandemic global emissions are on the rise and will exceed the 33.4 billion metric tons of CO_2 in 2019. The United Nations Framework Convention on Climate Change (UNFCCC) indicates that the set of measures included in updated nationally determined contributions (NDCs) (as of February 2021) would result in only a 0.5% drop in emissions by 2030, compared with the 25% decrease that is necessary. CSLF conclude that more drastic action is clearly necessary, although many countries have ambitious national plans. It's also clear that the great majority of climate mitigation scenarios show that CCUS has a crucial role in direct emission reduction from industrial processes and fossil-fuel power generation. Its deployment in hard-to-abate industries is also stressed. Significantly modelling suggests that without CCUS it's virtually impossible, and more costly, to reduce CO_2 emissions at a rate fast enough to limit global warming below 2°C. This conclusion is in line with the Energy Transition Committee (ETC 2018)[5] and McKinsey (2020)[6]. Negative emissions technologies are advocated to achieve reduction targets.

The IEA SDS scenario requires that almost 5.3 Gt CO_2 be captured and stored in the year 2050, with an additional 0.4 Gt CO_2 captured and used.

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1 IEA (2019a). *World Energy Outlook 2019*. Paris: International Energy Agency. https://www.iea.org/reports/world-energy-outlook-2019.

2 IEA (2020a). *Energy Technology Perspectives 2020*. Paris: International Energy Agency. https://www.iea.org/reports/energy-technology-perspectives-2020

3 IEA (2020b). *Energy Technology Perspectives 2020 Special Report on Carbon Capture Utilisation and Storage: CCUS in clean energy transitions*. Paris: International Energy Agency. https://webstore.iea.org/ccus-in-clean-energy-transitions CSLF Technology Roadmap 2021

4 IEA (2020c). *World Energy Outlook 2020*. Paris: International Energy Agency. https://www.iea.org/reports/world-energy-outlook-2020

5 ETC (2018). *Mission Possible. Reaching net-zero carbon emissions from harder-to-abate sectors by mid-century*. http://www.energy-transitions.org/sites/default/files/ETC_MissionPossible_FullReport.pdf

6 McKinsey (2020.) *Net Zero Europe: Decarbonization pathways and socioeconomic implications*. https://www.mckinsey.com/business-functions/sustainability/our-insights/how-the-european-union-could-achieve-net-zero-emissions-at-net-zero-cost

The Roadmap stresses the progress in CCUS since 2017 notably 25 projects in operation worldwide by 2020 and the development of industrial CO_2 infrastructure including the Alberta Carbon Trunk Line (ACTL) in Canada which began operation in 2020. Several other industrial CO_2 hubs are mentioned and some, such as the Longship project in Norway, passed a final investment decision (FID) in 2020.

In terms of Technology developments capture costs have been reduced through research, development and demonstration (R,D&D) by 15% - 20% over the last decade. There is considerable expansion in the use of hydrogen production from natural gas with CCUS to accelerate the transition to a hydrogen society, with cost and carbon footprint competitive with hydrogen from electrolysis in the short to medium time frame.

In addition to new national strategies several countries have introduced incentive policies to stimulate large-scale projects and CCUS hubs. The previous barrier in the London Protocol has been lifted allowing the export of CO_2 for offshore geological storage. International standards and recommendations for sustainable finance have been proposed.

This Roadmap has some sobering conclusions for the progress of CCUS. By the end of 2020, the global carbon capture and injection capacity in operation was approximately 40 million metric tons (Mt) CO_2/year. Planned projects scheduled to come online between 2025 - 2030 may add less than 300 Mt CO_2/year, around 50% of what is needed in (SDS). By 2050 CCS will need to be increased by a factor of 100 or more from the 2020 level of 40 Mt CO_2 per year. CSLF consequently recommends that CCUS should increase by a factor of 10-15 from the 2020 level and by a factor of 100 by 2050. The implications of reaching this level of deployment implies CCUS needs to store 650 Mt CO_2/year by 2030 equivalent to development of 200 – 300 sites between 2021 and 2030 assuming an average storage capacity of 2 – 3 Mt CO_2/year per site.

The CSLF 2021 Roadmap has included a section on hydrogen, and its integral role with CCUS, as a means to decarbonise cities and some industrial sectors as well as maritime, heavy-duty land transport and aviation. The report outlines a number of proposed hydrogen networks in Europe, one in the USA and an Australian / Japanese venture. Under the 2050 SDS for hydrogen production, 287 Mt of H_2/year could be produced by electrolysis but this quantity would require 14,000 TWh of electricity which is more than 60% of current global generation, about 33% - 35% of electricity output by 2050. Producing this quantity of hydrogen by steam methane reformation (SMR) would require 30% - 35% of current natural gas production. By 2050 hydrogen produced by renewable electricity and natural gas combined with CCUS will be needed in approximately equal proportions, although the SMR with CCUS route will dominate until after 2040.

The cost of low-carbon hydrogen produced from SMR with CCS is expected to stay in the range of 1–2 €/kg H_2 between 2019 and 2050. Hydrogen from electrolysis was in the range of 3–7 €/kg H_2 in 2019 but expected to decrease in cost compared with hydrogen from fossil fuels with CCUS by 2050.

The transition to greater use of renewable energy also has significant land-use implications. Hydrogen from electrolysis using electricity from wind will require 460.5 km^2 compared with 0.008 km^2 for hydrogen from natural gas with CCUS for the same (12.5 TWh/year) quantity.

The CSLF have provided helpful technology updates on capture, storage, deployment and utilisation. The Roadmap has taken these into account and outlines a series of suggested priority actions.

For capture these include:

Towards 2025:

- Demonstration of (TRL >7) CO2 technologies for power generation and industrial applications that were at TRL 5–7 in 2020.

Towards 2030;

- Commercialisation of mature (TRL >9) CO_2 capture technologies for power generation and industrial applications that that were at TRL 5–7 in 2020, with avoided cost in $/t$CO_2$ at least 25% below that of 2020 commercial technologies (average of around $60/t CO_2), while at the same time minimizing environmental impacts.
- Implement CCUS at 30% of fossil-fuel-based hydrogen production facilities.

Toward 2050

- Commercialisation of mature (TRL >9) CO_2 capture technologies for power generation and industrial applications that capture very close to 100% of the CO_2 and, at the same time, achieve at least 40% reduction of avoided carbon cost in $/t$CO_2$ compared to 2020 commercial technologies, while minimizing environmental impacts.
- Cover 50% of the global hydrogen demand by production from fossil fuels with CCS.

Priority actions for CCUS hubs

Toward 2025

- Start the construction of at least five new CCUS hubs.
- Continue to identify and mature hubs.

Toward 2030:

- Ensure rapid build-out of strategic power and industrial CO_2 capture clusters, with common CO_2 transportation and storage infrastructure (hubs), to secure that CCUS hubs collect and store at least 400 Mt CO_2/year.

Priorities for storage

Toward 2025:

- Commercialise monitoring technologies under development.
- Continue characterisation of CO_2 storage sites.

Toward 2030

- Characterise sufficient storage sites to secure an increase by a factor of 10 - 15 from the 2020 level (40 Mt CO_2/year) of long-term isolation of CO_2 from the atmosphere.
- Reduce monitoring and verification costs by 20% from 2020 levels.

Toward 2050

- Characterise sufficient storage sites to secure an increase by a factor of at least 100 from the 2020 level of long-term isolation of CO_2 from the atmosphere.

The cost of CO_2 storage is discussed in the Roadmap. It is stressed that cost will be site-dependent and in the United States varies between \$5 and \$55/t CO_2 for both onshore and offshore storage. Approximately 60% of the onshore and only 6% of offshore sites have cost less than \$10/t CO_2.

For Utilization the CSLF recommends:

Toward 2030:

- Governments should continue the development and deployment of second-generation utilization technologies by investing in pilot-scale and demonstration projects.
- Governments should establish a goal that a certain percentage of all government-procured products meet a low-carbon or "green" standard.

CSLF also commented on policy especially in the light of the lack of progress with NDCs reaching targets set by the Paris Agreement. Consequently the CSLF recommends:

- NDCs under the Paris Agreement must be strengthened.
- Strong efforts in post-COVID-19 recovery plans are needed to sufficiently decarbonize the economy.
- There is some reason for optimism, as many countries have reported various national strategies and specific CCUS policy initiatives for large-scale deployment that will be the main drivers of CCUS deployment in the short to medium term.

The CSLF 2021 Technology Road Map provides a comprehensive overview of the current status of CCUS and where the technology needs to go if it is to make a serious contribution to 2050 emission reduction targets. It's clear there are significant challenges for CCUS but there is evidence technological achievement at scale is possible. IEAGHG are participants in the CSLF Technical Group and provided inputs and feedback to this report.

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