The Value of Carbon Capture, Utilization, and Sequestration

Cuicui Chen and Henry Lee

POLICY BRIEF / MARCH 2020

HARVARD Kennedy School
BELFER CENTER
for Science and International Affairs

Carbon Capture, Utilization, and Sequestration (CCUS)

Coal-fired and natural-gas-fired power capacities account for 60% of the world's total power capacity, exceeding 2,000 and 1,600 gigawatts respectively. Many coal and natural gas production facilities are less than 15 years old, with the capacity to operate for at least another 25 years. If countries are even partially successful in reducing carbon emissions, the demand for green electricity is likely to be significantly higher. If demand for fossil fuels decreases, so will market prices; as a result, fossil fuels could become increasingly attractive to poorer developing countries. In addition, the heavy manufacturing facilities responsible for producing steel, cement, and chemicals emit substantial amounts of carbon.

It is highly probable that many fossil-fueled and manufacturing facilities will remain in operation over the 2040-2060 time period. This scenario would make it nearly impossible to limit global warming to 2 degrees Celsius: the international target set by the 2015 Paris Agreement. Unless countries can develop, demonstrate and deploy innovative technologies to strip the carbon from fossil fuels, it will be challenging to reach even a 3-degree goal.

One emerging technology with significant potential to limit global emissions is carbon capture, utilization and sequestration (CCUS). CCUS represents a class of technologies that directly capture carbon dioxide, either before or after combustion, and then either permanently store it in underground deposits or recycle it for further use.

As of now, CCUS has been deployed only in isolated pilot projects; most of which sell the resultant stream of carbon dioxide to oil producers as a tool to increase production in older wells. This market is both geographically and economically limited, particularly if oil prices remain low.

However, growing concern around climate change has ignited recent interest in CCUS technologies and a series of studies on its global market potential. A 2017 International Energy Agency report[1] suggests that to meet the 2-degree-Celsius target, CCUS must account for at least 20% of the reduction in annual global emissions by 2060. In the United States, Congress has approved generous tax credits for CCUS investments, generating new interest from investors. The number of CCUS projects is increasing in many countries, from the U.S. and Canada to China and Norway.

1 International Energy Agency, 2017. "Energy Technology Perspectives 2017: Catalysing Energy Technology Transformations", available at https://www.oecd-ilibrary.org/energy/energy-technology-perspectives-2017_energy_tech-2017-en.

This policy brief poses the following questions. First, what is the value of CCUS technologies from the public perspective, and how might that change over time? Second, how can governments most effectively pursue that value?

Components of Value

CCUS is not presently cost-competitive. However, governments can move forward by subsidizing CCUS; if these subsidies are generous enough, some investors are bound to embrace the technology. However, such a strategy is limited: both by the size of government subsidies and the limited number of viable projects. Furthermore, subsidies tend to lock in presently available technologies, when the benefits of more advanced versions of CCUS that are cost-competitive with alternative carbon mitigation investments may be substantial. Hence, each nation must start by considering how much of its research and development budget to allocate for CCUS.

The value of a nascent technology is determined by two elements: expected benefits of having the technology widely available, and expected costs of R&D to successfully advance it. A key factor in determining the expected cost of R&D is the increase in the probability of success for every dollar of R&D investment. A fresh technology in early stages of R&D may have a much higher probability of success for every dollar spent than a technology that has already been widely studied without any progress.

Non-technical factors, such as siting, liability, and operations, may also contribute to the relative success of an R&D investment. Determining the probability of success for R&D is fraught with uncertainty; however, analyzing the possible outcomes of various investment opportunities remains far better than ignoring their differences.

The expected benefit of a technology depends not only on its own merits, but also on those of competing technologies. For example, renewable energy options are cheaper than CCUS today; some might argue that governments should focus funds on scaling up the cheaper option and ignore more expensive alternatives. But 20 years from now, the capacity to incorporate solar and wind power into the grid might be limited by an inability to raise capital for new transmission, or by a lack of progress in energy storage technologies. Under these scenarios, early CCUS investments would prove much more beneficial.

In fact, developing CCUS early, even if it is relatively expensive at the time, can form an effective economic “hedging” strategy. The technical prospects of CCUS and renewables are sufficiently independent: if one fails, the likelihood of success for the other will not be affected. This is in contrast with the case of at-scale wind and solar power, as they can fail at the same time if energy storage and smart grid technologies are not available to overcome intermittency issues. Governments will benefit from diversifying their low-carbon R&D portfolios with options whose technical performances are not positively correlated.

The decision by policy makers on whether to develop CCUS influences. rather than is influenced by, climate policy. While the private value of CCUS depends on future climate policy, the social value does not. It depends on the expected benefits and costs of developing a technology for society, as opposed to merely business profits and costs. If the social value of CCUS is substantial but can only be tapped when governments impose a carbon tax, then governments should do so. The logic would be that governments should impose the tax because CCUS is valuable, as opposed to CCUS is valuable because we have a carbon tax.

Policy Implications

Too often, governments focus on a technology's short-term value, ignoring the nuances of longer-term benefits. In these cases, the value of making cost-effective CCUS technologies available could be substantial. Given the long lead times to develop a technology and create the necessary conditions for effective deployment, it will be challenging for countries to compensate for this lack of vision in future decades.

As costs and benefits change over time, CCUS's value will fluctuate. This makes short-term projections an inaccurate tool for assessing investment opportunities. Federal funding decisions for both R&D and deployment must consider a maximum range of future outcomes; predictions for the at-scale success of CCUS must reflect this. A forward-looking framework will allow governments to better understand the evolutionary patterns of a technology's financial value, which will more effectively inform public policy decisions.

The benefits of a far-reaching outlook become even more apparent when considering the variety of applications for CCUS technologies. Today, CCUS is primarily viewed as an option for capturing CO2 emissions from coal-fired generation plants, and some funding exists for its advancement. But 15 years from now, the explosion of global concern around climate change and air pollution may force the majority of coal plants to close, making that specific application of CCUS a long-term financial risk.

By 2035, it is likely that very few coal facilities will remain in operation across the United States; even China may be actively reducing its coal fleet. Simultaneously, natural gas demand may increase as its costs decrease with advancements in extraction technologies. This scenario would bolster the value of CCUS as a tool for gas-fired facilities; if a country had not invested in CCUS for gas-fired facilities, it might find itself lagging behind.

Nonetheless, it is impossible to predict with certainty which energy technologies will be most valuable 15 years from now. One might forecast that by 2035, the popular backlash against both natural gas and coal will have intensified, leading the international community to prioritize reducing carbon emissions from ammonia, steel and cement. This trend is likely enough to influence investment decisions, but we cannot know for sure until it happens.

Therefore, governments should adopt a portfolio approach to developing and adopting low-carbon technologies that fully reflect these uncertainties across at least a two-decade time scale. Governments can proceed by soliciting expert opinions on the R&D effectiveness of competing technologies (e.g. renewables at scale) and various CCUS sub-technologies (e.g. coal CCUS versus gas CCUS), and analyzing the correlation among their technical success rates. This scientific knowledge and academic expertise, paired with a focus on longer-term market projections, will help prepare a solid R&D portfolio of low-carbon technologies that hedges against technological and market risks.

These steps will not guarantee any national government a purely optimal technology investment portfolio. However, they build the basis for a far more advantageous strategy than what many countries currently favor: a process that revolves around short-term gain while ignoring the rapid changes in energy technology, environmental science, and market conditions that characterizes our era.

CUICUI CHEN is an Assistant Professor of Economics at the State University of New York (SUNY) at Albany.

HENRY LEE is the Jassim M. Jaidah Family Director of the Environment and Natural Resources Program (ENRP) at the Belfer Center for Science and International Affairs. He is a Senior Lecturer in Public Policy at Harvard Kennedy School.

This brief is partially based on "Dynamic R&D with Correlation and Learning: An Application to R&D in Low-Carbon Technologies," a working paper by Cuicui Chen.

Environment and Natural Resources Program
Belfer Center for Science and International Affairs
Harvard Kennedy School
79 John F. Kennedy Street, Cambridge, MA 02138

belfercenter.org/ENRP

Layout and design by Isabel Feinstein

Cover photo: Some smoke, April 27, 2019. (Unsplash/Pascal Meier)

Back photo: Aerial View of Road in the Middle of Trees, June 30, 2018. (Pexels/ Deva Darshan)