Recycling CO$_2$

*Transforming climate risk into opportunity and CO$_2$ into valuable products*

Reports by the Intergovernmental Panel on Climate Change and others have reinforced the urgency to massively change our lifestyles and economic structures, in order to prevent a serious deterioration in livelihood, human health and wellbeing on Earth. They call for the crucial need to decrease greenhouse gas emissions, but also to remove CO$_2$ from the atmosphere to e.g. reuse it as a resource in valuable products. This concept is called Carbon Capture and Utilization (CCU). CO$_2$ can be recycled for an almost unlimited range of carbon-containing products, from fuels to chemicals to new building materials. Thus, the near-carbon-neutral production of methanol, ethanol, gasoline, kerosene, acids, proteins, plastics and their replacements – even soap, perfumes, mattresses, yoga mats, vodka and hand sanitizer (just as examples!) – is possible. The reuse of CO$_2$, as a resource to manufacture novel forms of concrete, drywall and other building materials, effectively locks away the CO$_2$ permanently. A new economy based on CO$_2$ products is not a futuristic vision, it can happen now! The necessary technologies for capturing and utilizing carbon (via CO$_2$) are much more advanced than people realize. While, CCU innovations are sometimes initially more expensive than traditional practices (based on fossil carbon sources), we continue to work on technological improvements that reduce costs.

A framework and positioning paper on Carbon Capture and Utilization (CCU) by Sophia Hamblin Wang (Mineral Carbonation International and CO$_2$ Value Australia), Dr. Stefanie Kesting (Uniper SE and CO$_2$ Value Europe) and Professor Dr. Volker Sick (University of Michigan and Global CO$_2$ Initiative).

This positioning paper has been prepared in a time unlike any other, as the entire planet has shut down trade, transportation, education and local community life to respond to the COVID-19 pandemic.

Together, we represent research and businesses as well as major carbon re-use organizations in Australia, Europe and the United States. Working across three continents we share a vision to rapidly scale up technologies that use CO$_2$ as an ingredient to make valuable products. We consider the storage and recycling of CO$_2$ into feedstocks for the production of a range of everyday-use products as crucial for creating a low carbon emissions future.

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Marginal increases in cost now are minute compared to the hidden costs of climate change and subsequent industry shutdowns. For example, jet fuel innovation could bring about a significant change to global emissions by beginning to blend aviation fuels with kerosene from CO$_2$ for just a moderate increase in airfare costs.

**What’s the sense of urgency in responding to climate change right now? What can be learned from the current pandemic?**

Climate experts have been warning us for decades about the risks associated with excessive CO$_2$ emissions and the urgent need to act against it. Similarly, the implications of global health pandemics and effects have also been known for some time but it required the outbreak of a pandemic to act on a large, global scale.

Although they are both existential threats to humankind, COVID-19 and climate change have a key difference: immediacy of impact. We have seen the direct impact (within weeks) of immediate and evidence-based action on public health and economic outcomes regarding COVID-19. Climate change, however, requires direct action now, with much longer timelines before success can be measured. In fact, if the climate change movement is able to limit the temperature increase to 1.5 degrees or below, many humans will not notice a change, and this will be a success. Yet failure to act would leave the planet so poorly damaged that it becomes incompatible with human life.

While here is hope that a powerful vaccine can help to manage COVID-19 by immunizing the population, other efforts are needed to prevent future outbreaks of similar diseases. Equally, to mitigate the effects of climate change, we require more than just one solution. The rapid and widespread ‘defossilization’ of many human activities is essential – but it’s not enough.

**How can CO$_2$ Recycling and Re-use help?**

In order to avert a serious breakdown of our climate, large-scale industrial technologies designed to utilize CO$_2$ as a resource must be implemented and scaled up – fast.

Along with other measures, CCU, if rigorously implemented at an international scale across relevant industries, allows us to achieve a global net-zero carbon economy. The increasing availability of renewable energy allows this carbon economy to be economically sustainable and environmentally sound. For some industries it is inherently difficult, if not impossible to completely avoid CO$_2$ emissions, at least for quite some time (e.g. steel and cement plants, airplanes), CCU technologies provide another way to ensure that their CO$_2$ emissions are removed. This is the missing piece in the puzzle for a world that is charting a path towards zero emissions in energy generation yet still needs defossilization pathways for heavy industry and negative emissions technologies. CCU technologies facilitate crucial industries to transition towards net zero whilst remaining profitable. Moving forward, we need to accelerate CCU to lay the foundations for a more sustainable world.

**How does Carbon Capture and Utilization (CCU) work?**

Carbon is a key element in many products we use every day. It can be either taken from fossil sources like oil, or from CO$_2$ captured from industrial emissions or the atmosphere. Scientists and engineers have been working for decades to develop efficient processes that convert captured CO$_2$ into valuable products. This is called CO$_2$ utilization – also sometimes referred to as CO$_2$ transformation, CO$_2$ conversion, CO$_2$ recycling, CO$_2$ valorization, or CO$_2$ upcycling.

Most reactions to transform CO$_2$ molecules require energy input, and this must come from
a zero-carbon source to avoid adding any CO₂ emissions. The worldwide availability of renewable energy has increased substantially over the last few decades. This will be a growth factor for CCU, and the other way around: CCU will help growing renewable energy technologies and thus their even wider application across the whole world.

How advanced are these CCU technologies?
Some technologies have reached the maturity required for industrial scale production of new products, while other technologies are ready to be scaled up for industrial production levels. While the use of CO₂ in concrete or mineralized materials essentially removes the CO₂ at geological time scales, decomposing polymers and combusting fuels release CO₂ on a short time scale – yet the carbon is being recycled!

Concrete, second only to water as the world’s most widely used resource, offers the potential to hold gigatonnes of CO₂ as a rocklike substance. In fact, CO₂ can be used in concrete production in two ways. First, to convert minerals and even industrial waste into various rock materials that then are used as filler and aggregates in the concrete mix. Second, CO₂ can be used as curing agent for the cement binder, turning that CO₂ into rock as well. Several commercial carbon-sequestering efforts have been launched already in the past few years and more are in the pipeline. In addition, utilizing CO₂ to make concrete offers exciting new opportunities to create entirely new materials with superior performance over existing concrete, including better mechanical properties and resilience to environmental factors.

Polyurethanes are a class of chemicals that are used ubiquitously to make injection-molded parts, to generate thermal insulation foams for buildings, and foams for seats of mattresses. The chemical building blocks for polyurethanes are traditionally made from petroleum but a few years ago it was demonstrated that they can be made with a significant replacement of fossil carbon by CO₂-based carbon. Products are now commercially available.

The production of hydrocarbon fuels from CO₂ is similar to the reversal of the combustion reactions that we use to generate heat and power. Therefore, the energy required to power the reaction needs to be from renewable sources in order to be considered a low-carbon pathway. Our prediction that renewable energy will continue to accelerate rapidly in scale, combined with the fact that existing production facilities already convert CO₂ and CO from waste gas streams, present an exciting opportunity to capitalize on existing infrastructure. Some of these existing technologies use modified microbes, others catalytic materials to make products such as methane, methanol, ethanol, kerosene, and other fuels.

What’s next for CCU?
The journey towards a sustainable carbon economy has begun, but progress must be accelerated in order to address the urgency of our climate targets. The COVID-19 pandemic has shown us that coordinated and swift global action is possible when humanity needs it. A global lockdown of the planet’s economy and people was unthinkable until March 2020 and yet it happened because it was necessary.

Addressing the urgency of climate change is crucial for our survival. If we can shut down the whole world to address a virus, why can’t we make a worldwide effort to deal with climate change? We already have the technologies required to recycle CO₂. Making carbon capture and utilization technologies a pillar of the transition towards a sustainable future within a healthy global climate is not only possible, it is critical.