Q&A: Harnessing CO_2 for consumer goods and industrial materials

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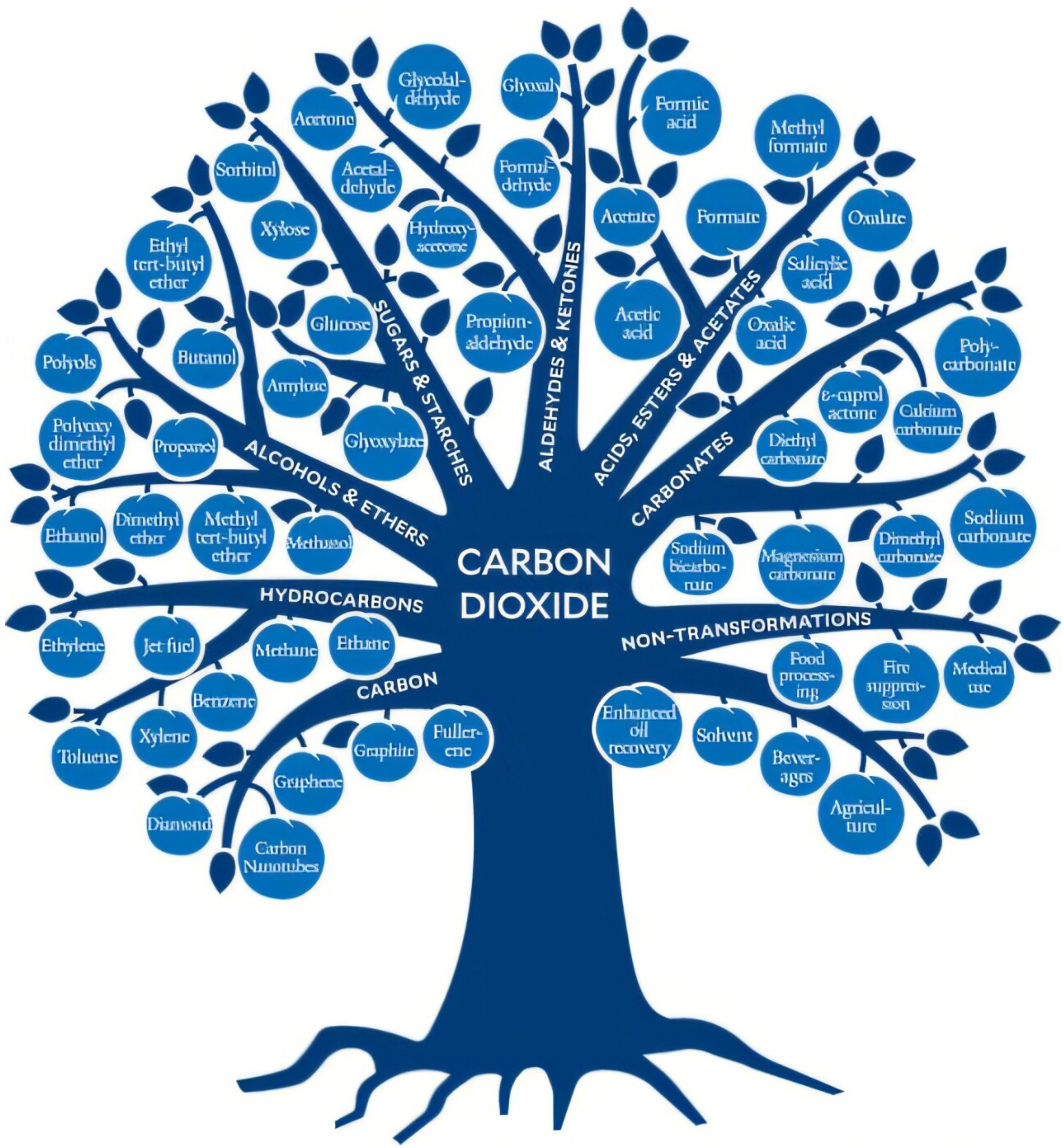

The CO_2 Tree highlighting the classes (branches) of compounds (fruits) that have been made from carbon dioxide from lab scale to commercial scale. Credit: *ACS Sustainable Chemistry & Engineering* (2024). DOI: 10.1021/acssuschemeng.4c07582

Carbon dioxide (CO_2) emissions are a major contributor to the climate crisis, and while the world works to reduce emissions, chemists and engineers are also working on how to capture and utilize the carbon dioxide already being emitted.

Once dismissed as impractical, researchers are developing methods to convert CO_2 into a wide range of valuable products, such as consumer goods, industrial materials or chemicals. This progress is exemplified by "The CO_2 Tree," which showcases the wide array of products achievable through CO_2 utilization using a tree metaphor.

Hanno Erythropel, a research scientist at the Yale Center for Green Chemistry and Green Engineering at the Yale School of the Environment, is part of an international team that published the article "The CO_2 Tree: The Potential for Carbon Dioxide Utilization Pathways" in *ACS Sustainable Chemistry & Engineering*. He recently spoke with YSE News about how chemical CO_2 conversion can help mitigate the climate crisis and also why it is not a silver bullet.

Hanno Erythropel in the lab. Credit: Mara Lavitt

How does chemically converting CO_2 into products work?

Chemically speaking, CO_2 is a molecule like any other, and chemists convert molecules to create the materials needed for our modern society. What makes CO_2 special is that it is usually the end-product of combustion and related processes, and it is considered "low energy" because to convert it back into useful materials, one needs energy and usually hydrogen to remove oxygen atoms from it.

Nevertheless, that is exactly what chemists strive for: We try to design effective ways to convert one molecule into another. When looking at the CO_2 Tree we created for the manuscript, we organized the fruits—the materials already obtainable from CO_2 today—from most reduced (all oxygen removed) such as in fuels or graphite on the left, to the most oxidized (least oxygen removed) such as in baking powder, sodium bicarbonate, on the right.

Can converting CO_2 into products help us meet our climate goals?

We know that we need to reduce our CO_2 output stemming from fossil resources, but the CO_2 in the atmosphere can also serve as a resource, especially because we need to find and use alternative carbon sources to the currently used fossil ones. If chemists want to do their part in addressing climate change, this is a good way to say, "well, how can we convert CO_2 to something useful?"

Making the materials and chemicals for our society out of CO_2, rather than fossil resources, is an inherently circular approach: Chemicals and materials will eventually become CO_2 again, which is then again a resource. Doing so, using renewable energy, as we point out in the manuscript, essentially harvests such renewable energy into the material world.

We sincerely hope that the presented list of available compounds is soon obsolete, as research and development in the area led by teams of creative chemists and engineers will have made many more chemicals and materials from CO_2 accessible.

Is there a concern that people will see these and think we don't need to reduce CO_2 emissions because we can make products from it?

This is a very valid point, one which was also raised during the review process. Let's be clear: CO_2 utilization will only be one factor, besides reducing fossil emissions and carbon capture, to address the climate crisis.

We want to be really clear that what we have outlined here are the many transformations of CO_2 that are currently possible, but that the decisions about what should be done must address more complex criteria, such as the source of CO_2, the type of catalyst used, the energy balance, and other life cycle factors. Ignoring these important factors can result in doing the right things the wrong way; in other words, converting waste CO_2 into valuable products but simultaneously creating unintended consequences.

So, the goal of this manuscript is not to judge what should or should not be done but rather to raise awareness of all the fantastic work on converting CO_2 into something useful that already exists. Then, when implementing such reactions, we do have to make sure we do the right things right. For example, if more CO_2 is generated and released than is incorporated during the process, or a toxic catalyst was used to do so, then the problem might have been made worse. So, there is a need to be thoughtful.

What do you hope will be the biggest takeaway from the study?

The big hope is that chemists, scientists, regulators, and anyone interested will look at this and say, "Oh, wait a minute. It is possible to convert CO_2 into useful materials!" In the manuscript, we have cited examples of reactions for various materials and provided resources for those interested in looking into this in greater detail.

As we outline in the manuscript and our very own Professor Paul Anastas has said, "We can only hope that in a few years' time, this list of possible products we provided is very much outdated, and that one would have to create a whole new tree image to capture the progress in the field."

More information: Heather O. LeClerc et al, The CO_2 Tree: The Potential for Carbon Dioxide Utilization Pathways, *ACS Sustainable Chemistry & Engineering* (2024). DOI: 10.1021/acssuschemeng.4c07582

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