LLNL's Terraforming Soil Project and Related Posts

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1. Introduction

I've said it many times in my writings: I try to stay close to home. Although I may occasionally devote a few words to international matters, I greatly prefer to report on U.S., California, or better yet, my home town of Livermore. Although a few reading these words may not know much about Livermore, but most have heard of our two major National Labs: Lawrence Livermore National Labs (LLNL), and Sandia National Lab, Livermore Campus (Sandia's HQ campus is in New Mexico). Also The Livermore Valley serves as a northeastern extension for Silicon Valley businesses. This post is about a Department of Energy (DOE) program that LLNL is playing a major part in.

2. DOE's Energy Earthshots™

The U.S. Department of Energy (DOE) today (Sep 29) announced $264 million in funding for 29 projects to develop solutions for the scientific challenges underlying DOE's Energy Earthshots™ Initiative to advance clean energy technologies within the decade. The funding will support 11 new Energy Earthshot Research Centers led by DOE National Laboratories and 18 university research teams addressing one or more of the Energy Earthshots™ that are focused on six different areas, including industrial decarbonization, carbon storage, and offshore wind. The Department launched the Energy Earthshots Initiative to spur decarbonization efforts that will help the United States meet President Biden's ambitious climate and clean energy goals, including a 50% reduction in carbon emissions by 2030 and a net-zero carbon economy by 2050.[1]

"Our Energy Earthshots are game-changing endeavors to unleash the technologies of the clean energy transition and make them accessible, affordable, and abundant," said U.S. Secretary of Energy Jennifer M. Granholm. "The Energy Earthshot Research Centers and the related work happening on college campuses around the country will be instrumental in developing the clean energy and decarbonization solutions we need to establish a 100% clean grid and beat climate change."

The Energy Earthshots™ connect DOE's basic science and energy technology offices to accelerate innovations toward more abundant, affordable, and reliable clean energy solutions. These efforts seek to revolutionize many sectors across the United States and will rely on fundamental science and innovative technology to be successful.

The 29 projects were selected by competitive peer review under two DOE solicitations: the National Laboratory Program Announcement for Energy Earthshot Research Centers and the Funding Opportunity Announcement for Science Foundations for Energy Earthshots. Both solicitations covered the first six Energy Earthshots: Carbon Negative Shot™, Enhanced Geothermal Shot™, Floating Offshore Wind Shot™, Hydrogen Shot™, Industrial Heat Shot™, and Long Duration Storage Shot™. Since then, DOE announced a seventh: the Clean Fuels & Products Shot™…

[1] Department of Energy, "DOE Announces $264 Million for Basic Research in Support of Energy Earthshots™," Sep 29,2023, https://www.energy.gov/articles/doe-announces-264-million-basic-research-support-energy-earthshotstm

The centers will be housed at eight DOE National Laboratories and will receive a combined $195 million across four years.

Argonne National Laboratory, Lemont, Illinois

- *C-STEEL: Center for Steel Electrification by Electrosynthesis*
- *Brookhaven National Laboratory, Upton, New York*
- *C4M: Center for Coupled Chemo-Mechanics of Cementitious Composites for EGS*[2]

Lawrence Berkeley National Laboratory, Berkeley, California

- *CIWE: Center for Ionomer-based Water Electrolysis*
- *RESTOR-C: RESTORation of Soil Carbon by Precision Biological Strategies*

Lawrence Livermore National Laboratory, Livermore, California

- *Terraforming Soil EERC: Accelerating Soil-Based Carbon Drawdown through Advanced Genomics and Geochemistry*

National Renewable Energy Laboratory, Golden, Colorado

- *DEGREES: Degradation Reactions in Electrothermal Energy Storage*
- *FLOWMAS: Floating Offshore Wind Modeling and Simulation*

Oak Ridge National Laboratory, Oak Ridge, Tennessee

- *NEETER: Non-Equilibrium Energy Transfer for Efficient Reactions*

Pacific Northwest National Laboratory, Richland, Washington

- *ACE-FWICC: Addressing Challenges in Energy: Floating Wind in a Changing Climate*
- *CUSSP: Center for Understanding Subsurface Signals and Permeability*

Princeton Plasma Physics Laboratory, Princeton, New Jersey

- *PEHPr: Center for the Science of Plasma-Enhanced Hydrogen Production*

2.1. Terraforming Soil Energy Earthshot Research Center

The Terraforming Soil Energy Earthshot Research Center (EERC) may sound minor on the surface (pun intended), but it is both major and critical to mitigating climate change.

While the United States' 166 million hectares (410 million acres) of agricultural soils have lost a vast amount of carbon in the past century due to cultivation and erosion, there is clear potential to reverse this trend and actively manage agricultural lands with strategies that capture CO_2 from the atmosphere. The Terraforming Soil Energy Earthshot Research Center (EERC) will research new bio- and geo- engineered techniques to understand, predict and accelerate scalable and affordable CO_2 drawdown in soils, via both organic and inorganic carbon cycle pathways.[3]

[2] EGS = Enhanced Geothermal Systems

[3] Anne M. Stark, LLNL, "Lawrence Livermore grabs two spots in DOE's Energy Earthshot program," Sep 29, 2023, https://genomics.llnl.gov/article/50411/lawrence-livermore-grabs-two-spots-does-energy-earthshot-program#:~:text=The%20Terraforming%20Soil%20Energy%20Earthshot%20Research%20Center%20%28EERC%29,via%20both%20organic%20and%20inorganic%20carbon%20cycle%20pathways

LLNL noted that soils store a vast amount of carbon dioxide in both organic and inorganic form, up to 3,000 billion tons globally, which is more carbon than is found in the atmosphere and land plants combined.[4]

In addition to LLNL, collaborators on the terraforming project include the University of California, Berkeley, University of California, Davis, Rice University, Princeton University, Yale University, Carleton College, Massachusetts Institute of Technology, Northern Arizona University, Colorado State University, Lawrence Berkeley National Laboratory, Pacific Northwest National Laboratory, Andes Ag, Inc., and the Woodwell Climate Research Center.

3. Carbon Dioxide Removal

Carbon dioxide removal encompasses a wide array of approaches that capture carbon dioxide (CO_2) that is already in the atmosphere or ocean. The CO_2 can then be stored in geological, biobased, and ocean reservoirs or in value-added products. For example, it can be stored in low-carbon concrete and natural sinks such as forests, soils, wetlands, and oceans to create negative emissions (i.e., when more carbon is removed from the atmosphere or ocean than is generated by its removal). [5]

Several climate models, including those produced by the United Nations Intergovernmental Panel on Climate Change, show that reducing the amount of CO_2 entering the atmosphere from the industrial, power, and transportation sectors alone is not enough to combat climate change. Why? Because reducing emissions doesn't address the trillions of tons of CO_2 already in our atmosphere, caused by planet-heating pollution that has been accumulating since the industrial age.

So, as we continue to deploy clean energy technologies to create the decarbonized energy and industrial system of the future, we will need carbon dioxide removal to counterbalance emissions from hard-to-abate sectors such as agriculture and shipping so that ultimately, we can remove legacy CO_2 emissions from the atmosphere once we reach the Biden-Harris Administration's net-zero goals.

But it's important to understand the scale that's required for a carbon dioxide removal industry to have the intended climate impact. By 2050, we need to be removing gigatons of CO_2 from the atmosphere and/or oceans. To put this into perspective, one gigaton of CO_2 is equivalent to approximately one-fifth of the United States' annual CO_2 emissions in 2022.

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[4] Independent (Livermore's Weekly Newspaper), "LLNL Will Head Up Carbon Dioxide Research," Oct 5, 2023, Note that the link following this text is to a web summary of this article, but the above referenced text is from the hard-copy paper. https://www.independentnews.com/news/regional_and_ca/llnl-to-head-carbon-dioxide-soils-research/article_f69582a2-6139-11ee-88fe-2f636c4ff242.html

[5] Energy.gov, Office of Fossil Energy and Carbon Management, "Carbon Negative Shot," https://www.energy.gov/fecm/carbon-negative-shot

To advance the development of this emerging but necessary industry, the U.S. Department of Energy launched Carbon Negative Shot—an all-hands-on-deck call for innovation in carbon dioxide removal pathways that will capture carbon dioxide from the atmosphere and store it at gigaton scales for less than $100/net metric ton of carbon dioxide-equivalent.

The Carbon Negative Shot requires the investment of funding and resources to enable the scale-up of multiple carbon dioxide removal approaches in support of the Biden-Harris Administration's goal of net-zero emissions by 2050. Below are the pathways that DOE has focused on to date:

3.1. Other Resources

I have written frequently on Negative Emissions Technology (a.k.a. NET or Carbon Dioxide Removal). Below are summaries for and links to these earlier posts. The first reference below is closely related to Terraforming Soil.

Ag-NET: This paper mainly discusses agricultural negative emissions technology (thus its name). The recently passed Inflation Reduction Act (IRA) provides substantial funding for this practice. However the potential problem with this is that it's currently difficult to quantify the effectiveness of Ag-NET, but IRA recognizes this and includes significant funding to develop better measurement methods.

The big problem with Ag-NET is that the processes for plants and soil absorbing and releasing CO_2 are really complex. Furthermore, these processes are different for different locations, climates, crops, soil-types, etc. It's relatively easy to measure the CO_2 (and other greenhouse gases), released by smokestacks or tailpipes, but not so much for the releases and absorption in soils, plants, and livestock.

https://energycentral.com/c/ec/ag-net

Author's comment: I would guess that the "Terraforming Soil Energy Earthshot" initiative (subsection 2.1) is a major part of the effort to understand the processes for plants and soil absorbing and releasing CO_2.

New Networks Compendium: I started writing the "New NETWORKS" series almost two years ago. Thus, it didn't surprise me recently when, that there were major developments in negative emissions technology (NET). The first was a subject I wrote about over a year ago:

XPRIZE officially launched the $100 Million XPRIZE Carbon Removal competition. In honor of the launch, XPRIZE founder Peter H. Diamandis sat down with Elon Musk, who is funding the competition through the Musk Foundation.

The above contest has now reached a major milestone which is covered in section 2. A summary of a report on Negative Emissions Technologies and Reliable Sequestration from the National Academies of Sciences, Engineering and Medicine is contained in section 3.

https://energycentral.com/c/ec/new-networks-compendium

Wet NET: “Have a Plan B, and maybe even a Plan C. Because unexpected changes are most difficult to handle when we don't have a backup.”

— Germany Kent, American Print and Broadcast Journalist

Having looked at the subject of climate change quite a bit, there are many ways we can fix this problem, IF we work on it diligently. However humans have a habit of doing really dumb things, like not fixing a big problem we created, one that has already screwed up our climate big time, and is likely to create even worse problems in the future.

And thus my argument for all of the Plan Bs and Plan Cs we can find.

Most of my readers know that NET stands for Negative Emissions Technology. The title NET are carbon dioxide negative emissions technologies that involve the oceans.

https://energycentral.com/c/rm/wet-net

New NETWORKS, Part 5: Oxi-Fuel Combustion: NETWORK is my term for “Negative Emissions Technologies.” These are the most valuable of all renewables. They not only do not add greenhouse gas (GHG) to the atmosphere, but they have the potential of removing GHG from the atmosphere while in some cases providing other benefits.

The Network described by this post is (sort of) BECCS, but the “CC” really superfluous because no carbon capture is required. The output of the process is pure CO_2, water vapor and heat that can be used to produce electricity or provide process heat.

https://energycentral.com/c/cp/new-networks-part-5-oxi-fuel-combustion

New NETWORKS, Part 4 – Peridotite & Soil: Mantle rocks are minerals that normally only exist in Earth’s Mantle, a layer that is normally starts 4 miles below the surface, and extends to 2,000 miles below the surface. Thus it makes up 67% of the mass of Earth. Rocks in this layer normally stay in this layer, but in a few locations they rise to the surface. That is the case with peridotite.

Mantle peridotite reacts with H_2O and CO_2 near the Earth’s surface. Note the CO_2.

Thus even though there are huge deposits of peridotite above ground, it would need to be mined and pulverized to completely store CO_2 in it. Not very efficient. But there is another way that might very efficient, and is capable of storing huge amounts of CO_2.

If Mantle Rocks might be thought of as an exotic material, soil is definitely not. It’s everywhere: in our yards, forests, deserts, plains mountains, everywhere. We will talk about a particular type of soil, that which is used for agriculture (it too is pretty common). This soil probably has the capability to store more CO_2 than peridotite, if we modify our farming practices to do so.

https://energycentral.com/c/ec/new-networks-part-4-%E2%80%93-peridotite-soil

New NETWORKS, Part 3: Two Solutions: California has two challenges. One is the yearly batch of wildfires that keep getting worse every year. In 2020 the acreage burned was more than double any previous year, and other metrics were similarly dire.

The other challenge is that we have the most ambitious goals for mitigating climate change in the U.S.

One might think that the challenge from wildfires would be detrimental to our climate change goals, and indeed in most ways it is, but there is at least one synergy between these as described in the following paper.

https://energycentral.com/c/cp/new-networks-part-3-two-solutions

New NETWORKS, Part 2: Mineralization for GHG Capture: This paper covers several potential methods using mineral incorporation (a.k.a. mineralization) to store and/or permanently sequester carbon dioxide (CO_2), the main greenhouse gas (GHG). Section 2 is about a simple process that will combine two hazardous industrial wastes, alkaline mineral waste and carbon dioxide (CO_2). This process creates a stable mineral that can be safely buried or perhaps used in long-lived structures. Others that are described in section 3 are similar methods already in use.

https://energycentral.com/c/ec/new-networks-part-2-mineralization-ghg-capture

New NETWORKS, Part 1: BECCS: This post covers sources of biomass that have the potential contribute to carbon dioxide sequestration while fulfilling other human needs.

https://energycentral.com/c/ec/new-networks-part-1-beccs