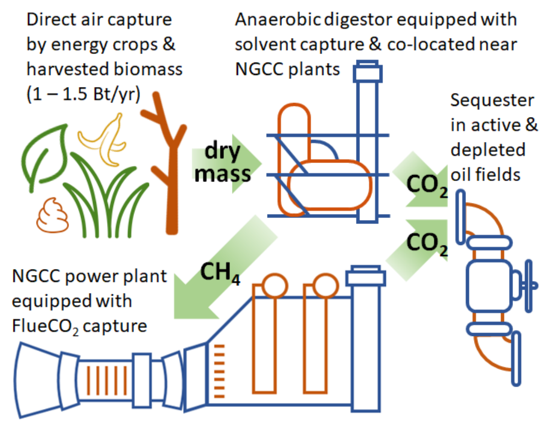
The Negative Emission Mission

What is the fastest and most cost-effective path to negative carbon dioxide (CO_2) emissions?

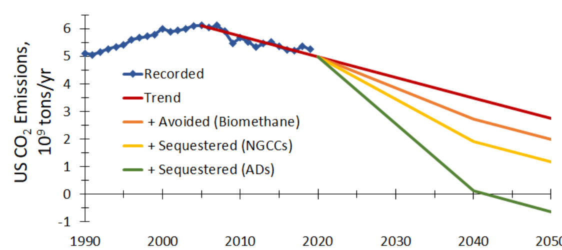
Can alignment with existing plans and infrastructure enable the best paths forward?

Photosynthetic carbon capture by energy crops and related biomass is the most efficient mechanism for directly capturing CO_2 from air. The US Departments of Energy (DOE) and Agriculture (USDA) have targeted the production of 1 billion tons of dry biomass for conversion to biofuels by 2030 and a high-yield scenario of 1.5 billion tons by 2040.[1,2] This biomass could be converted to liquid transportation fuels, such as bioethanol. The US has presently replaced about 10% of its gasoline demand with bioethanol through starch fermentation. The domestic approach to biomass conversion, however, needs revision as 1) the US has neared its capacity for starch fermentation while cellulosic fermentation has failed to thrive, and 2) there does not appear to be plausible technical options to capture the CO_2 emitted by the vehicles.[2]

To achieve negative carbon emissions in this scenario, the USDA is advising the production of bioelectricity from energy crops instead of biofuels.[2] Mature anaerobic digestion (AD) technology will efficiently convert the energy crops to biogas.[2] The resulting biomethane will be used to generate electricity using natural gas combined cycle (NGCC) power plants. Natural gas has surpassed coal for domestic power generation because NGCCs have better performance, lower costs, and less CO_2 emissions.[3] Since NGCCs also have the greater flexibility required to compliment variable renewable energy resources (solar, wind), most models use natural gas power plants as the bridge to carbon-negative futures until nuclear and/or grid-scale electricity storage capabilities become established over the next few decades. If biomass production and processing capabilities are established in accordance with the near-future scenarios, the existing natural gas pipelines and NGCC infrastructure can be leveraged to generate bioelectricity. The transition of fossil fuel-powered vehicles and heating systems to electric replacements will continue to focus the importance of capturing carbon from NGCCs over the next 10 – 30 years. Mature solvent-based technology *can* capture carbon from NGCCs, however, the low CO_2 concentrations in the exhaust gases result in unacceptable energy and economic costs.[3] *Luna Innovations is therefore developing the FlueCO$_2$ to outfit new and existing NGCCs as well as combined heat and power (CHP) for more practical carbon capture costs at any scale.*



The Negative Emission Mission paradigm routes carbon from the DOE/USDA biomass targets through anaerobic digestors (AD) co-located with existing natural gas combine cycle power plants (NGCC).



Negative emissions can be achieved by meeting the DOE's high yield biomass energy target of 1.5 billion tons/yr for 2040.[1] Analysis assumes 90% capture from all NGCCs and ADs, 1,300 TWh per billion ton biomass, and 1.1 ton CO_2 produced per ton biomass by AD.[2]

The combination of direct air capture by photosynthesis, capture from both anaerobic digesters & natural gas power plants, and CO_2 sequestration in active & depleted oil wells can achieve negative emission by 2040. Carbon sequestration will focus on displacing the water and nitrogen that has been injected into depleted oil fields in the long term. The captured carbon can be applied to enhance oil recovery in the near term because it will take time to wean the domestic economy off petroleum-derived fuels, plastics, and other products.

[1] *2016 Billion-Ton Report*, DOE 2016; [2] *Dedicated Energy Crops and Competition for Agricultural Land*, USDA 2017; [3] *Cost and Performance Baseline for Fossil Energy Plants Vol. 1*. NETL 2019.

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