LCA Tools Available at NETL

Solutions for Today | Options for Tomorrow

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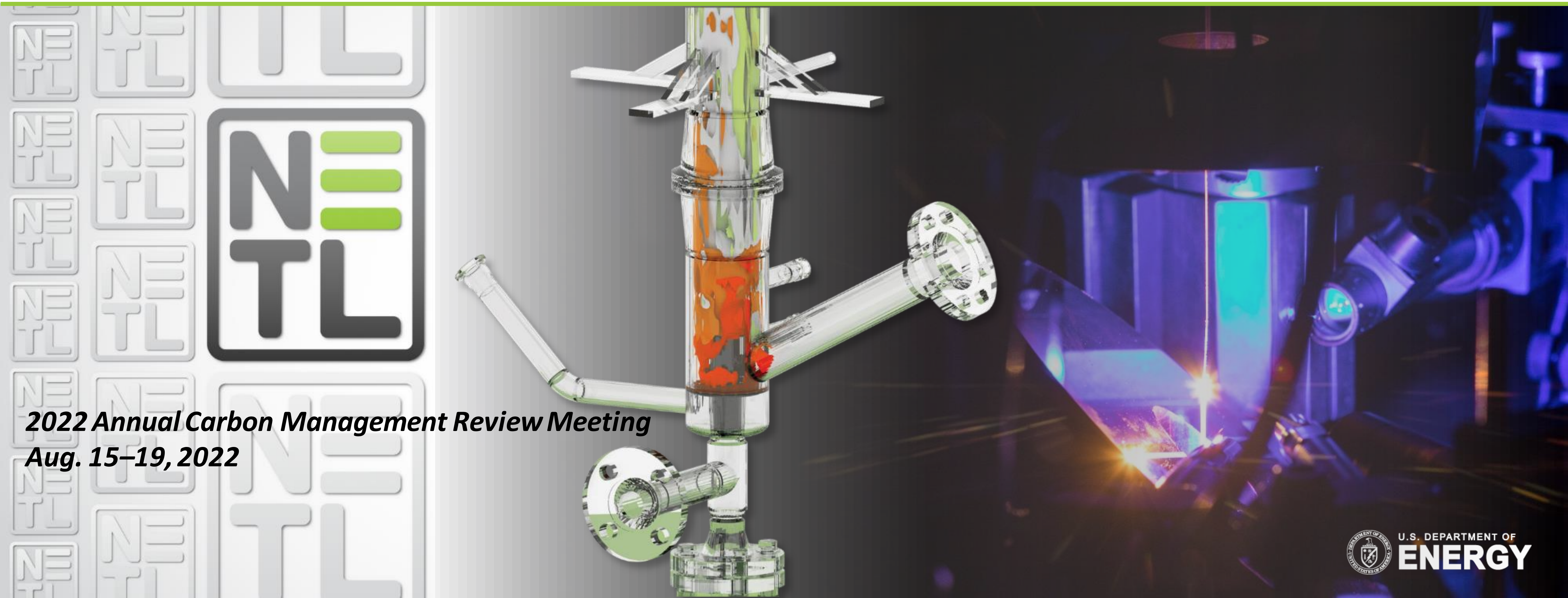


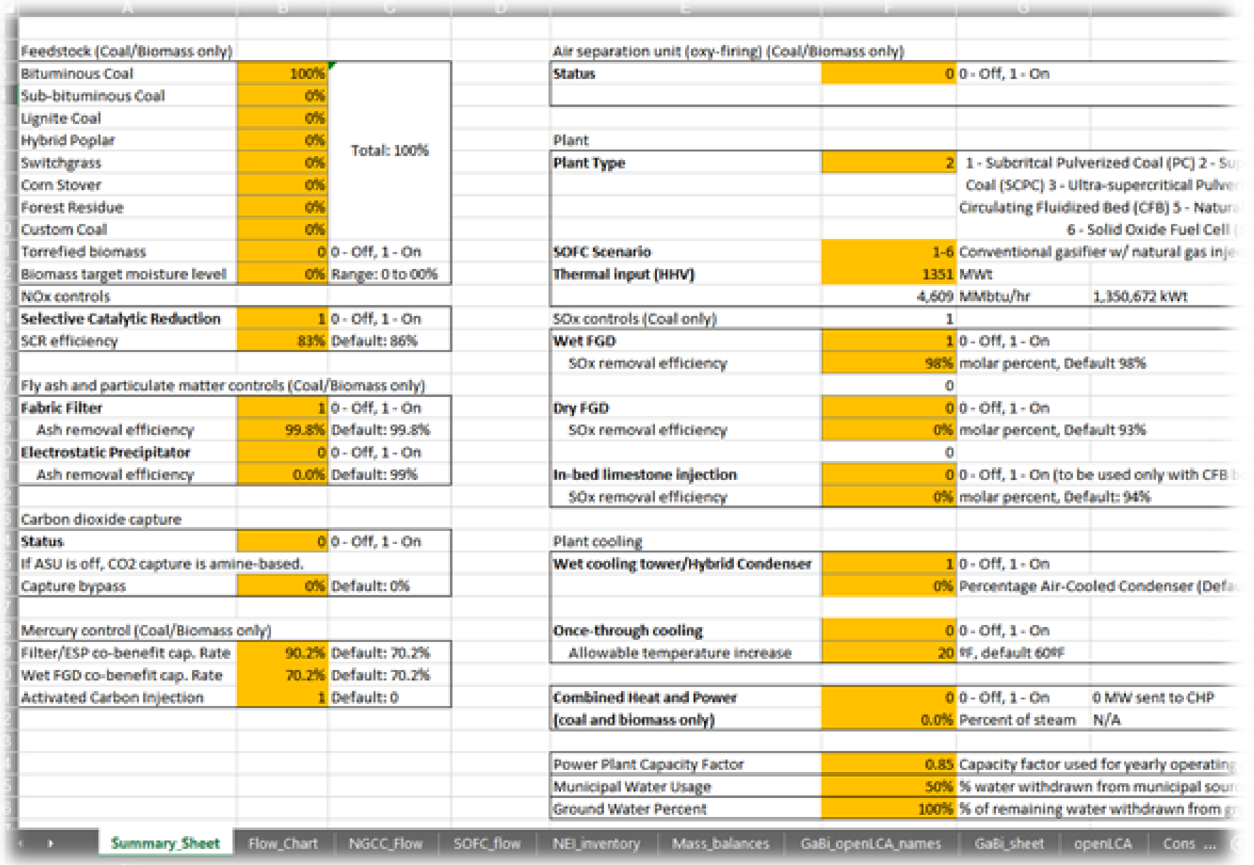
2022 Annual Carbon Management Review Meeting
Aug. 15–19, 2022

Agenda

- Power Plant Flexible Model (PPFM).
- Electricity LCI / Grid Mix Explorer.
- Upstream dashboard.
- Upcoming updated saline storage LCA Model.
- DOE Direct Air Capture (DAC) guidance.
- DAC guidance/toolkit for development this year.
- Biomass profiles added to the CO2U guidance database.
- Bioenergy with Carbon Capture and Storage (BECCS) screening tool.
- Upcoming work.

About Power Plant Flexible Model

- **Spreadsheet model for**
  - Pulverized coal.
  - Circulating fluidized bed power plants.
  - Cooling types.
  - Emissions control.
- **Reduced-order model allowing change of coal characteristics and configuration of pollution control equipment.**
- **Emissions limited to those available in NETL techno-economic assessments.**
  - CO_2, SO_2, Hg, NO_X, particulate matter (PM).

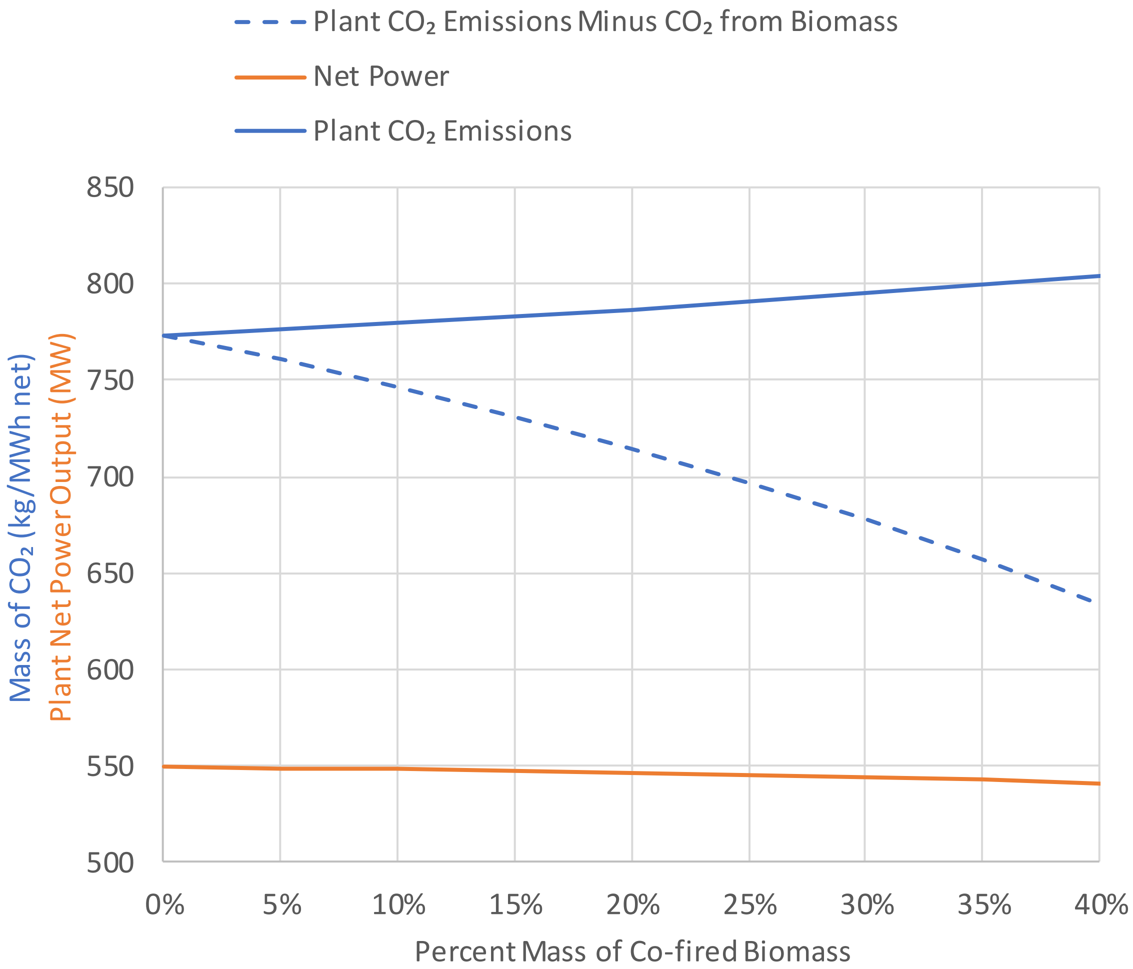


https://netl.doe.gov/research/energy-analysis/search-publications/vuedetails?id=785

PPFM Uses

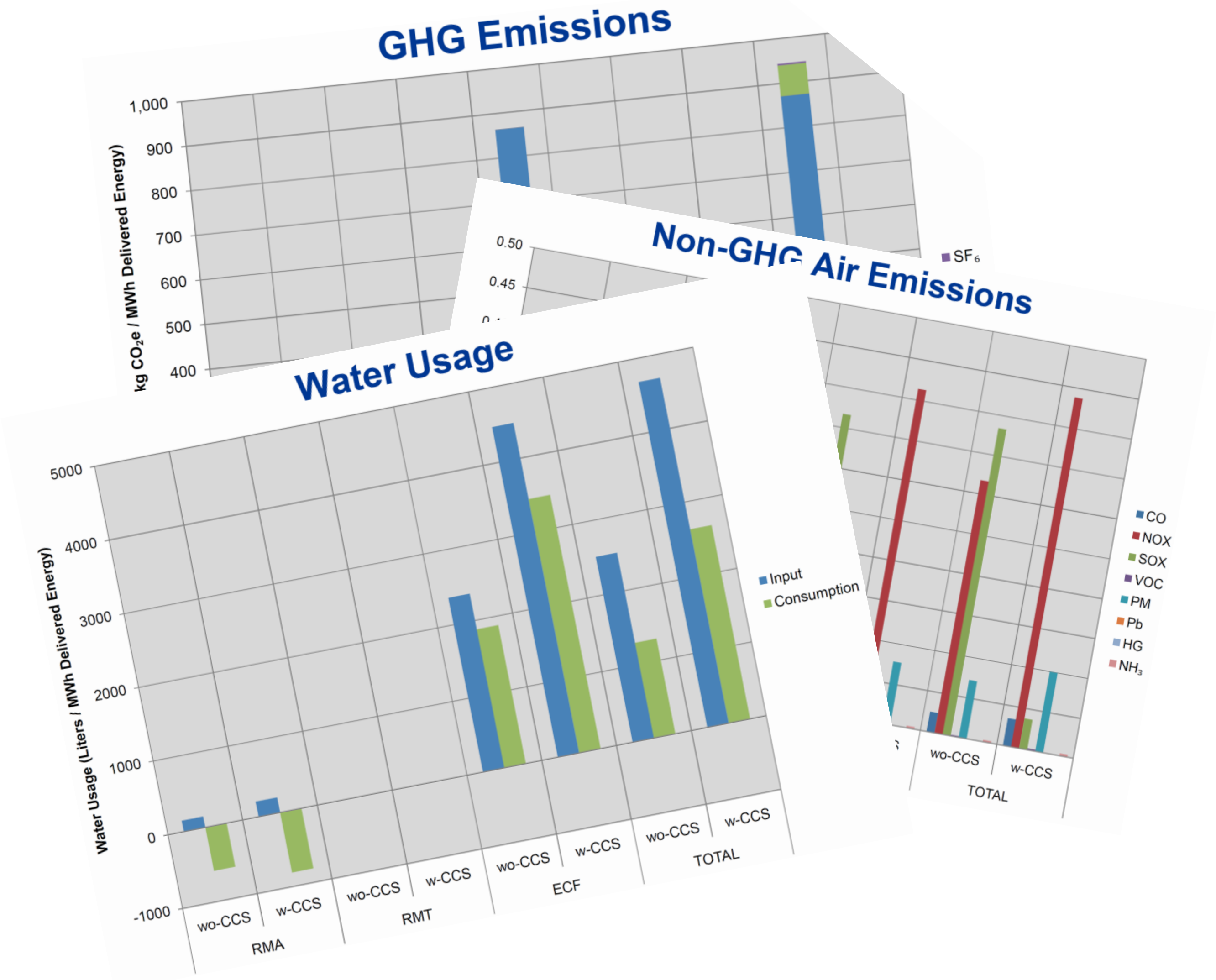
Co-fire biomass vs. CO_2 emissions and net plant power

- **PPFM intended as a tool to quickly assess changes in equipment or feedstock.**
- **Example: Can relatively quickly assess impacts of co-firing varying amounts of biomass while maintaining sulfur emissions.**
    - 97.6% to 98% removal rate for SO_2 (Wet Flue Gas Desulfurization) at 0.327 kg SO_2/MWh net.



Moving Beyond GHGs, CAPs, and Water Use

- **Past focus:** LCAs have been performed on greenhouse gases (GHGs), criteria air pollutants (CAPs), and water use.
- **Broadening analysis:** Expanding inventory across all NETL models to support broader analyses; Impact analysis - EPA TRACI 2.1.
- **Motivation:** As an input to other models (i.e., CO_2-enhanced oil recovery, CO_2-EOR); PPFM emissions inventory needed to be expanded.



The Electricity Baseline

A complete inventory of U.S. power consumption in 2016

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- **What is the electricity baseline?**
  - Open-source life-cycle inventory data.
  - Formatted for the Federal LCA Commons.
  - Based on publicly accessible data sources.
  - Designed for automated data processing.

- **How is the baseline used?**
  - Historical, current, and anticipated environmental footprint of U.S. electricity.

Goals

- High quality data for technology evaluation
- Assessment of regional impacts/benefits
- Consistent national baseline

Objectives

- Complete inventory for U.S. power consumption in 2016
- Open-source data
- Transparent modeling approach
- Coordination with EPA and DOE

The Electricity Baseline

A complete inventory of U.S. power consumption in 2016

Where can the baseline be found?

LCA Practitioners

- ✓ JSON-LD and ILCD exports
- ✓ Choose selected region and export full product system to openLCA for connection with rest of system

lcacommons.gov/lca-collaboration

Energy and Env Analysts

- ✓ Create customized technology mix and inventory
- ✓ Explore inventory and TRACI impacts for selected region
- ✓ Add advanced technologies

netl.doe.gov/LCA

Researchers & Developers

- ✓ Complete transparency into inventory dev
- ✓ Flexibility to adjust model parameters
- ✓ Integration into other frameworks

github.com/USEPA/ElectricityLCI

Model Framework Summary

Goals

- High-quality data for technology evaluation.
- Assessment of regional impacts/benefits.
- Consistent national baseline.

Objectives

- Complete inventory for U.S. power consumption in 2016.
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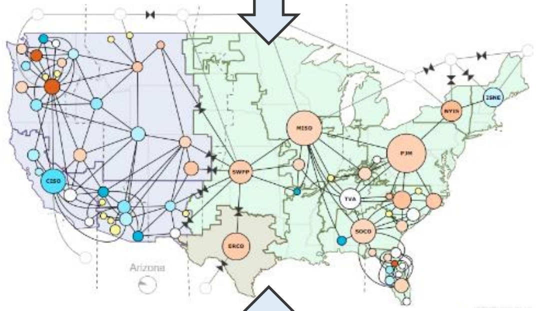
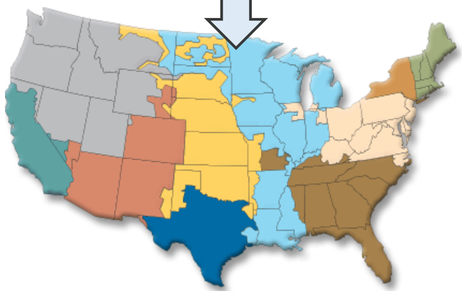
- Transparent modeling approach.
- Coordination with EPA and DOE.

>7,000 Generation Facilities

68 Balancing Authorities



10 FERC Market Regions



Upstream Dashboard

Raw Material Acquisition (RMA)

Include RMA	On
RMA Process List	Illinois No. 6 Coal

Parameters	Value
Coal Mine Methane (scf/ton)	173
Methane Capture (%)	0

* Natural Gas values are representative of average production
* The fractions of Uranium enrichment are normalized to 1

Include RMA 2*	Off
RMA Process List	Not Set

Parameters	Value
Not Set	Not Set
Not Set	Not Set
Not Set	Not Set
Not Set	Not Set

* Should only be used for FT Diesel

Raw Material Transport (RMT)

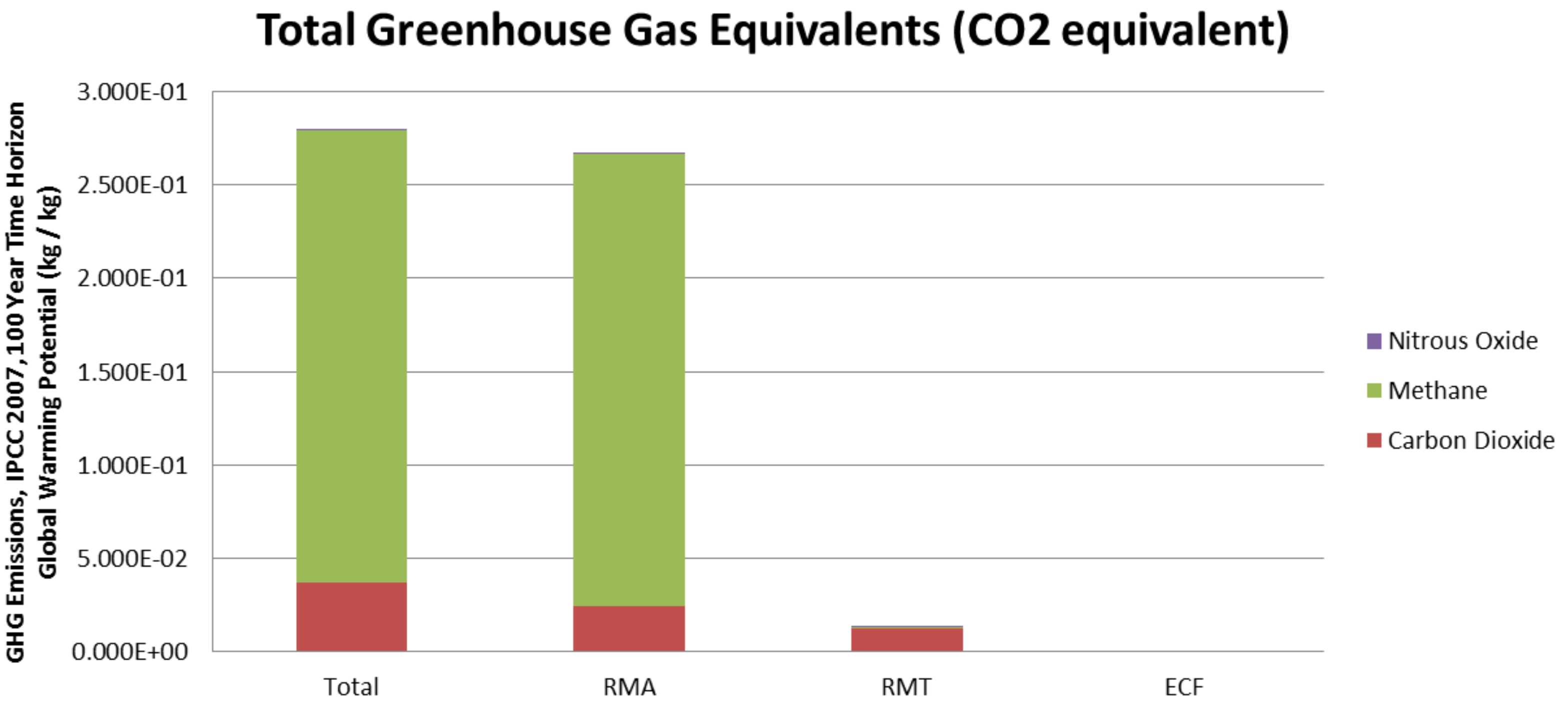
Include RMT	On
Num of Transp. Mode	4
RMA Suggested RMT	

Transportation Mode**	Unit	Value
Petroleum Pipeline	mi	394.6
Petroleum Water Carrier	mi, one way	4309
Petroleum Tanker Truck	mi, one way	2.7
Petroleum Rail	mi, one way	1.2

- **Purpose:** To provide cradle-to-gate inventories for common power plant feedstocks with Monte Carlo functionality.

- **Raw material acquisition and transport customizability:** Limited parameterization is provided to customize the feedstocks (e.g., coal mine methane, biomass yield rate, and transport distances) and energy conversion facility.

Upstream Dashboard



Results

- Emissions inventory table and GHG equivalents.
- Graph of GHG equivalents.
- Monte Carlo simulation.
- Criteria Air Pollutants and water use.

Upcoming Saline Storage LCA Model

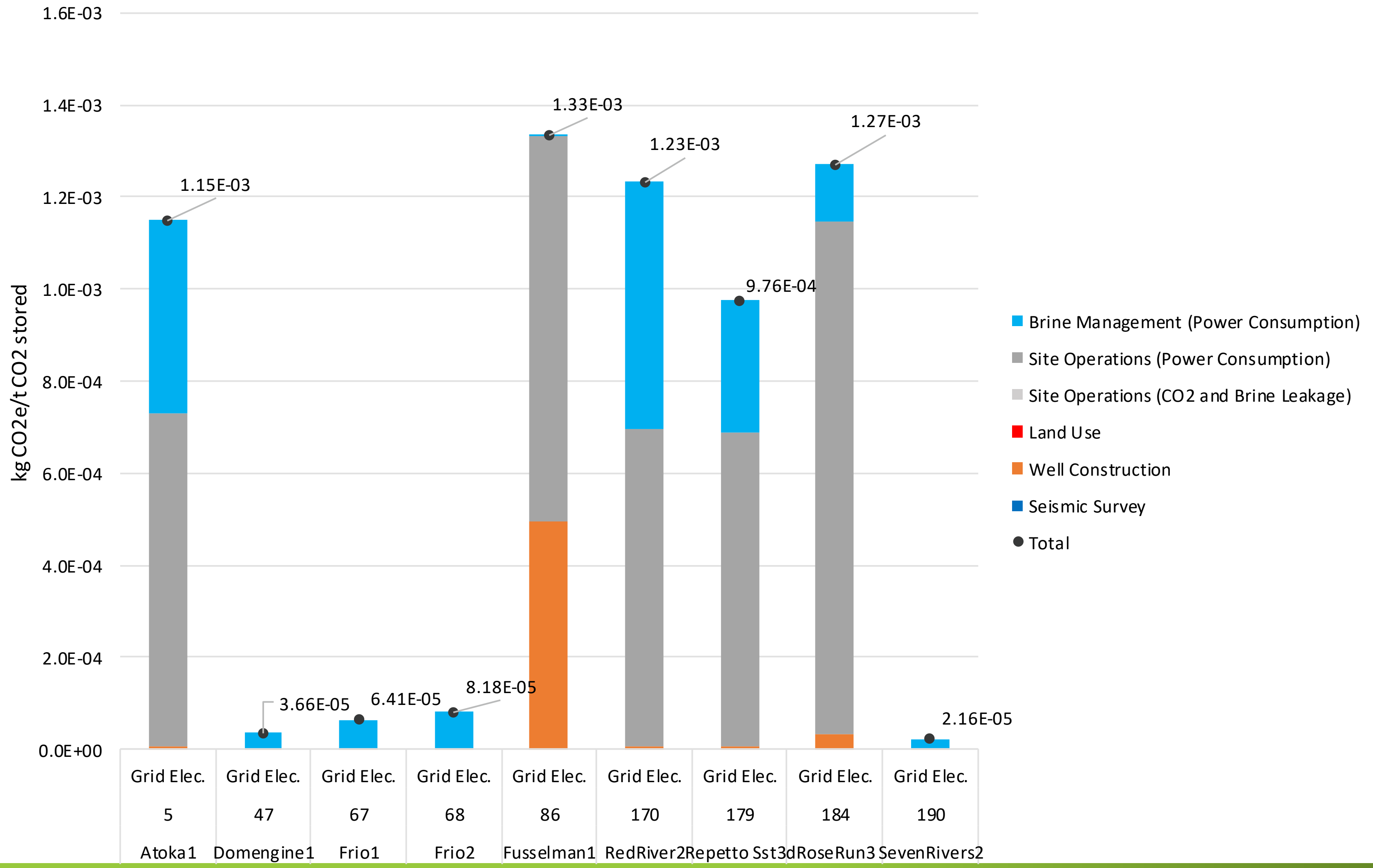
- **Gate-to-grave boundary, 100-yr period.**
  - Site preparation.
  - Well construction.
  - CO_2 storage operations.
  - Site monitoring.
  - Brine management.
  - Well closure.
  - Land use.
- **Covers all 228 identified U.S. saline aquifer formations.**
  - Vary power supply types and water management strategies.
- **With and without land reversion options added.**
- **Updated Excel and openLCA models.**
- **TRACI 2.1, IPCC AR5 impact method.**

Upcoming Saline Storage LCA Model

Global Warming Potential (GWP), 20-yr impacts

Parameters:

- Fuel use rates.
- Combustion emissions factors.
- Non-combustion use factors.
- Energy use.
- Saline aquifer operations.



Upcoming Saline Storage LCA Model

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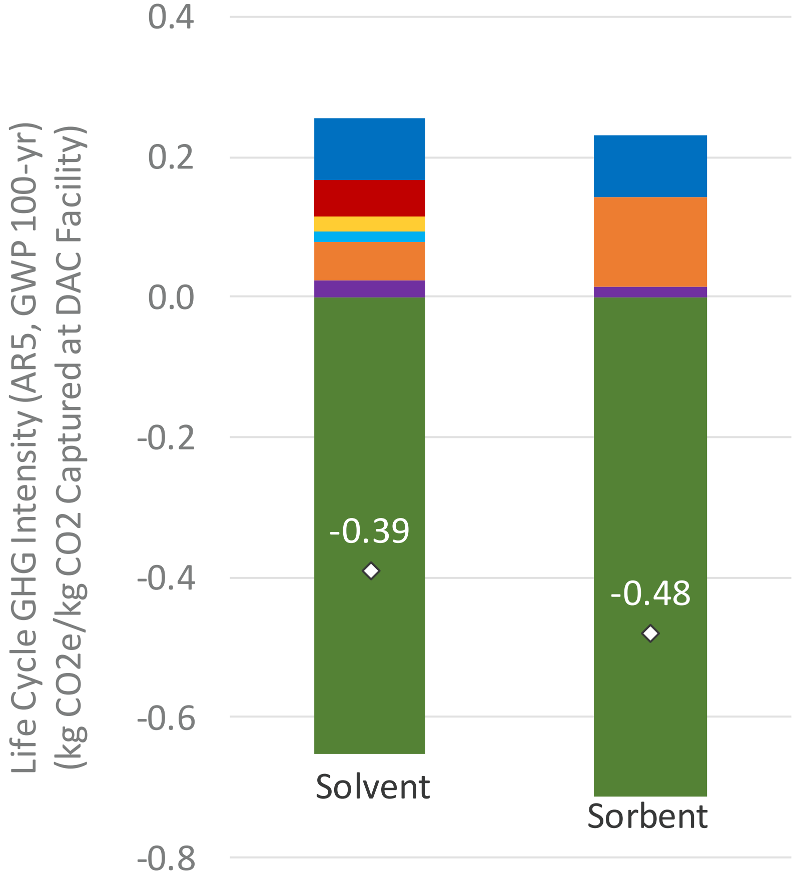
Findings

- **The injectability of a formation has a large influence on the magnitude of impacts.**
- **Scenarios.**
  - Grid electricity has higher overall impacts on freshwater consumption and PM.
  - Diesel has higher overall impacts on acidification, 100-year GWP, ozone depletion, and smog.
  - Natural gas and diesel show high relative impacts on eutrophication and 20-year GWP.
- **Natural gas for site operations and brine management scenarios shows the best environmental results.**
- **CO_2 and brine leakage are significant drivers of impact uncertainty.**

Direct Air Capture (DAC)

Objective: Expand number of DAC system configurations – current industry configurations



	Solvent	Sorbent
Auxiliary *	<0.01	<0.01
Compressor (CO_2 Product)	0.09	0.09
Air Separation Unit	0.05	
Slaker	0.02	
Calciner (Natural Gas)	<0.01	
Pellet Reactor	0.02	
Air Contactor	0.05	0.13
Natural Gas (Upstream)	0.02	0.01
Calcium Carbonate (Upstream)	<0.01	
Potassium Hydroxide (Upstream)	<0.01	
Water		
Mass of Atmospheric CO_2 **	-0.65	-0.71
Total	-0.39	-0.48

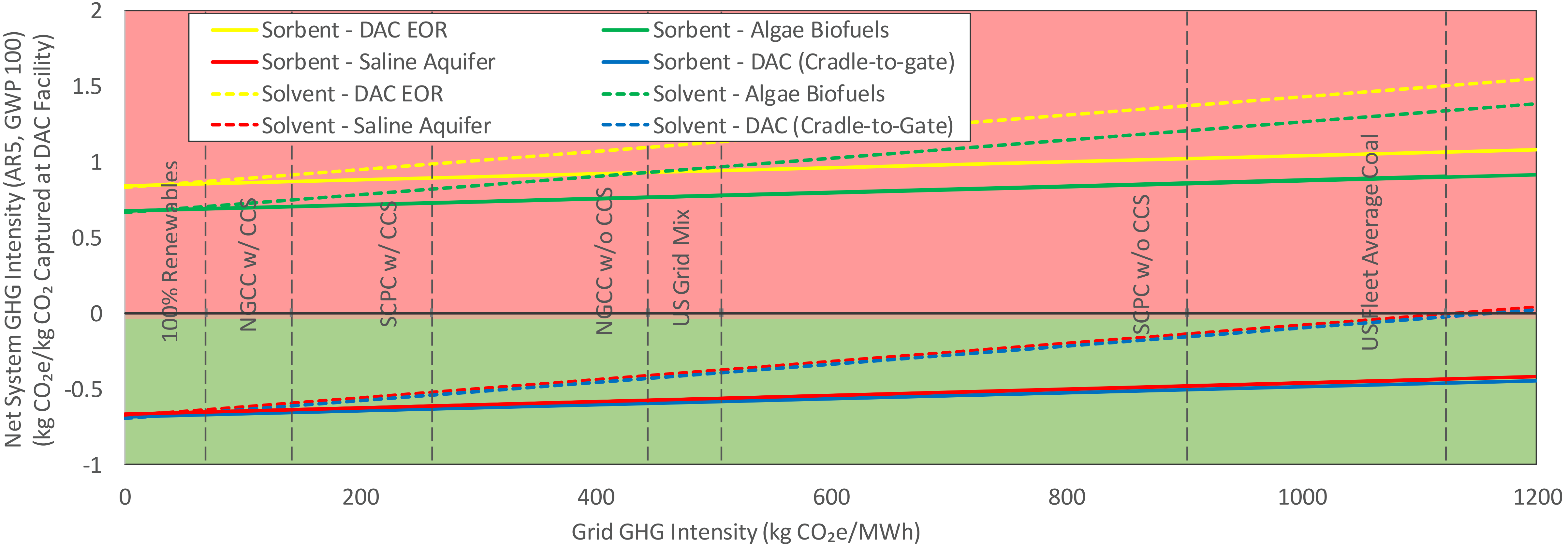
* Auxiliary loads consist of circulating water pumps, cooling tower fans, CO_2 capture and removal auxiliaries (for natural gas boiler), CO_2 compression (for natural gas boiler), feedwater pumps, ground water pumps, selective catalytic reduction (attached to the natural gas boiler for flue gas treatment), and miscellaneous plant balance.

** The Mass of Atmospheric CO_2 is less than 1 kg because a portion of the kg of CO_2 product is captured from natural gas combustion onsite and not removed from the atmosphere.

- Manuscript in internal review.
- Updates/additional profiles (Infinitree, Skytree, Climeworks).

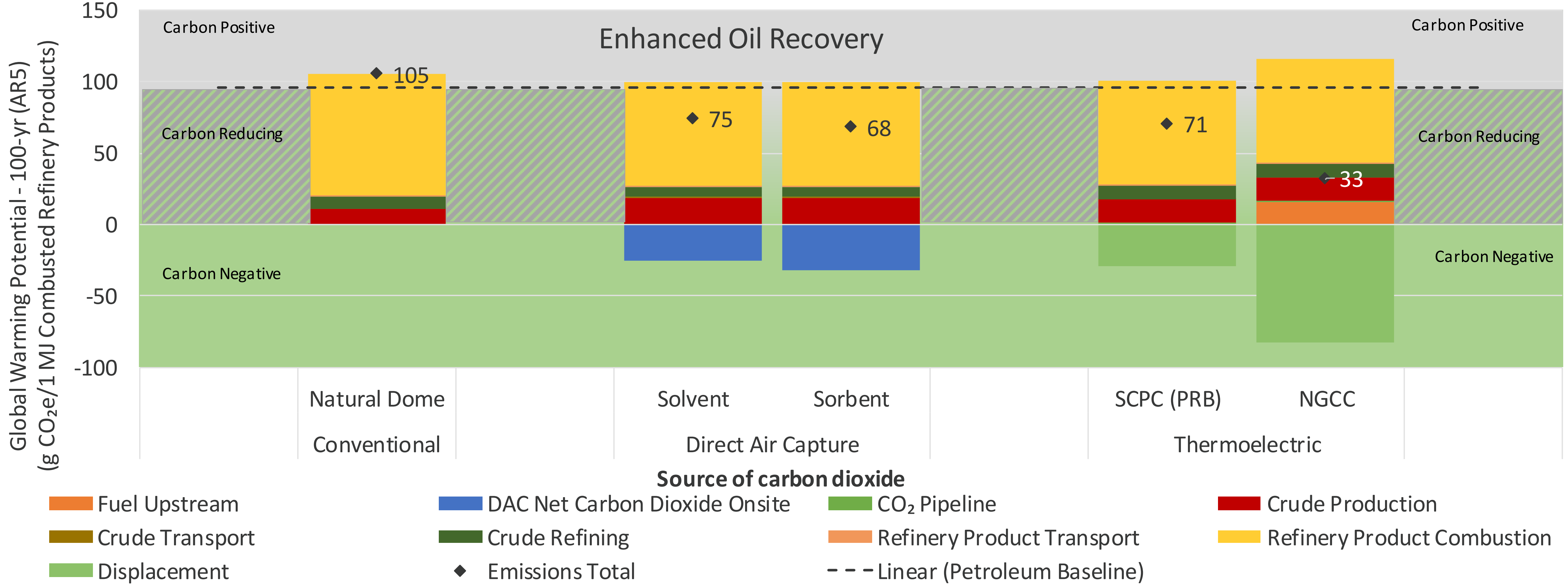
DAC-to-Aquifer Storage

Provides negative emissions under all modeled grid intensities.



DAC-to-EOR

DAC-to-EOR provides a scenario for carbon reducing technologies but not negative emissions technologies.



DOE FECM Best Practice Document – Goals

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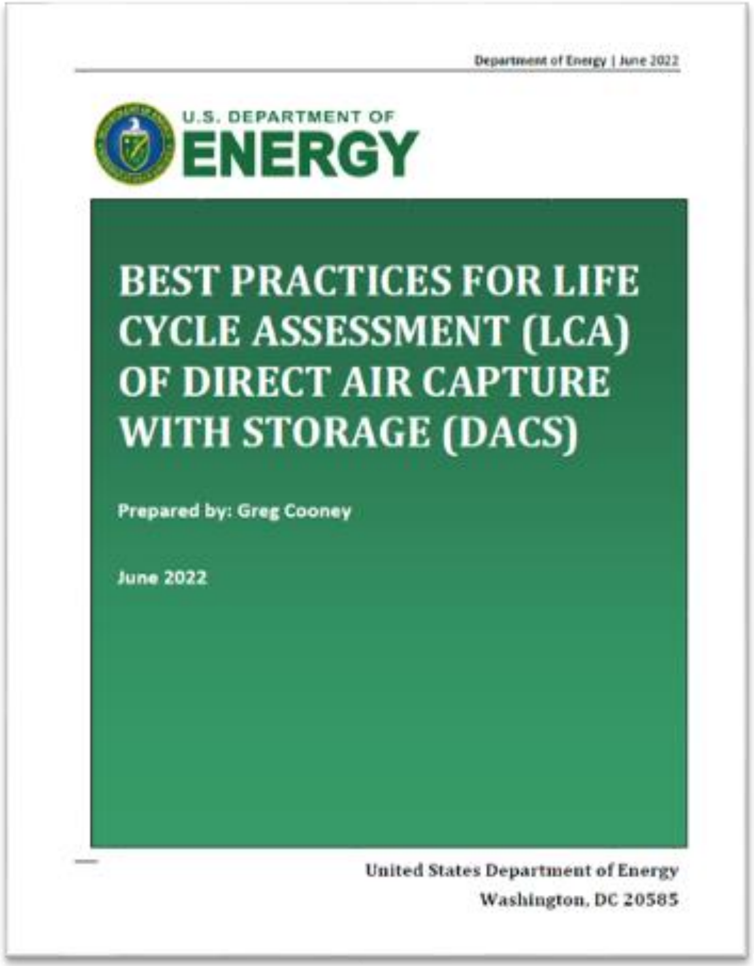
- Foster consistency of LCA of Direct Air Capture with Storage (DACS) systems to enable more complete understanding of potential impacts of carbon dioxide removal.

- Assess sensitivity and uncertainty in results to provide confidence in the study outcomes and potential risk envelopes for technology performance.

- Understand potential tradeoffs and co-benefits of DACS systems.

- Leverage best practices from the LCA research and practitioner community.


Department of Energy | June 2022

U.S. DEPARTMENT OF ENERGY

BEST PRACTICES FOR LIFE CYCLE ASSESSMENT (LCA) OF DIRECT AIR CAPTURE WITH STORAGE (DACS)

Prepared by: Greg Cooney

June 2022

United States Department of Energy
Washington, DC 20585

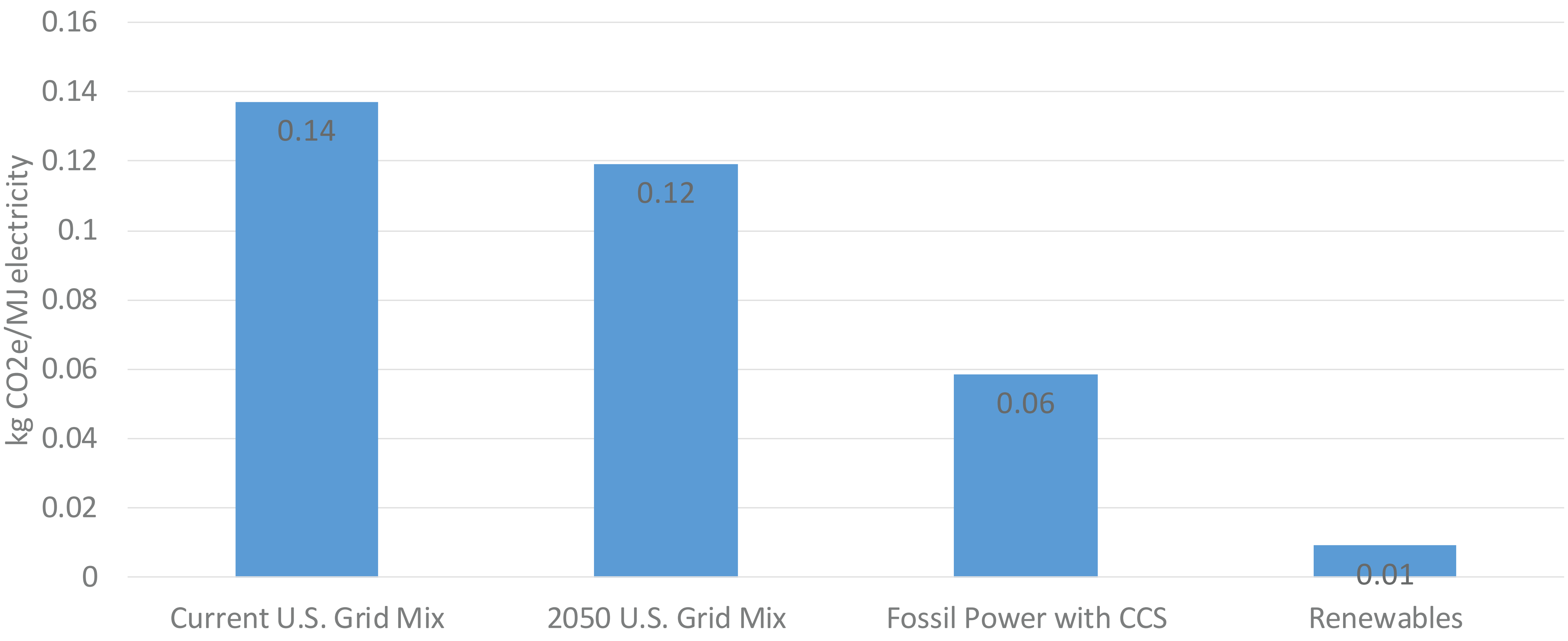
https://www.energy.gov/fecm/best-practices-LCA-DACS

BECCS Profiles for CO2U Database

- **New grid mix and biomass roll-ups are added to CO2U database.**
  - 2020 U.S. grid mix.
  - 2050 U.S. grid mix.
  - Fossil power w/ CCS.
  - Renewables.
  - Saline Aquifer Transport and Storage.
  - Forest residue.
  - Southern yellow pine.
  - Hybrid poplar.
  - Switchgrass.
  - Corn stover.
- **Metadata is included.**
  - Inventory sources, date of representativeness, disclaimer.
- **CO2U Toolkit change log has been updated.**
  - Worked with web development team and posted changes.

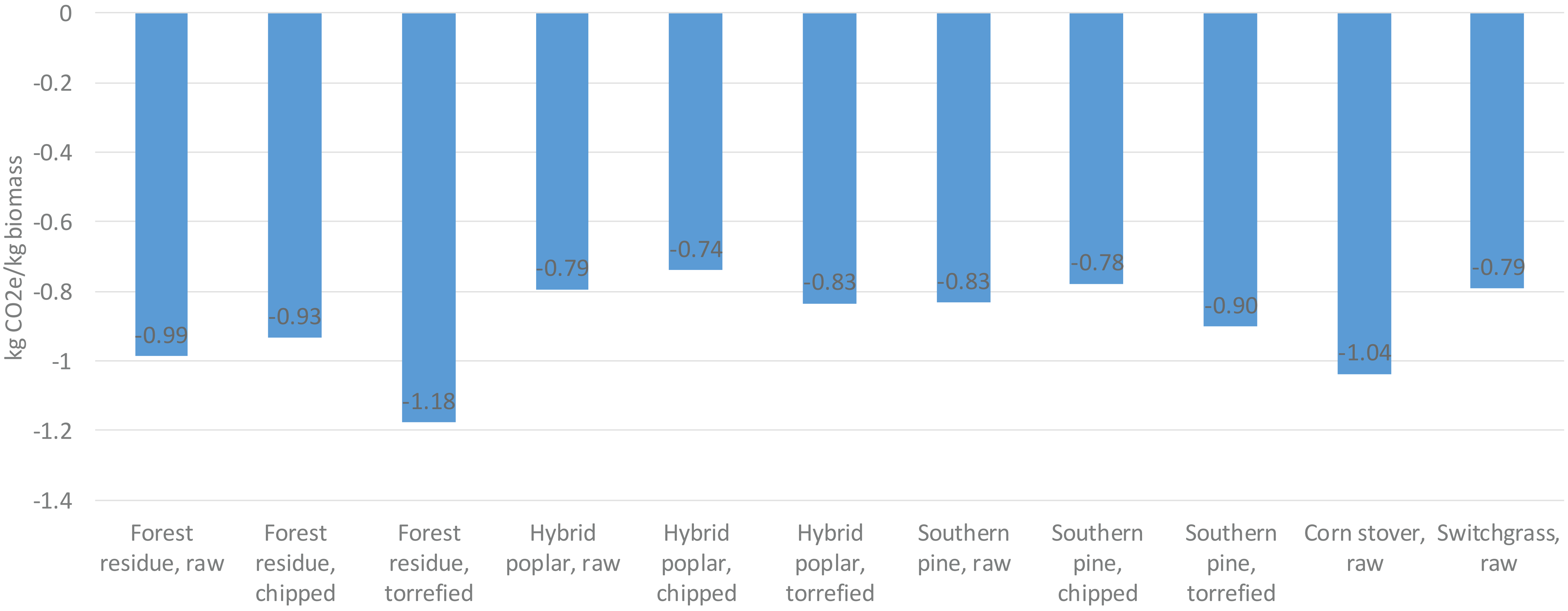
BECCS Profiles for CO2U Database

GWP, 100-yr impacts – Grid



BECCS Profiles for CO2U Database

GWP, 100-yr impacts – Biomass

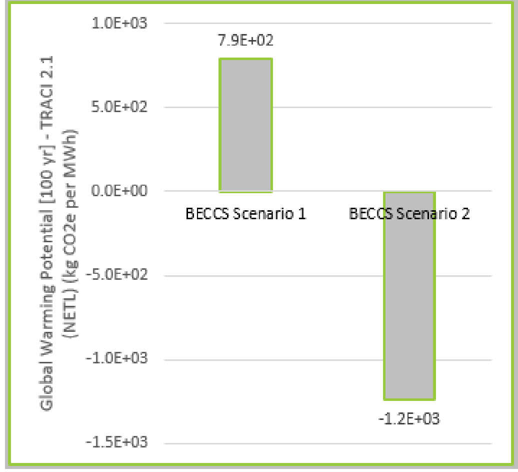


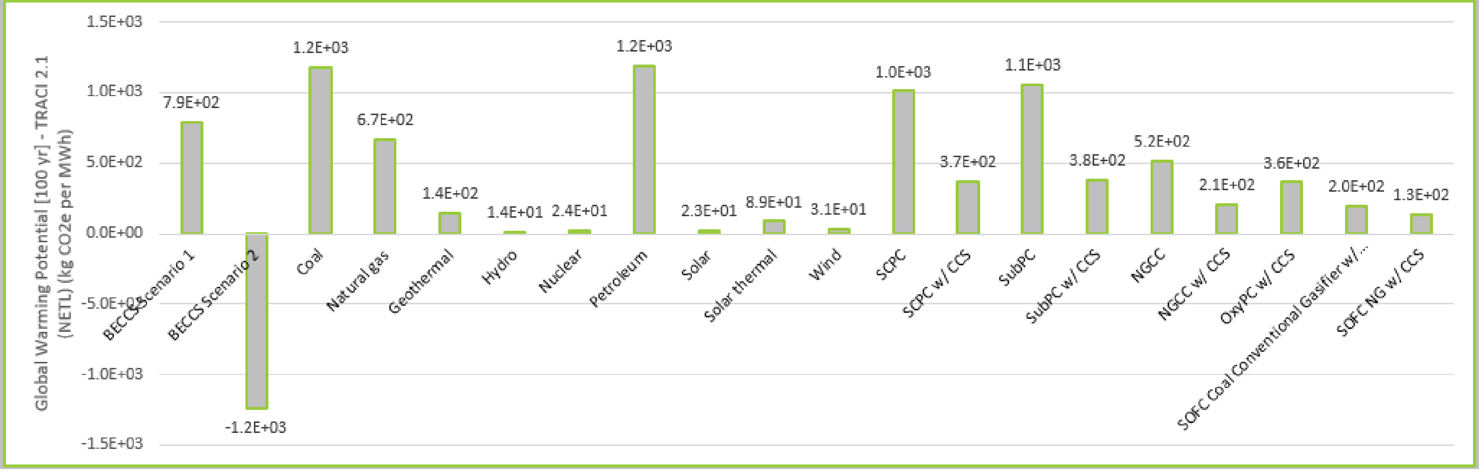
BECCS Screening Tool

Global Warming Potential [100 yr] - TRACI 2.1 (NETL) (kg CO2e per MWh)

Impact Category	Global Warming Potential [100 yr] - TRACI 2.1 (NETL)	Result 1	Result 2	
	Note: Do not adjust areas in gray	7.9E+02	-1.2E+03	kg CO2e per MWh
	Cells in white can be adjusted			
	Areas in orange are under development in 2021			
	Areas in blue are dropdown menus			

Inputs	BECCS Scenario 1	BECCS Scenario 2	Units	Scaling Factor	Acceptable Range	Default Values	Difference 1	Difference 2
Biomass Type	Hybrid Poplar	Hybrid Poplar						
Coal Type	Subbitiminous	Subbitiminous						
Processing	Pelletization and Drying	Torrefaction						
Moisture Content	10%	5%	%	10%	0%-100%	10%	0%	5%
Coal Transportation	320	600	km	0.006039743	0-3,500	321.868	-1.868	278.132
Harvest Residue	50	50	% of yield	-0.02784	25-100	50	0	0
Biomass Yield	6214	6214	kg per acre-year	-0.000767461	3,000-12,500	6214	0	0
Coal Mine Methane	0.002696	0.002696	cubic meters per kg coal	9363.501484	0.002-0.02	0.002696	0	0
Biomass Transport	1.00x	1.00x	radius change - tied to yield	0.188	0.71x-1.44x	1	0	0
Biomass Mass %	20	100	%			35	-15	65
Carbon Capture	no	yes				yes		
Disposition	Saline Aquifer	EOR				Saline Aquifer		





Upcoming Work – BECCS Retrofit

Existing Sub-Critical Pulverized Coal Power Plants

- **Background:** A 2012 NETL study showed that retrofit of an existing plant to co-fire biomass (10%) increased the cost of electricity by 31%.[4]
- **Updating the model:** To provide an option for conversion of up to 100% biomass plus the addition of CCS.
  - Systems smaller than the 650 MW greenfield plant will be explored as existing plants may be smaller, biomass has a lower heating value than coal, and parasitic loads from the capture system will lower net output.
  - Drax Power Station in the United Kingdom has converted four of its six coal units to operate on biomass.[5]

4. Skone, Timothy J., et al. Role of alternative energy sources: pulverized coal and biomass co-firing technology assessment. No. NETL/DOE-2012/1537. National Energy Technology Laboratory (NETL), Pittsburgh, PA, Morgantown, WV, and Albany, OR (United States), 2012.
5. "Drax closer to coal-free future with fourth biomass unit conversion" Drax Press Release. August 20, 2018. https://www.drax.com/ press_release/drax-closer-coal-free-future-fourth-biomass-unit-conversion/

Upcoming Work – Circulating Fluidized Bed

Ongoing Analysis of 100 MW CFB with Hybrid Poplar and Forest Residue

- **Circulating fluidized bed (CFB) technologies are favored for combustion and gasification processes.**
  - Globally, CFBs make up 18% of biomass co-firing.[1]
  - CFBs fueled by 100% biomass exist but are not prevalent.
- **Key characteristics of CFBs include:**
  - Load flexibility and high heat transfer rates.
  - Fuel flexibility, ideal for handling high moisture and ash content of low-rank coals and biomass.[2]
  - Uniform temperature throughout gasifier (850–950°C).[3]
  - Low NOx emissions due to low temperatures.

Exhibit: Schematic of a CFB[2]

1. (Sugiyono, 2022), https://iopscience.iop.org/article/10.1088/1755-1315/963/1/012007
2. (NETL website), https://netl.doe.gov/research/coal/energy-systems/gasification/gasifipedia/fluidizedbed
3. (Vakkilainen, 2017), http://dx.doi.org/10.1016/B978-0-12-804389-9.00010-1

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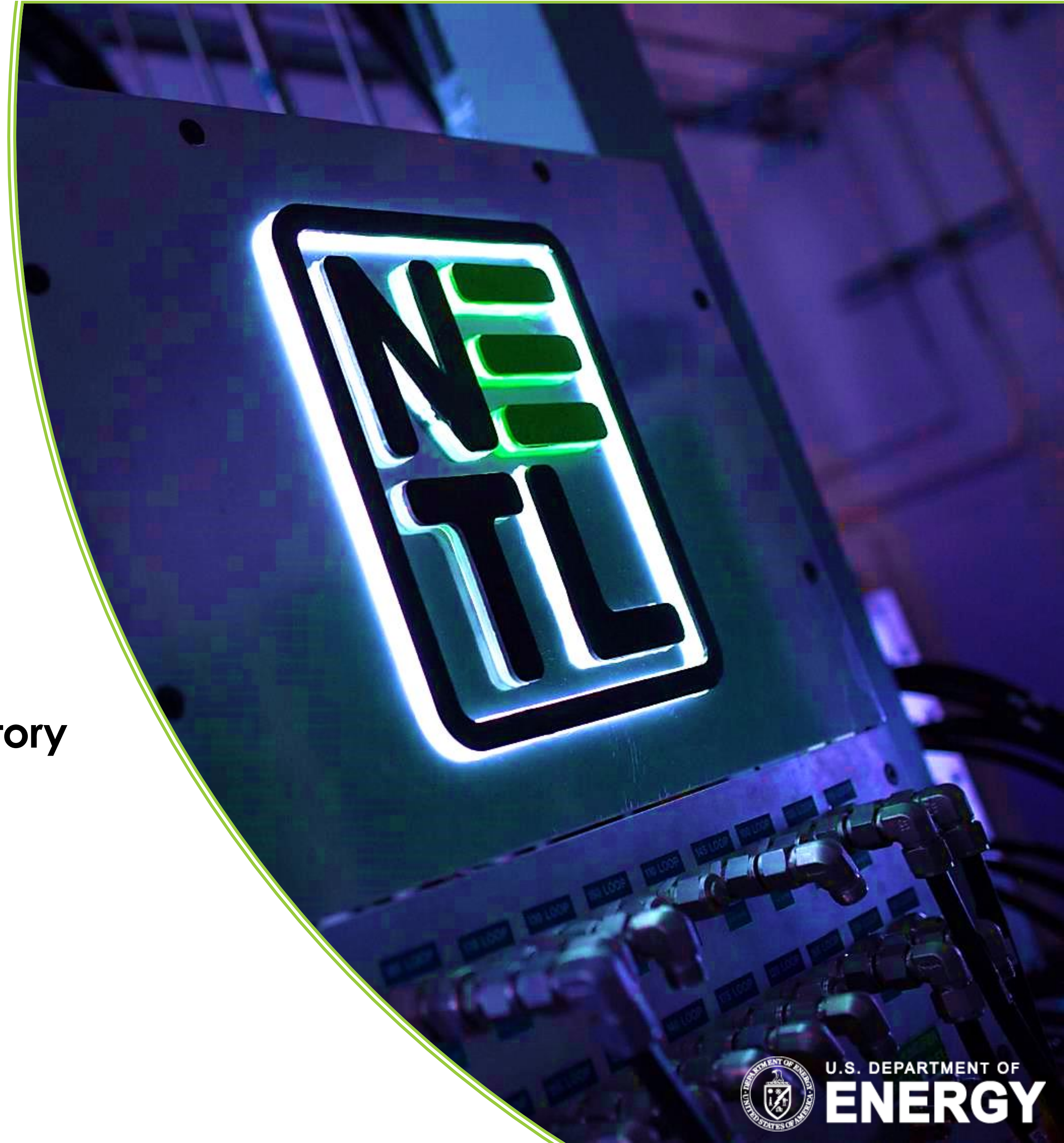

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