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PNNL-39019

Core Model Proposal #400:

Electricity Generation CCS Emission Factors

February 2026

Maridee Weber
Nathan Wiens

U.S. DEPARTMENT of ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Richland, Washington 99354

Core Model Proposal #400: Electricity Generation CCS Emission Factors

Product: Global Change Analysis Model (GCAM)

Institution: Joint Global Change Research Institute (JGCRI)

Authors: Maridee Weber, Nathan Wiens

Reviewers: Rachel Hoesly, Steven J. Smith

Date committed: December 16, 2025

IR document number: PNNL-39019

Related sector: emissions

Type of development: data

Purpose: This core model proposal provides updated emission factors to GCAM and GCAM-USA to differentiate CCS and non-CCS technologies for electricity generation. The work in this proposal modifies the existing code so that it can accept inputs with an additional nesting subsector layer, such as is used in the electricity generation sector in GCAM-USA.

Description of Changes

CCS and non-CCS electricity generation emission factors (EFs) in GCAM were previously not differentiated. This CMP updates CCS EFs in GCAM and GCAM-USA based on a variety of data sources.

Data Sources:

Electricity Generation Source	SO2, NOx, and PM Emission Factors
Coal	Cost and Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas to Electricity IGCC: Exhibit ES-2. Performance summary and environmental profile for IGCC cases PC: Exhibit ES-3. Performance summary and environmental profile for PC cases
Natural Gas	Cost and Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas to Electricity Exhibit ES-4. Performance summary and environmental profile for NGCC cases
Biomass	Technoeconomic and Life Cycle Analysis of Bio-Energy with Carbon Capture and Storage (BECCS) Baseline Exhibit ES-2. Cost and performance summary and environmental profile for all cases
Refined Liquids	EFs are copied from Natural Gas, as specific EFs for refined liquids CCS were not available, and any CCS technology would be a gasification technology.

Biomass IGCC CCS EFs are derived from biomass conventional CCS EFs, using the relationship of coal conventional CCS to coal IGCC CCS EFs.

BC and OC EFs are derived from PM based on BC and OC emission fractions.

Electricity Generation Source	BC Fraction	OC Fraction	Data Source
Coal	0.006	0	Bond et al (Table 5); hard coal, pulverized
Natural Gas	0.06	0.5	Bond et al (Table 5); for all natural gas
Biomass	0.038	0.323	EPA Trends (spreadsheet attached)*
Refined Liquids	0.3	0.09	Bond et al (Table 5); middle dist. oil, industry/power

* national_state_tier1_sector_2002_2024_21feb2025_tons.xlsx (downloaded from: https://www.epa.gov/air-emissions-inventories/air-pollutant-emissions-trends-data) assuming OM/OC=1.6.

Electricity Generation Source	CO and VOC Emission Factors
Coal	Update of Emission Factors of Greenhouse Gases and Criteria Air Pollutants, and Generation Efficiencies of the U.S. Electricity Generation Sector Table 6, GREET 2019 value
Natural Gas	Update of Emission Factors of Greenhouse Gases and Criteria Air Pollutants, and Generation Efficiencies of the U.S. Electricity Generation Sector Table 6, GREET 2019 values. Different values used for combined cycle vs. steam turbine.

Biomass	Update of Emission Factors of Greenhouse Gases and Criteria Air Pollutants, and Generation Efficiencies of the U.S. Electricity Generation Sector Table 6, GREET 2019 value
Refined Liquids	Update of Emission Factors of Greenhouse Gases and Criteria Air Pollutants, and Generation Efficiencies of the U.S. Electricity Generation Sector Table 6, GREET 2019 value. Steam turbine values used for both steam turbine and combined cycle, as EFs for combined cycle were not available.

Note systematic differences for oil and gas.

GCAM Implementation

This proposal also modifies the work done in *CMP # 336 Non-CO2 Controls* which creates a structure in gcamdata to easily incorporate new emissions factors. The work in this proposal modifies the existing code so that it can accept inputs with an additional nesting subsector layer, such as is used in the electricity generation sector in GCAM-USA.

The following table outlines the changes in the data system:

File Name	Type	Description
A53.global_elec_gen_CCS_EFs.csv	input data	New global CCS emissions factors for coal, gas, biomass, and refined liquids subsectors for SO2, NOx, BC, OC, CO, and NMVOC.
A53.USA_elec_gen_CCS_EFs_water.csv	input data	New United States CCS emissions factors for coal, gas, biomass, and refined liquids nesting subsectors for SO2_1, NOx, PM10, PM2.5, BC, OC, CO, and NMVOC.

zemissions_L253.emission_control.R	code modification	Code changes to create flexibility in the processing of data read in from emission control drop folders to keep nesting subsector level if present
zemissions_xml_emission_controls.R	code modification	Code changes to separate processing of data with nesting subsectors and add that data to the end of xml output

zemissions_L253.emission_control.R

This chunk modifies the preexisting code to accept data with an additional subsector layer or nesting subsector. In the previous version, the code arranged the outputs in descending row number and used "distinct()" to keep the most recent emission control for cases where there are multiple. This update modifies the process by adding "nesting.subsector" as an argument in the "distinct()" function if "nesting.subsector" is a column in the data frame. If there is no nesting subsector in the data frame, then the process does not change from the original version. This modification was made in all instances where the function is used.

zemissions_xml_emission_controls.R

The primary function of this chunk is to read in the emission control inputs and create the necessary xml's. This proposal adds a new capability of creating emissions control xmls with nesting subsector as additional level. To do so, this chunk was modified to check whether nesting subsectors are present in the input data and if so split input into nesting and non-nesting data frames as the inputs are being read into the chunk. If there is a "nesting.subsector" column, the data frame is renamed to end with "_nesting", all data from the input where the "nesting.subsector" column is not NA is assigned to is assigned to the new data frame, and the "nesting.subsector" column is renamed to "subsector0". The instances where "nesting.subsector" is not available, the data is assigned to a data frame with original input name and the "nesting.subsector" column is removed. If there is no "nesting.subsector" column, then the input is read in unchanged and assigned to a data frame with the original input name.

For each of the four output xml's, "emission_factor_controls.xml", "emission_factor_controls_user.xml", "emission_factor_controls_USA.xml", and "emission_factor_controls_user_USA.xml", the data frames with nesting subsectors are added to the output if they exist.

Applications to GCAM and GCAM-USA

In GCAM, SO2 and N2O emission factors are updated for CCS technologies in the coal, gas, and biomass subsectors for all regions. SO2 emission factors are set to zero and N2O changes result in slightly higher emissions for biomass conv CCS and coal conv pul CCS and lower emissions for biomass and coal IGCC CCS and gas CC CCS. These results for SO2 and N2O are the same in GCAM-USA.

Validation

In order for CCS technologies to be utilized, we applied a carbon tax of $20 starting in 2025, increasing 1.276x each period. Red represents this branch, Blue represents core.

GCAM-USA:

Figure 1: Total USA BC Emissions from CCS Technologies

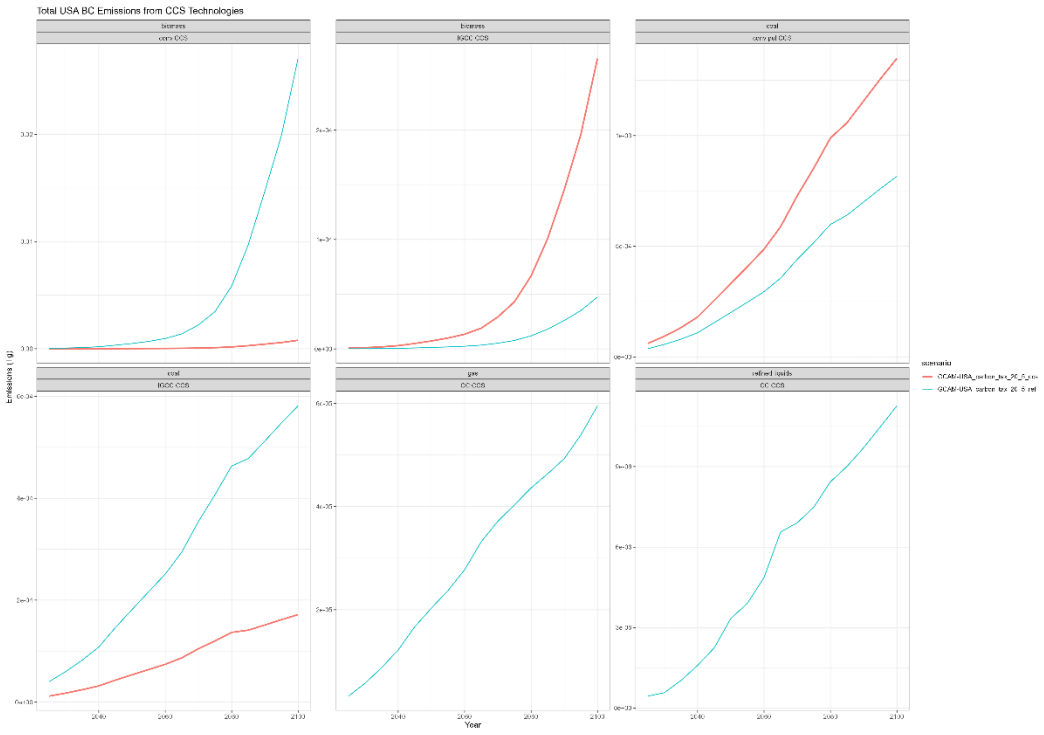


Figure 2: Total USA CO Emissions from CCS Technologies

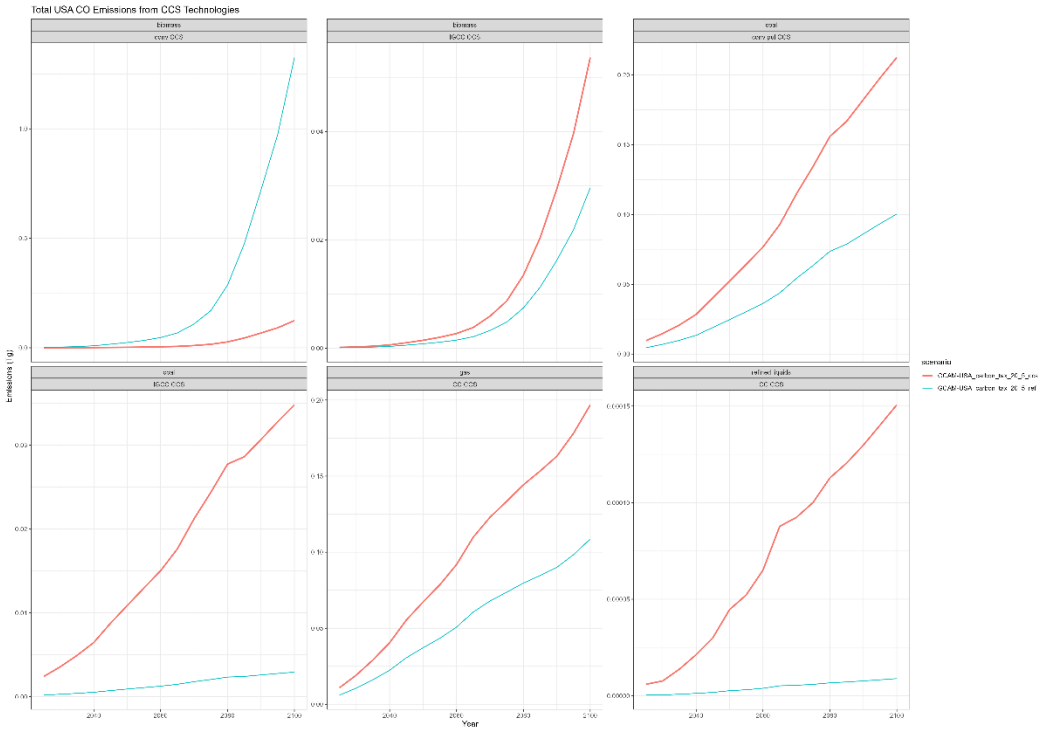


Figure 3: Total USA NMVOC Emissions from CCS Technologies

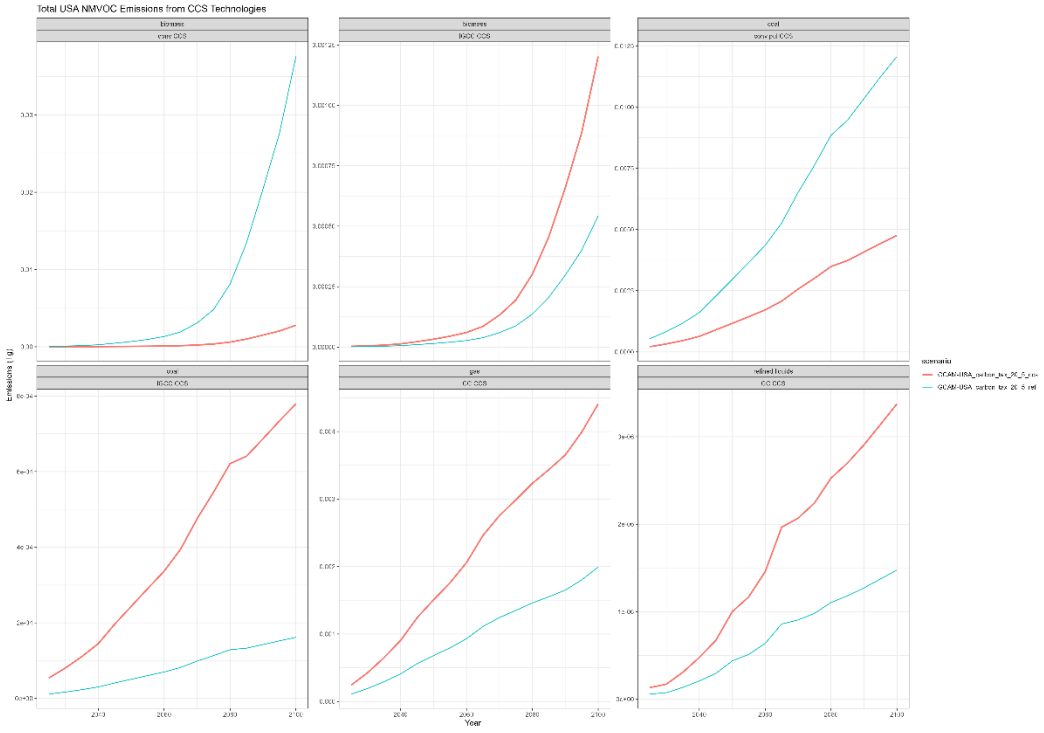


Figure 4: Total USA NOx Emissions from CCS Technologies

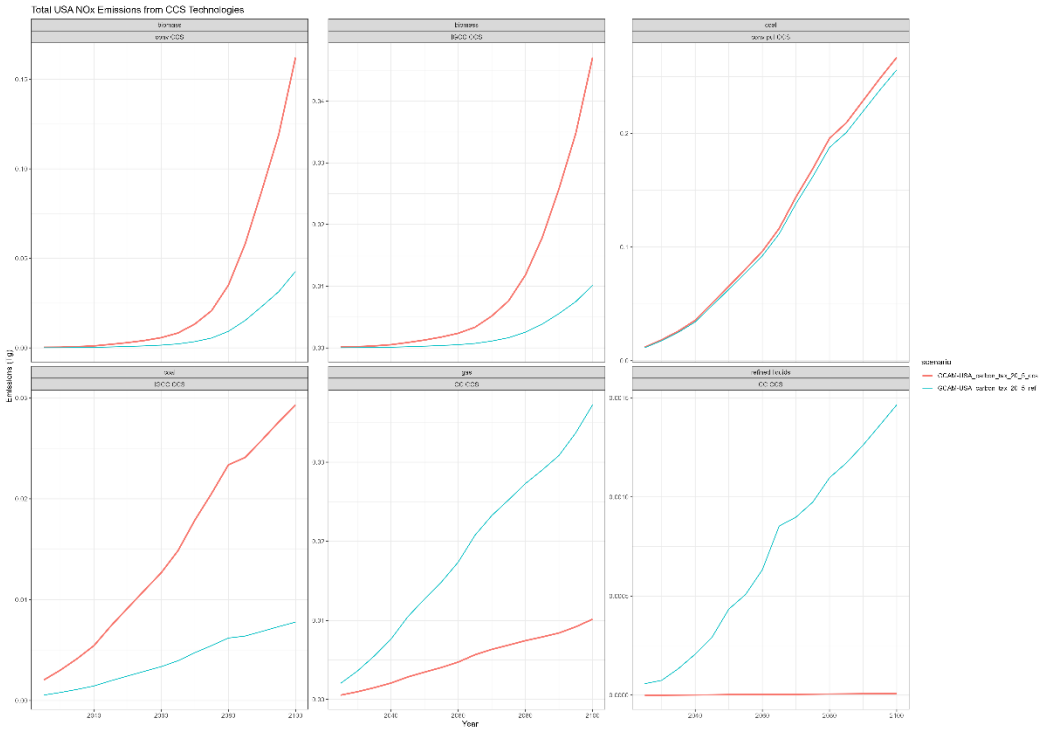


Figure 5: Total USA OC Emissions from CCS Technologies

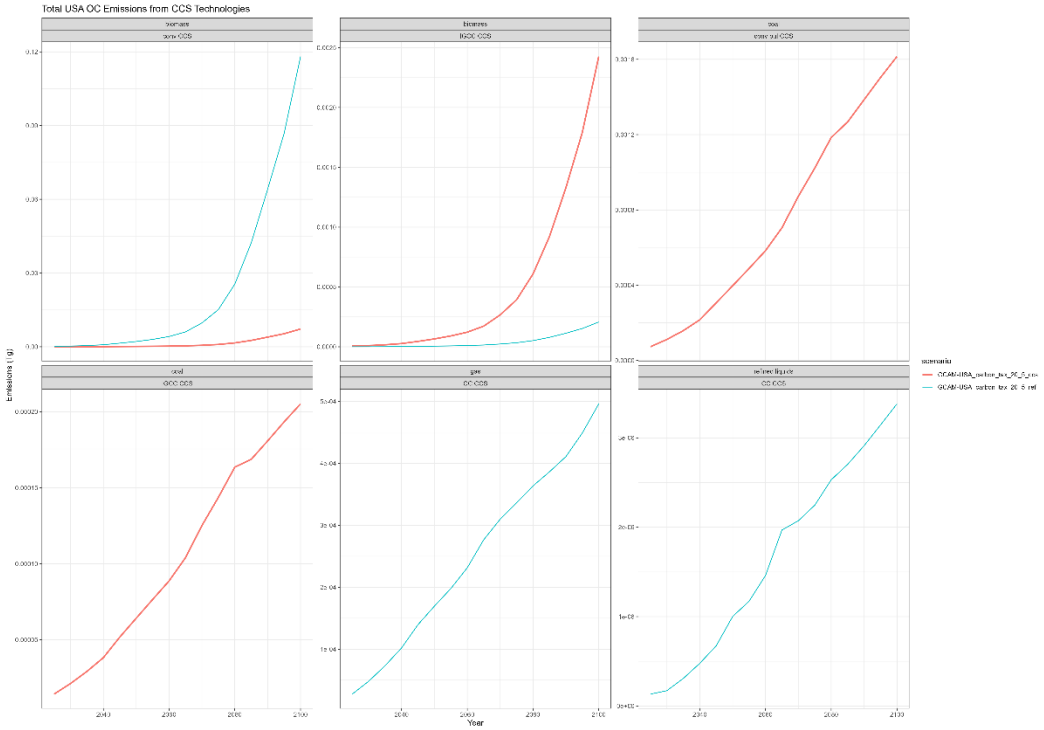


Figure 6: Total USA PM10 Emissions from CCS Technologies

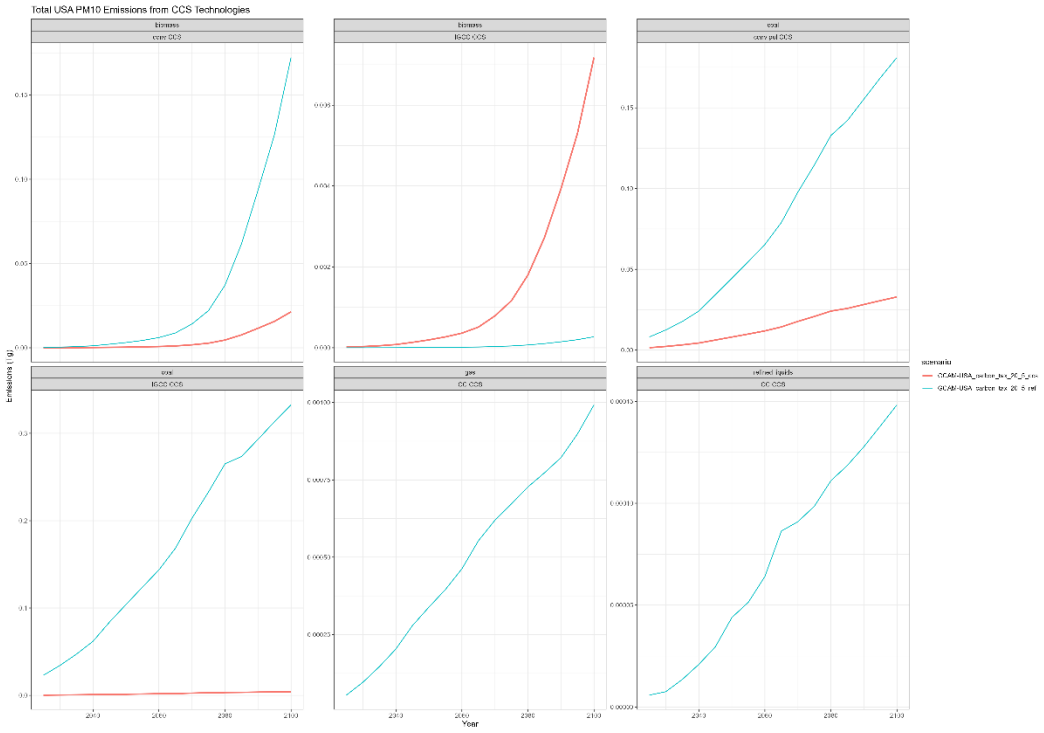


Figure 7: Total USA PM2.5 Emissions from CCS Technologies

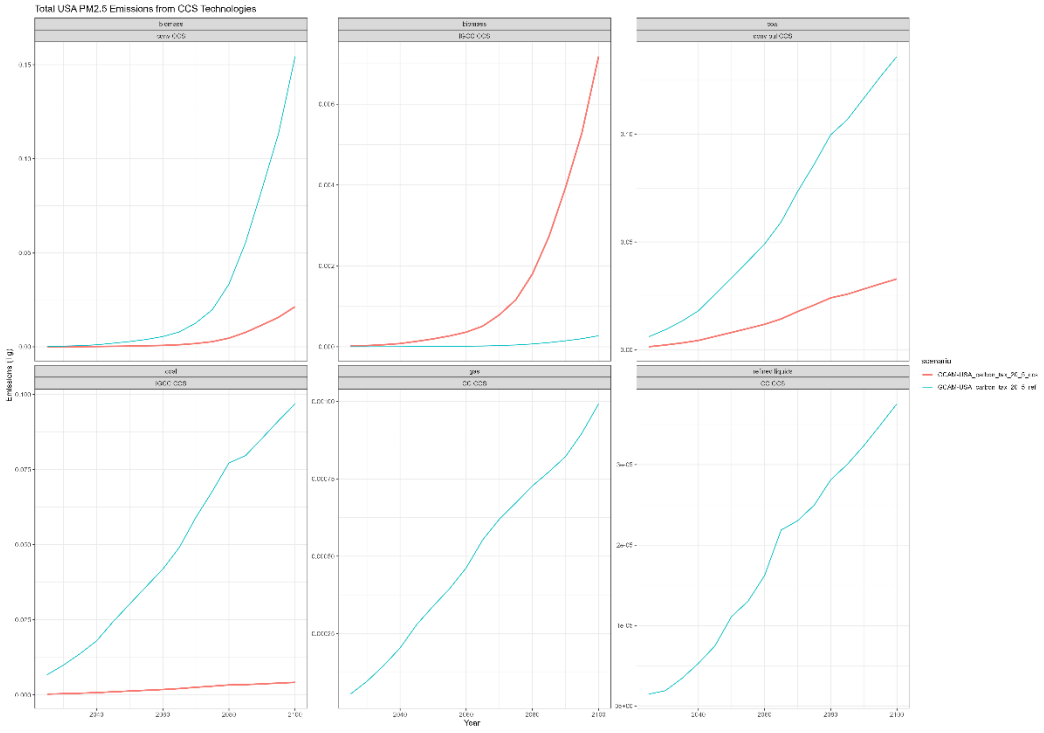
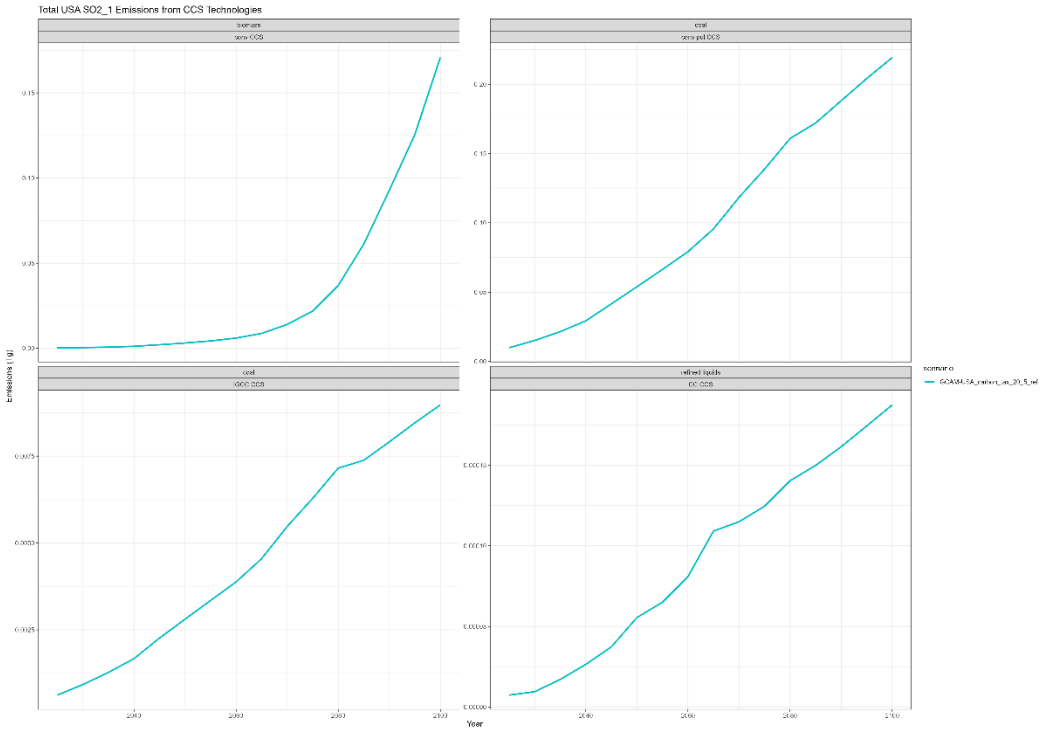


Figure 8: Total USA SO2 Emissions from CCS Technologies (CCS technologies have zero SO2 emissions)



GCAM:

Figure 9: Total Global CO Emissions from CCS Technologies

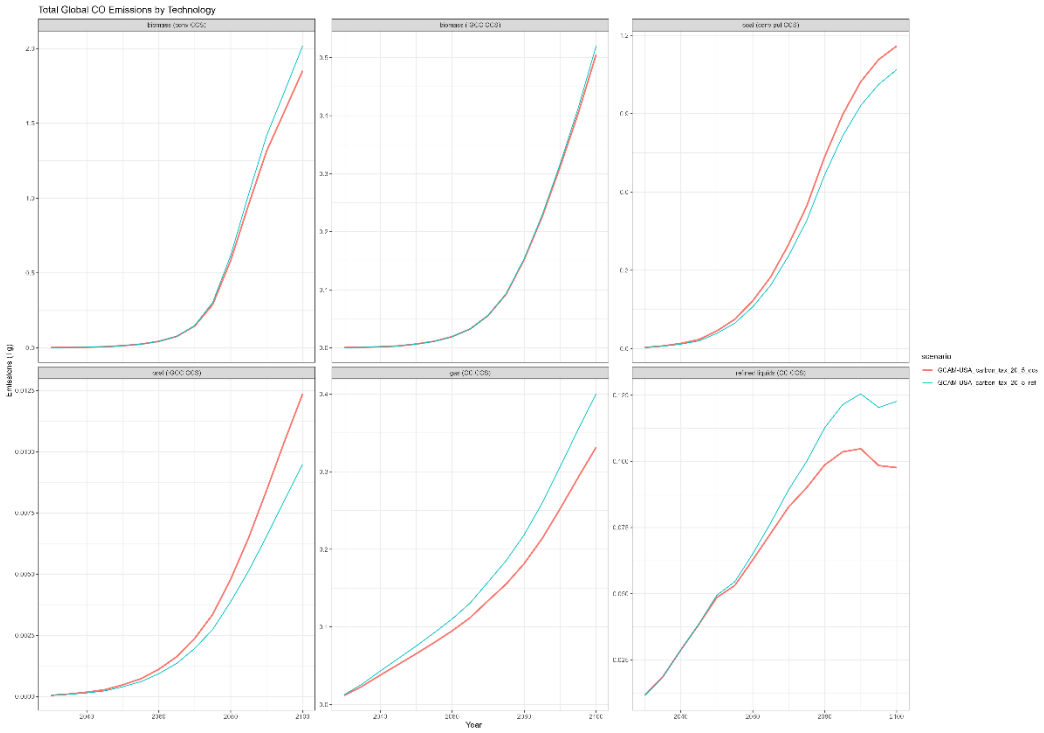


Figure 10: Total Global NOx Emissions from CCS Technologies

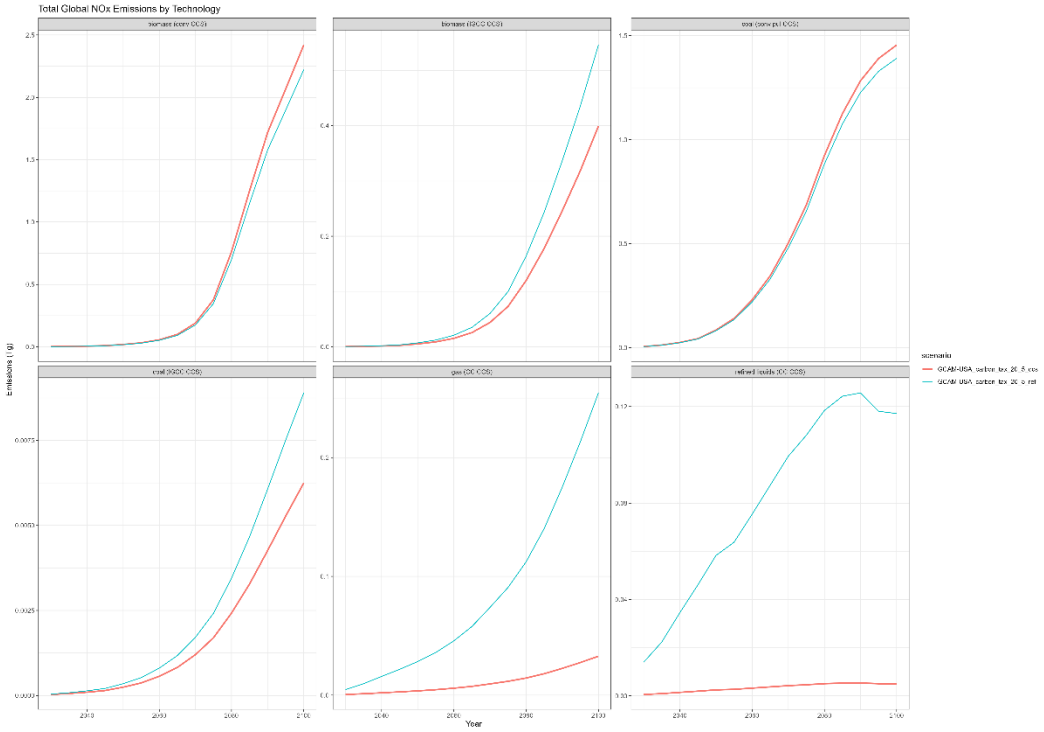


Figure 11: Total Global BC Emissions from CCS Technologies

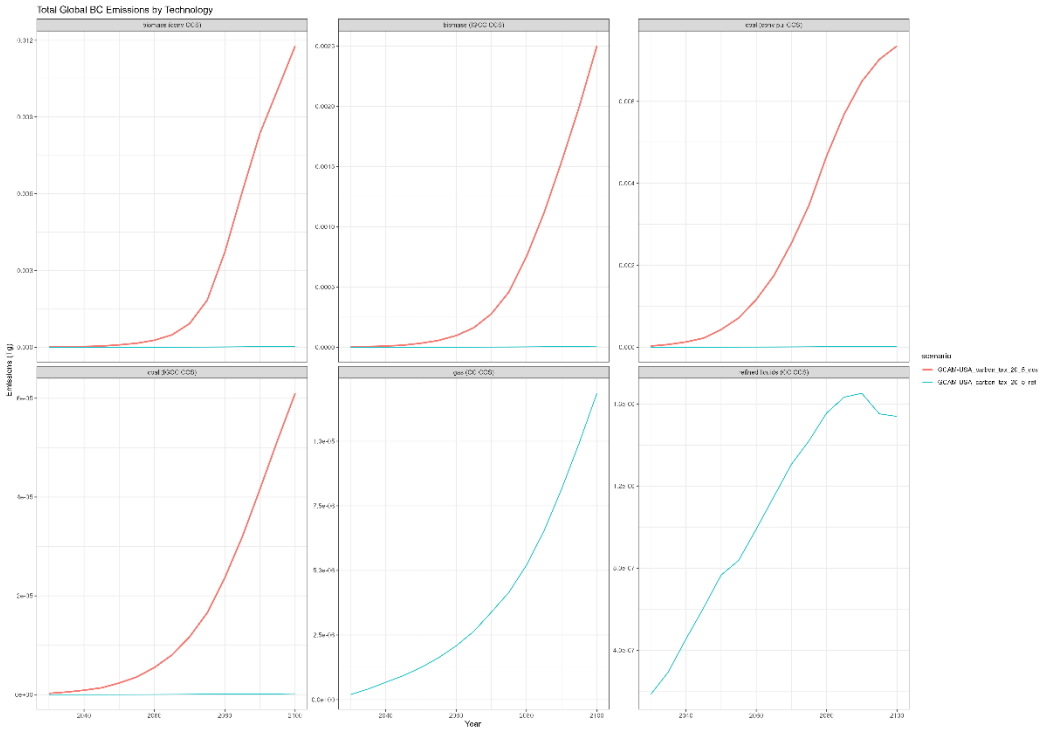


Figure 12: Total Global NMVOC Emissions from CCS Technologies

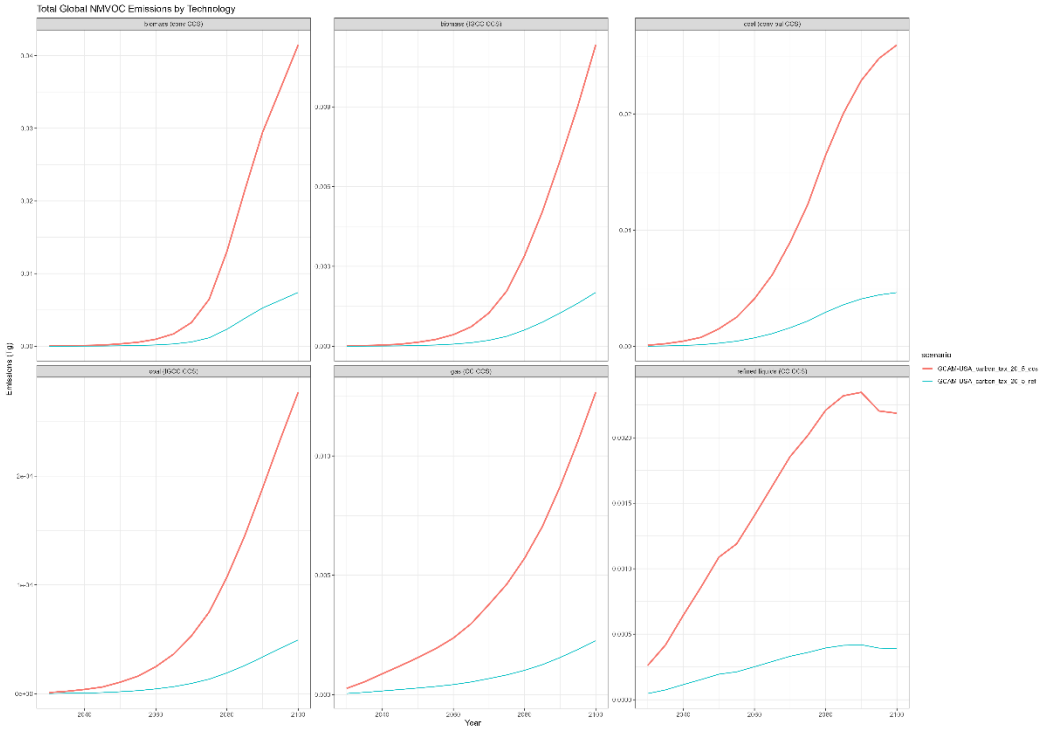


Figure 13: Total Global SO2 Emissions from CCS Technologies (CCS technologies have zero SO2 emissions)

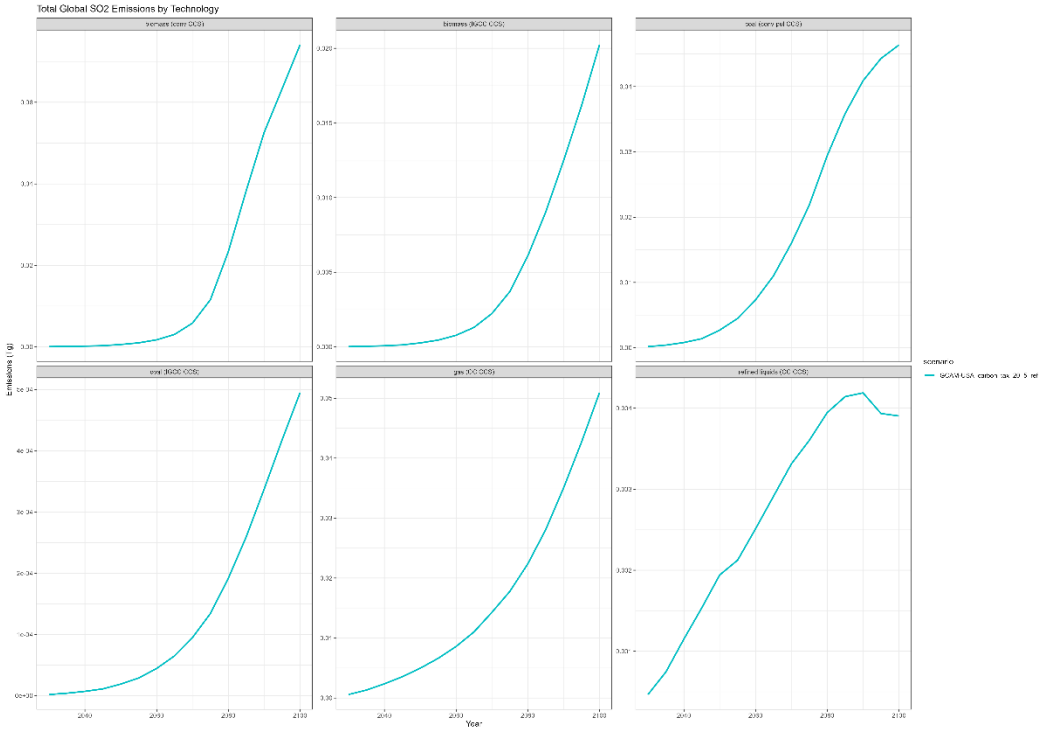
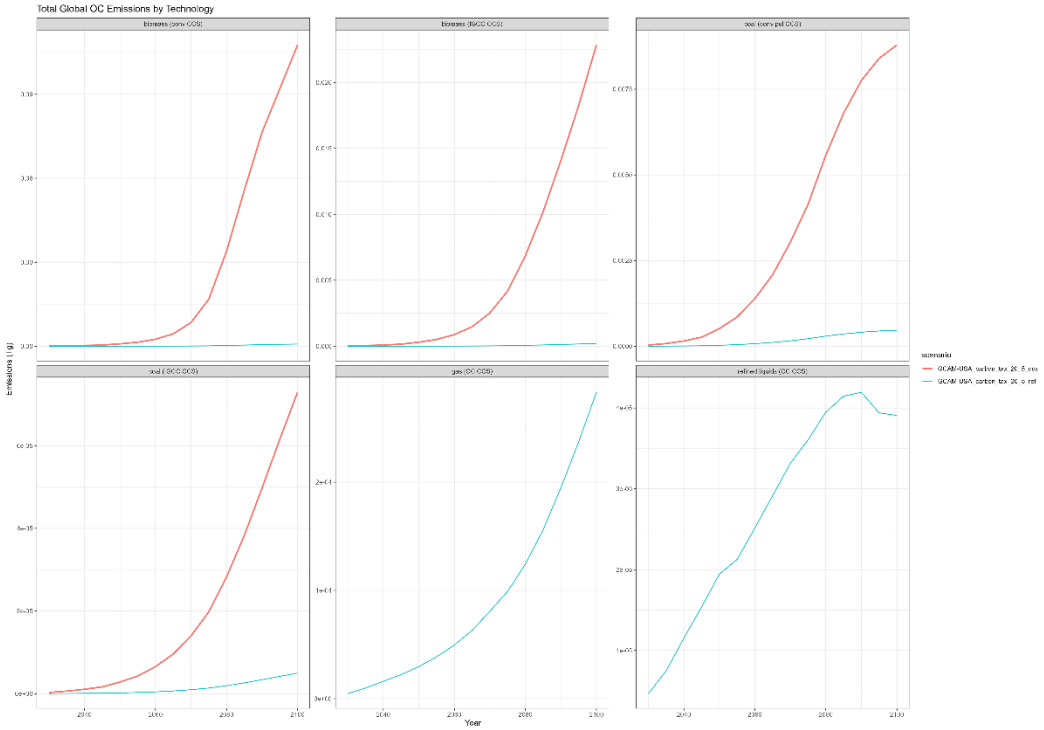


Figure 14: Total Global OC Emissions from CCS Technologies



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