Appendix 2: Data and Modeling Assumptions

Accounting Methods Dictate Carbon Removal Credit Integrity and Outcomes

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1. Data for assessing upstream systems

The biomass carbon removal and storage (BiCRS) scenarios involve various upstream systems as shown in Figure 1b-1f. This includes corn cultivation and harvesting (Figure 1b and 1e), wood harvesting during sustainable forest management (Figure 1c and 1d), sawmill operations (Figure 1d), and switchgrass cultivation and harvesting (Figure 1f). For woody biomass harvested during sustainable forest management, we use a carbon intensity of about 18.5 kg CO2eq. per tonne of wood from Zhang et al. (2016).[1] This carbon intensity describes shelterwood logging of natural hardwoods and does not include land use change which is difficult to estimate for managed forestry operations. For all other biomass resources (e.g., corn, corn stover, sawmill residues and switchgrass), we evaluate carbon intensities using Agile-Cradle-to-Grave (Agile-C2G), a physical units-based input–output life-cycle inventory model. Material and energy balances for corn cultivation and harvesting, sawmill operations, and switchgrass cultivation and harvesting are reported in Tables A2-1, A2-2, and A2-3, respectively. See Section 4 of this appendix for additional Agile-C2G data.

Table A2-1. GREET data for corn cultivation and harvesting[2]

Inputs	Value	Unit
Farming energy use (assume diesel)	3.68E+02	MJ
Nitrogen (assume urea)	1.56E+01	kg
P_2O_5	5.24E+00	kg
K_2O	5.43E+00	kg
$CaCO_3$	5.79E+01	kg

Herbicide (assume 50/50 atrazine/glyphosate)	3.02E-01	kg
Insecticide (assume negligible)	1.57E-03	kg
Outputs	**Value**	**Unit**
Corn	1.00E00	tonne
Corn stover (total above-ground biomass)	1.00E00	tonne
Soil Emissions	**Value**	**Unit**
N content of biomass	5.57E+00	kg per tonne of corn
N in N_2O emissions as % of N in N fertilizer and biomass	1.26%	%
N_2O emissions	2.68E-01	kg N_2O per tonne of corn

Table A2-2. Saw mill mass and energy balance from Khatri et al. (2025)[3]

Inputs	Value	Unit
Logs	1.82E+00	m3
Transportation (assume flatbed truck)	7.09E+01	tkm
Diesel	1.23E+00	L
Gasoline	1.20E-01	L
Natural gas	1.70E-02	m3
Propane (assume liquified petroleum gas)	2.70E-02	L
Electricity	3.78E+01	kWh
Outputs	**Value**	**Unit**
Rough green lumber	1.00E+00	m^3
Residues	3.11E+02	kg

Table A2-3. GREET data for switchgrass cultivation and harvest[2]

Inputs	Value	Unit
Farming energy use (assume diesel)	6.90E+01	MJ
Nitrogen (assume urea)	4.73E+00	kg
P_2O_5	2.24E+00	kg
K_2O	3.10E+00	kg
$CaCO_3$	5.67E+00	kg
Herbicide (assume 47/53 split between glyphosate and atrazine)[4]	5.15E-02	kg
Outputs	**Value**	**Unit**

Switchgrass	1	dry tonne
Soil Emissions	**Value**	**Unit**
N content of biomass	5.37E-01	kg per tonne of switchgrass
N in N_2O emissions as % of N in N fertilizer and biomass	1.26%	%
N_2O emissions	2.09E-01	kg N_2O tonne of switchgrass

2. BECCS Modeling

For both bioenergy with CCS (BECCS) scenarios (Figure 1d and 1e), we use a simplified model to estimate facility-level input output data reported in Table 2 of the main text. We assume a 50 MW plant with a capacity factor of 85%. Total power generation is therefore 372,300 MWh/year for both scenarios (Equation 1).

Power generation (MWh) = Capacity * Capacity Factor * Hours (per year) *(1)*

To estimate the electricity consumed by the CCS unit versus electricity exported to the grid, we assume that the CCS has a parasitic load share of 29%.[5] For our modeling purposes, this means that 29% of the carbon emissions associated with the BECCS plant (including those associated with raw material production, land use change and transportation) are allocated to the energy consumption in the activity-level LCA. In addition to energy allocation which is applied in the main activity-LCA results, we also show results applying the average U.S. grid intensity (see Figure 2 and 3 in the main text).

To estimate the annual feedstock loading rate for each BECCS scenario (Equation 2), we consider a facility thermal efficiency of 27%[6,7] and the energy content of the relevant feedstock (assume HHV) (Table A2-4).

Feedstock demand = [Power generation / Thermal efficiency] / Feedstock energy content *(2)*

Table A2-4. Biomass Characteristics from Kiprop Limo et al. (2024)[8]

	Sawdust Residue	Corn Stover	Unit
Carbon Content	47.16	39.54	%
HHV	17.93	17.38	MJ/kg

The total CO_2 removal potential (Equation 3) is estimated based on feedstock demand and the carbon content of the relevant feedstocks (Table A2-4). To estimate carbon storage for each BECCS scenario (Equation 4), we assume a post-combustion CO_2 capture rate of 90%.[9]

$$CO_2 \text{ removal potential} = \text{feedstock demand} * \text{C content of feedstock} * \text{mass factor ratio of } CO_2\text{:C} \quad (3)$$

$$\text{Gross carbon storage} = CO_2 \text{ removal potential} * CO_2 \text{ capture rate} \quad (4)$$

3. Summary of Modeling Assumptions

Table A2-5. Modeling assumptions for DACS scenarios

Category	Modeling description	
	DACS 1: Solvent-based DACS	DACS 2: Sorbent-based DACS
Gross carbon storage	This describes the quantity of CO2 injected underground for geologic sequestration. It does not include leaks post-capture.	
Emissions associated with energy inputs (electricity & fuels)	Energy inputs for this scenario include electricity and natural gas. Emissions associated with production of these energy inputs are accounted for using Agile-C2G and associated LCA data reported in Section 4. Natural gas is combusted for energy. Combustion emissions are not included as they are assumed to be captured alongside atmospheric CO_2. Leakage of natural gas-based CO_2 from storage is assumed to be negligible. Carbon equivalence of energy inputs is assessed with Agile-C2G and the data reported in Section 4.	The only energy input for this scenario is electricity. We use the US average grid carbon intensity for the carbon equivalence of this energy input. See data reported in Section 4.
Emissions associated with key materials	Key materials for this scenario include $CaCO_3$ and KOH. Embodied emissions in these materials are evaluated using Agile-C2G and associated LCA data reported in Section 4.	The key material for this scenario is amine-functionalized polymer sorbent. The carbon equivalence of this is adapted from Hanes et al. (2026). [10]
Carbon storage reversal	Reversal emissions are estimated assuming a 0.003% leakage rate from storage.[11,12]	

Table A2-6. Modeling assumptions for BiCRS scenario 1: corn-to-ethanol biorefinery with carbon capture and storage (CCS)

Category	Modeling description
Gross carbon storage	This describes the quantity of biogenic CO_2 injected underground for geologic sequestration. It does not include leaks post-capture. It does not include the capture of fossil-based CO_2 emissions from fuel combustion.
Land use change	This includes emissions associated with land use change for corn

	cultivation. To evaluate the relevant CO2e impacts, we use values adapted from GREET as per guidelines from the U.S. Department of Energy.[13]
Feedstock emissions	This includes emissions associated with corn cultivation (e.g., fuel combustion emissions, embodied emissions in fuels and materials, and soil emissions) excluding land use change which is reported on separately (see above). Input-output data for corn cultivation and soil emissions data is adapted from GREET (see Section 1 of this appendix).[2]
Facility-level emissions	This includes emissions from on-site combustion of natural gas that are not captured by the CCS unit.
Emissions associated with energy inputs (electricity & fuels)	Energy inputs for this scenario include electricity and natural gas. Emissions associated with production of these energy inputs are accounted for using Agile-C2G and associated LCA data reported in Section 4.
Carbon storage reversal	Reversal emissions from geologic storage are estimated assuming a 0.003% leakage rate.[11,12]
Transportation emissions	We assume 80 km distance for transportation of corn to the ethanol biorefinery. We assume the transportation method is flatbed trucking. Trucking emissions are evaluated using Agile-C2G and associated LCA data reported in Section 4.

Table A2-7. Modeling Assumptions for BiCRS Scenario 2: Pulp mill with CCS

Category	Modeling description
Gross carbon storage	This describes the quantity of biogenic CO_2 injected underground for geologic sequestration. It does not include leaks post-capture. It does not include the capture of fossil-based CO_2 emissions from fuel combustion.
Land use change	We assume that forests are sustainably managed and do not include any land use change for this scenario. We make this assumption in part because of the lack of reliable data related to the emissions impact of land use change for sustainably managed forests.
Feedstock emissions	This includes emissions associated with harvesting woody biomass. The carbon equivalence of harvested woody biomass is adapted from Zhang et al. (2016).[1] See Section 1 of this appendix for further details.
Facility-level emissions	All fuel combustion emissions are assumed to be captured by the CCS unit but are not credited in accounting of gross carbon storage.
Emissions associated with energy inputs (electricity & fuels)	The only energy input for this scenario is heavy fuel oil. We use residual fuel oil as a proxy for heavy fuel oil. Production emissions of the fuel are evaluated with Agile-C2G and associated LCA data

	reported in Section 4.
Carbon storage reversal	Reversal emissions from geologic storage are estimated assuming a 0.003% leakage rate.[11,12]
Transportation emissions	We assume 80 km distance for transportation of woody biomass to the pulp mill. We assume the transportation method is flatbed trucking. Trucking emissions are evaluated using Agile-C2G and associated LCA data reported in Section 4.

Table A2-8. Modeling Assumptions for BiCRS Scenario 3: BECCS with sawmill residues

Category	Modeling description
Gross carbon storage	This describes the quantity of biogenic CO_2 injected underground for geologic sequestration. It does not include leaks post-capture. It does not include the capture of fossil-based CO_2 emissions from fuel combustion.
Land Use Change	We assume that woody biomass used by the sawmill upstream of the BECCS facility is the same as that used in the previous scenario (pulp mill w/ CCS). See relevant assumptions in Table AS-7 for explanation of exclusion.
Feedstock Emissions	The feedstock for this scenario is sawmill residues. Associated emissions include sawmill operations and upstream woody biomass harvesting. We use the same assumptions from the previous scenario (pulp mill w/ CCS) to evaluate wood harvesting upstream of the sawmill. Sawmill operations are evaluated using the data in Section 1 of this appendix and Table A2-2.
Emissions Associated with Energy Inputs (Electricity & Fuels)	The BECCS facility is net-energy producing. The primary fuel is the biomass feedstock and we assume other energy inputs are negligible.
Carbon Storage Reversal	Reversal emissions from geologic storage are estimated assuming a 0.003% leakage rate.[11,12]
Transportation Emissions	We assume 80 km distance for transportation of sawmill residues to the BECCS facility. We assume the transportation method is flatbed trucking. Trucking emissions are evaluated using Agile-C2G and associated LCA data reported in Section 4. Upstream transportation of woody biomass to the sawmill is included in feedstock emissions.

Table A2-9. Modeling Assumptions for BiCRS Scenario 4: BECCS with corn stover

Category	Modeling Description
Gross Carbon Storage	This describes the quantity of CO_2 injected underground for geologic sequestration. It does not include leaks post-capture.
Land Use Change	This includes land use change associated with corn cultivation. To

	evaluate the relevant CO_{2e} impacts, we use values adapted from GREET as per guidelines from the U.S. Department of Energy.[13]
Feedstock Emissions	This includes emissions associated with corn cultivation (e.g., fuel combustion emissions, embodied emissions in fuels and materials, and soil emissions) excluding land use change which is reported on separately (see above). Input-output data for corn cultivation and soil emissions data is adapted from GREET (see Section 1 of this appendix).[2] No allocation is used to attribute away emissions to the primary corn product vs. corn stover. We assume that 30% of corn stover can be harvested sustainably.[14]
Emissions Associated with Energy Inputs (Electricity & Fuels)	The BECCS facility is net-energy producing. The primary fuel is the biomass feedstock and we assume other energy inputs are negligible.
Carbon Storage Reversal	Reversal emissions from geologic storage are estimated assuming a 0.003% leakage rate.[11,12]
Transportation Emissions	We assume 80 km distance for transportation of corn to the ethanol biorefinery.

Table A2-9. Modeling Assumptions for BiCRS Scenario 5: Pyrolysis of switchgrass for biochar production

Category	Modeling Description
Gross Carbon Storage	This describes the quantity of CO_2 equivalence of the carbon in produced biochar.
Land Use Change	We do not include land use change associated with switchgrass cultivation due to data scarcity and uncertainty.
Feedstock Emissions	This includes emissions associated with switchgrass cultivation (e.g., fuel combustion emissions, embodied emissions in fuels and materials, and soil emissions). Input-output data for corn cultivation and soil emissions data is adapted from GREET (see Section 1 of this appendix).[2]
Facility-Level Emissions	This includes emissions from on-site combustion of natural gas.
Emissions Associated with Energy Inputs (Electricity & Fuels)	The only energy input for this scenario is natural gas. Associated production emissions are evaluated with Agile-C2G and relevant LCA data reported in Section 4.
Carbon Storage Reversal	We assume that 20% of carbon in biochar is labile and emitted back to the atmosphere as CO_2 in the first few years after application.[15]
Transportation Emissions	We assume 80 km distance for transportation of switchgrass to the pyrolysis facility.

Table A2-10. Modeling Assumptions for Land-Based Mineralization Scenarios

Category	Modeling Description	
	Mineralization 1: Greenhouses	Mineralization 2: Tilling
Gross Carbon Storage	This includes CO_2 drawdown into stable carbonates during the removal timeframe of 100 years. Site-specific and method-specific estimates are adapted from Schmidt et al. (2026).[16]	
Land Use Change	Site-specific and method-specific land use change estimates are adapted from Schmidt et al. (2026).[16]	
Counterfactual Storage	This accounts for mineralization that would have taken place in the absence of the CDR intervention. Site-specific counterfactual storage estimates are adapted from Schmidt et al. (2026).[16]	
Facility-Level Emissions	There are no on-site combustion emissions for this scenario.	This includes diesel combustion emissions.
Emissions Associated with Energy Inputs (Electricity & Fuels)	We assume all equipment in this scenario is electrified so the only energy input is electricity. We use the US average grid carbon intensity for the carbon equivalence of this energy input. See data reported in Section 4.	We assume mining, transport and mixing equipment in this scenario is diesel-powered, while grinding equipment is electric. The energy inputs for this scenario therefore include diesel and electricity. We use the US average grid carbon intensity for the carbon equivalence of electricity. See data reported in Section 4. Diesel production emissions are evaluated with Agile-C2G and relevant LCA data reported in Section 4.
Carbon Storage Reversal	We assume that mineralized carbon is highly stable and has negligible risk of reversal during the removal timeframe.	

4. LCA Data for Material and Energy Inputs

We use the Agile-C2G LCA model and associated data previously documented in Nordahl et al. (2025)[17] to assess the embodied emissions in materials and energy consumed across the system supply chain for each scenario. Relevant data is re-reported in Tables A2-11 and A2-12 below.

Table A2-11. LCA Data: Emission Factors

All values are in units of kg of pollutant (given by column name) per unit indicated at the end of the unit process name. These are not necessarily life-cycle emission factors and only definitely include direct emission impacts (in several cases, this means fugitive emissions associated with fuel combustion); full life-cycle impacts must be assessed through the model using this data along with IO data from Table A2-12. When possible, GHG emission factors are separated by pollutant type; in cases where this is not possible, total GHG impact in CO_2 equivalence is given by the CO_2 column while the CH_4 and N_2O columns are marked with zeros. Zero entries can indicate no direct emissions, negligible direct emissions or unknown direct emissions.

Unit process	CO_2	CH_4	N_2O	Source(s)
atrazine.kg	8.71E+00	1.56E-04	1.25E-04	[18]
glyphosate.kg	0.00E+00	0.00E+00	0.00E+00	NA
CaCO3.kg	1.61E-03	5.15E-08	3.19E-08	[18]
K2O.kg	4.50E-01	8.91E-04	7.64E-06	[19]
urea.kg	3.57E-01	1.11E-03	9.71E-06	[19]
P2O5.kg	6.74E-02	1.29E-04	1.04E-06	[19]
coal.MJ	6.97E-04	1.39E-04	8.73E-09	[19]
diesel.MJ	5.09E-03	3.93E-08	2.02E-07	[18]
RFO.MJ	4.00E-03	8.74E-06	6.83E-08	[20]
refgas.MJ	7.06E-02	0.00E+00	0.00E+00	[19]
crudeoil.MJ	2.62E-03	8.24E-05	3.12E-08	[20]
electricity.US.kWh	4.14E-01	4.40E-05	7.00E-06	[21]
gasoline.MJ	3.56E-03	3.48E-05	1.32E-07	[20]
H2.kg	1.06E+01	5.98E-02	4.00E-05	[22]
Naturalgas. conventional.MJ	4.06E-03	8.70E-05	2.60E-08	[18]
Naturalgas. shale.MJ	3.80E-03	9.19E-05	2.59E-08	[18]
naturalgas_select.MJ	0.00E+00	0.00E+00	0.00E+00	NA; Selection variable with IO references to shale and conventional production shares
flatbedtruck.mt_km	1.24E-01	0.00E+00	0.00E+00	[23]
tankertruck.mt_km	8.46E-02	0.00E+00	0.00E+00	[23]
liquidpipeline.mt_km	0.00E+00	0.00E+00	0.00E+00	NA
rail.mt_km	1.86E-02	0.00E+00	0.00E+00	[23]
barge.mt_km	2.22E-02	0.00E+00	0.00E+00	[23]
marinetanker.mt_km	6.91E-03	8.02E-08	0.00E+00	[23]
butane.MJ	5.16E-03	2.24E-07	4.35E-08	[24]
lpg.kg	5.22E-01	1.45E-03	8.28E-06	[24]
KOH.kg	1.73E-01	3.09E-06	1.78E-06	[21]
KCl.kg	1.82E-01	3.28E-06	2.92E-06	[21]
urea_application.kg	0.00E+00	0.00E+00	6.35E-03	[25,26]

Table A2-12. LCA Model: Input-Output Matrix Relationships

Our LCA model uses a physical units-based input-output matrix that is populated with life-cycle inventories for each unit process/product included. The relevant non-zero values are included in this table. Each unit process/product is listed with a unit. The value indicates the amount of the upstream/downstream requirement in its listed unit required to make 1 unit of the primary unit product/process. For unit processes from Table A2-11 that are not included in this table, there are either (1) no upstream/downstream impacts for that parameter or (2) insufficient input/output data is available and full life-cycle emissions are included in the emission factors in Table A2-11.

Unit process	Life-cycle requirements	Value	Units	Source
atrazine				
	diesel	4.41E+01	MJ/kg	18
	RFO	4.41E+01	MJ/kg	18
	electricity.US	6.94E+00	kWh/kg	18
	natural gas_select	3.38E+01	MJ/kg	18
	tanker truck	4.26E-01	mt_km/kg	19
	rail	1.26E+00	mt_km/kg	19
glyphosate				
	tankertruck	4.26E-01	mt_km/kg	19
	rail	1.26E+00	mt_km/kg	19
CaCO3				
	coal	3.66E-03	MJ/kg	18
	diesel	1.30E-02	MJ/kg	18
	RFO	1.64E-03	MJ/kg	18
	electricity.US	2.44E-04	kWh/kg	18
	gasoline	2.56E-03	MJ/kg	18
	naturalgas_select	1.22E+00	MJ/kg	18
	flatbedtruck	8.00E-02	mt_km/kg	19
K2O				
	diesel	2.40E+00	MJ/kg	19
	naturalgas_select	2.70E+00	MJ/kg	19
	tankertruck	4.26E-01	mt_km/kg	19
	rail	1.26E+00	mt_km/kg	19
urea				
	electricity.US	1.29E+00	kWh/kg	18
	naturalgas_select	5.16E+00	MJ/kg	18
	tankertruck	4.26E-01	mt_km/kg	19
	rail	1.26E+00	mt_km/kg	19
P2O5				
	diesel	3.90E+00	MJ/kg	19
	naturalgas_select	1.50E+00	MJ/kg	19

	tankertruck	4.26E-01	mt_km/kg	[19]
	rail	1.26E+00	mt_km/kg	[19]
coal				
	diesel	2.30E-03	MJ/MJ	[19]
	RFO	2.53E-04	MJ/MJ	[19]
	electricity.US	2.09E-03	kWh/MJ	[19]
	gasoline	1.89E-04	MJ/MJ	[19]
	naturalgas_select	5.82E-05	MJ/MJ	[19]
	flatbedtruck	2.55E-03	mt_km/MJ	[19]
	rail	5.34E-02	mt_km/MJ	[19]
	barge	2.24E-02	mt_km/MJ	[19]
diesel				
	RFO	3.11E-02	MJ/MJ	[18]
	refgas	5.81E-02	MJ/MJ	[18]
	crudeoil	1.00E+00	MJ/MJ	[18]
	electricity.US	8.93E-04	kWh/MJ	[18]
	H2	1.08E-04	kg/MJ	[18]
	naturalgas_select	5.19E-02	MJ/MJ	[18]
	tankertruck	3.53E-03	mt_km/MJ	[18]
	liquidpipeline	2.10E-02	mt_km/MJ	[18]
	butane	9.92E-05	MJ/MJ	[18]
RFO (residual fuel oil)				
	RFO	2.70E-02	MJ/MJ	[18]
	refgas	3.73E-02	MJ/MJ	[18]
	crudeoil	1.00E+00	MJ/MJ	[18]
	electricity.US	3.71E-04	kWh/MJ	[18]
	H2	1.20E-05	kg/MJ	[18]
	naturalgas_select	2.43E-02	MJ/MJ	[18]
	tankertruck	3.53E-03	mt_km/MJ	[18]
	liquidpipeline	2.10E-02	mt_km/MJ	[18]
	butane	7.20E-05	MJ/MJ	[18]
refgas				
	crudeoil	1.00E+00	MJ/MJ	NA
crudeoil				
	diesel	3.06E-03	MJ/MJ	[18]
	RFO	2.04E-04	MJ/MJ	[18]
	crudeoil	2.04E-04	MJ/MJ	[18]
	electricity.US	1.08E-03	kWh/MJ	[18]
	gasoline	4.08E-04	MJ/MJ	[18]
	naturalgas_select	1.26E-02	MJ/MJ	[18]

	tankertruck	5.49E-03	mt_km/MJ	[18]
	liquidpipeline	2.85E-02	mt_km/MJ	[18]
	rail	2.42E-02	mt_km/MJ	[18]
	barge	4.39E-03	mt_km/MJ	[18]
	marinetanker	1.10E-01	mt_km/MJ	[18]
gasoline				
	RFO	9.28E-02	MJ/MJ	[27]
	refgas	9.26E-02	MJ/MJ	[27]
	crudeoil	1.00E+00	MJ/MJ	[27]
	electricity.US	1.44E-02	kWh/MJ	[27]
	H2	5.26E-05	kg/MJ	[27]
	naturalgas_select	6.27E-02	MJ/MJ	[27]
	tankertruck	3.53E-03	mt_km/MJ	[27]
	liquidpipeline	2.10E-02	mt_km/MJ	[27]
	butane	6.44E-02	MJ/MJ	[27]
H2				
	electricity.US	2.69E-01	kWh/kg	[22]
	naturalgas_select	1.43E+02	MJ/kg	[22]
flatbedtruck				
	diesel	1.78E+00	MJ/mt_km	[23]
	flatbedtruck	2.50E-01	mt_km/mt_km	[23]
tankertruck				
	diesel	1.22E+00	MJ/mt_km	[23]
	tankertruck	2.50E-01	mt_km/mt_km	[23]
liquidpipeline				
	electricity.US	1.84E-02	kWh/mt_km	[28]
rail				
	diesel	2.68E-01	MJ/mt_km	[23]
	rail	2.50E-01	mt_km/mt_km	[23]
barge				
	diesel	3.20E-01	MJ/mt_km	[23]
	barge	2.50E-01	mt_km/mt_km	[23]
marinetanker				
	RFO	1.00E-01	MJ/mt_km	[23]
	marinetanker	2.50E-01	mt_km/mt_km	[23]
butane				
	naturalgas_select	1.00E+00	MJ/MJ	NA
KOH				
	diesel	1.41E+00	MJ/kg	[21]
	electricity.US	3.28E+00	kWh/kg	[21]

	naturalgas_select	1.22E+00	MJ/kg	21
	kcl	1.52E+00	kg/kg	21
KCl				
	RFO	1.41E+00	MJ/kg	21
	electricity.US	5.29E-01	kWh/kg	21
	naturalgas_select	1.22E+00	MJ/kg	21

5. Tabulated Results by Scenario

The following tables describe CO_2e fluxes associated with 1 standard year of operation for each scenario. Table A2-13 includes tabulated results for both DACS scenarios for which activity-level LCA and NFF results are the same. Tables A2-14 through A2-18 report results for BiCRS scenarios by framework and by category. Table A2-19 includes tabulated results for both mineralization scenarios for which activity-level LCA and NFF results are the same.

Table A2-13. Tabulated Results for DACS Scenarios

	DACS 1: Solvent-based DACS (tonnes CO_2e/year)	DACS 2: Sorbent-based DACS (tonnes CO_2e/year)
Gross Carbon Storage	8.00E+05	6.00E+05
Emissions Associated with Energy Inputs (Electricity & Fuels)	-1.88E+05	-4.05E+05
Emissions Associated with Key Materials	-1.77E+04	-4.31E+04
Carbon Storage Reversal	-2.40E+03	-1.80E+03
Summary Metrics		
Gross Storage	8.00E+05	6.00E+05
Net Carbon Benefit (activity-level LCA)	5.92E+05	1.50E+05
Net Removal (NFF)	5.92E+05	1.50E+05
Efficiencies		
Carbon Benefit Efficiency (activity-level LCA)	73.94%	25.00%
Removal Efficiency (NFF)	73.94%	25.00%

Table A2-14. Tabulated Results for BiCRS Scenario 1: Corn-to-ethanol biorefinery with carbon capture and storage (CCS)

	NFF (tonnes CO_2e/year)	LCA (tonnes CO_2e/year)

Gross Carbon Storage	1.03E+05	1.03E+05
Land Use Change	-1.90E+04	0.00E+00
Feedstock Emissions	-7.75E+04	0.00E+00
Facility-Level Emissions	-6.64E+03	0.00E+00
Emissions Associated with Energy Inputs (Electricity & Fuels)	-6.01E+04	-1.35E+04
Carbon Storage Reversal	-3.09E+02	-3.09E+02
Transportation Emissions	-6.34E+03	0.00E+00
Avoided Emissions (coproduct)	NA	0.00E+00
Avoided Emissions (waste diversion)	NA	0.00E+00
Avoided Emissions (reduced soil emissions)	NA	0.00E+00
Summary Metrics		
Gross Storage	1.03E+05	
Net Carbon Benefit (activity-level LCA)	8.93E+04	
Net Removal (NFF)	-6.68E+04	
Efficiencies		
Carbon Benefit Efficiency (activity-level LCA)	86.60%	
Removal Efficiency (NFF)	-64.73%	

Table A2-15. Tabulated Results for BiCRS Scenario 2: Pulp and paper mill with CCS

	NFF (tonnes CO_2e/year)	**LCA (tonnes CO_2e/year)**
Gross Carbon Storage	1.86E+06	1.86E+06
Feedstock Emissions	-5.16E+04	0.00E+00
Emissions Associated with Energy Inputs (Electricity & Fuels)	-2.11E+04	-9.29E+03
Carbon Storage Reversal	-5.57E+03	-5.57E+03
Transportation Emissions	-4.84E+04	0.00E+00
Summary Metrics		
Gross Storage	1.86E+06	
Net Carbon Benefit (activity-level LCA)	1.85E+06	
Net Removal (NFF)	1.73E+06	
Efficiencies		
Carbon Benefit Efficiency (activity-level LCA)	99.20%	
Removal Efficiency (NFF)	93.19%	

Table A2-16. Tabulated Results for BiCRS Scenario 3: Bioelectricity production from sawmill residues with CCS

	NFF (tonnes CO_2e/year)	LCA (tonnes CO_2e/year)
Gross Carbon Storage	4.31E+05	4.31E+05
Feedstock Emissions	-4.97E+04	0.00E+00
Emissions Associated with Energy Inputs (Electricity & Fuels)	0.00E+00	-1.58E+04
Carbon Storage Reversal	-1.29E+03	-1.29E+03
Transportation Emissions	4.81E+03	0.00E+00
Summary Metrics		
Gross Storage	4.31E+05	
Net Carbon Benefit (activity-level LCA)	4.14E+05	
Net Removal (NFF)	3.85E+05	
Efficiencies		
Carbon Benefit Efficiency (activity-level LCA)	96.03%	
Removal Efficiency (NFF)	89.27%	

Table A2-17. Tabulated Results for BiCRS Scenario 4: Bioelectricity production from corn stover with CCS

	NFF (tonnes CO_2e/year)	LCA (tonnes CO_2e/year)
Gross Carbon Storage	3.53E+05	3.53E+05
Land Use Change	-1.49E+04	0.00E+00
Feedstock Emissions	-2.02E+05	0.00E+00
Emissions Associated with Energy Inputs (Electricity & Fuels)	0.00E+00	-6.43E+04
Carbon Storage Reversal	-1.06E+03	-1.06E+03
Transportation Emissions	-4.96E+03	0.00E+00
Summary Metrics		
Gross Storage	3.53E+05	
Net Carbon Benefit (activity-level LCA)	2.88E+05	
Net Removal (NFF)	1.31E+05	
Efficiencies		
Carbon Benefit Efficiency (activity-level LCA)	81.49%	
Removal Efficiency (NFF)	36.92%	

Table A2-18. Tabulated Results for BiCRS Scenario 5: Pyrolysis of switchgrass for biochar production

	NFF (tonnes CO_2e/year)	**LCA (tonnes CO_2e/year)**
Gross Carbon Storage	5.60E+04	5.60E+04
Feedstock Emissions	-8.05E+03	-8.05E+03
Facility-Level Emissions	-2.46E+02	-2.46E+02
Emissions Associated with Energy Inputs (Electricity & Fuels)	-3.43E+01	-3.43E+01
Carbon Storage Reversal	-1.12E+04	-1.12E+04
Transportation Emissions	-1.46E+03	-1.46E+03
Avoided Emissions (reduced soil emissions)	NA	7.50E+02
Summary Metrics		
Gross Storage	5.60E+04	
Net Carbon Benefit (activity-level LCA)	3.58E+04	
Net Removal (NFF)	3.50E+04	
Efficiencies		
Carbon Benefit Efficiency (activity-level LCA)	63.86%	
Removal Efficiency (NFF)	62.52%	

Table A2-19. Tabulated Results for Mineralization Scenarios

	Mineralization 1: Greenhouse method with electrified equipment (tonnes CO_2e/year)	**Mineralization 2: Tilling method with diesel-powered equipment (tonnes CO_2e/year)**
Gross Carbon Storage	4.60E+05	1.04E+04
Land Use Change	-8.47E+02	-8.47E+02
Counterfactual Storage	-3.26E+03	-3.26E+03
Facility-Level Emissions	0.00E+00	-2.57E+03
Emissions Associated with Energy Inputs (Electricity & Fuels)	-1.39E+04	-9.10E+02
Summary Metrics		
Gross Storage	4.60E+05	1.04E+04
Net Carbon Benefit (activity-level LCA)	4.42E+05	2.81E+03
Net Removal (NFF)	4.42E+05	2.81E+03

Efficiencies		
Carbon Benefit Efficiency (activity-level LCA)	96.09%	27.01%
Removal Efficiency (NFF)	96.09%	27.01%

7. Comparison of LCA and the NFF Methods

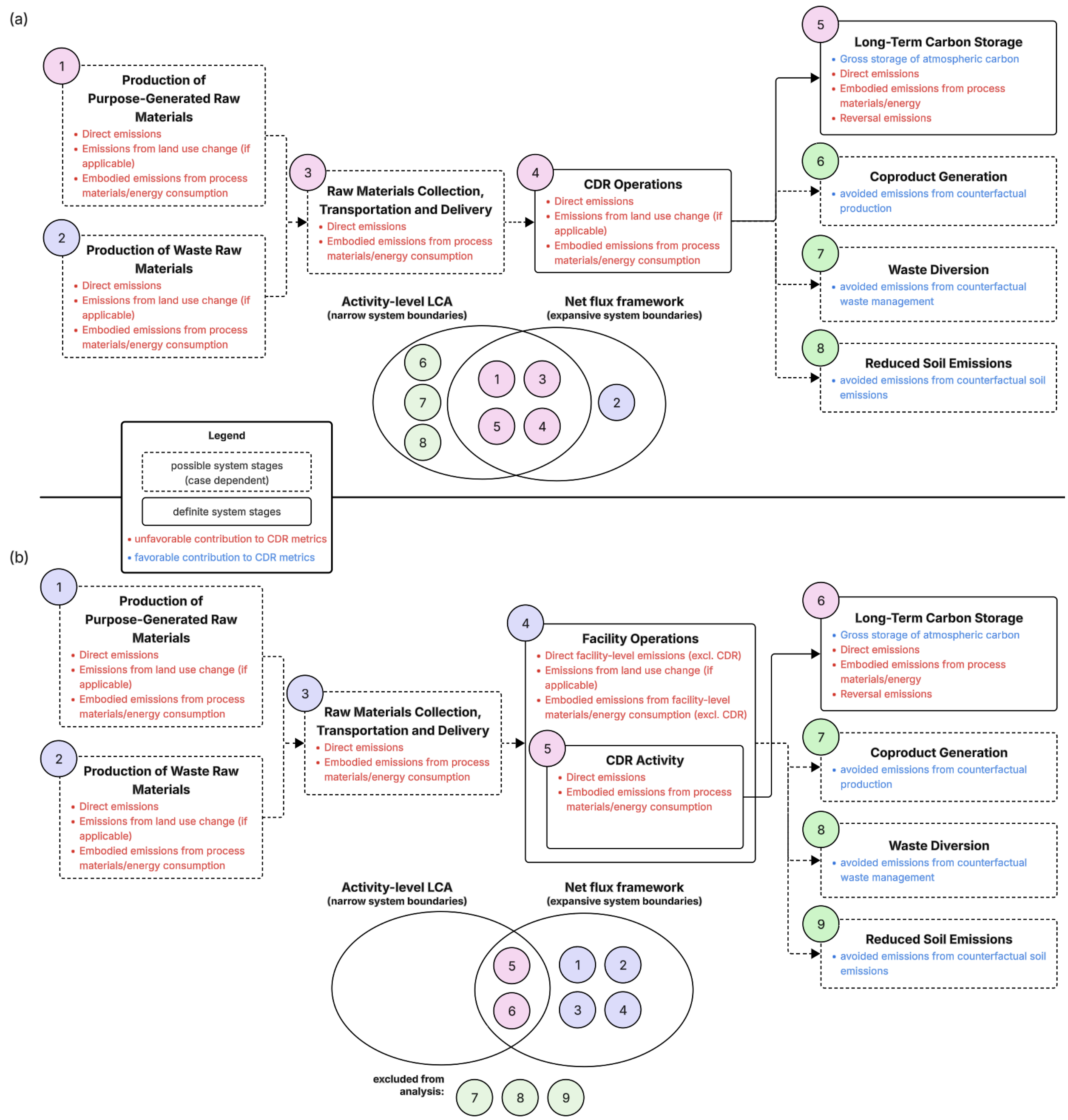

Figure A2-1. Examples of generalizable flow diagrams and system boundaries for CDR systems in which (a) activity-level and facility-level operations are the same and (b) facility-level operations include the CDR Activity in addition to other upstream processes

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