

Life Cycle Assessment of GTI Cool-GTL Fuels Production

tcbi  mass+2026

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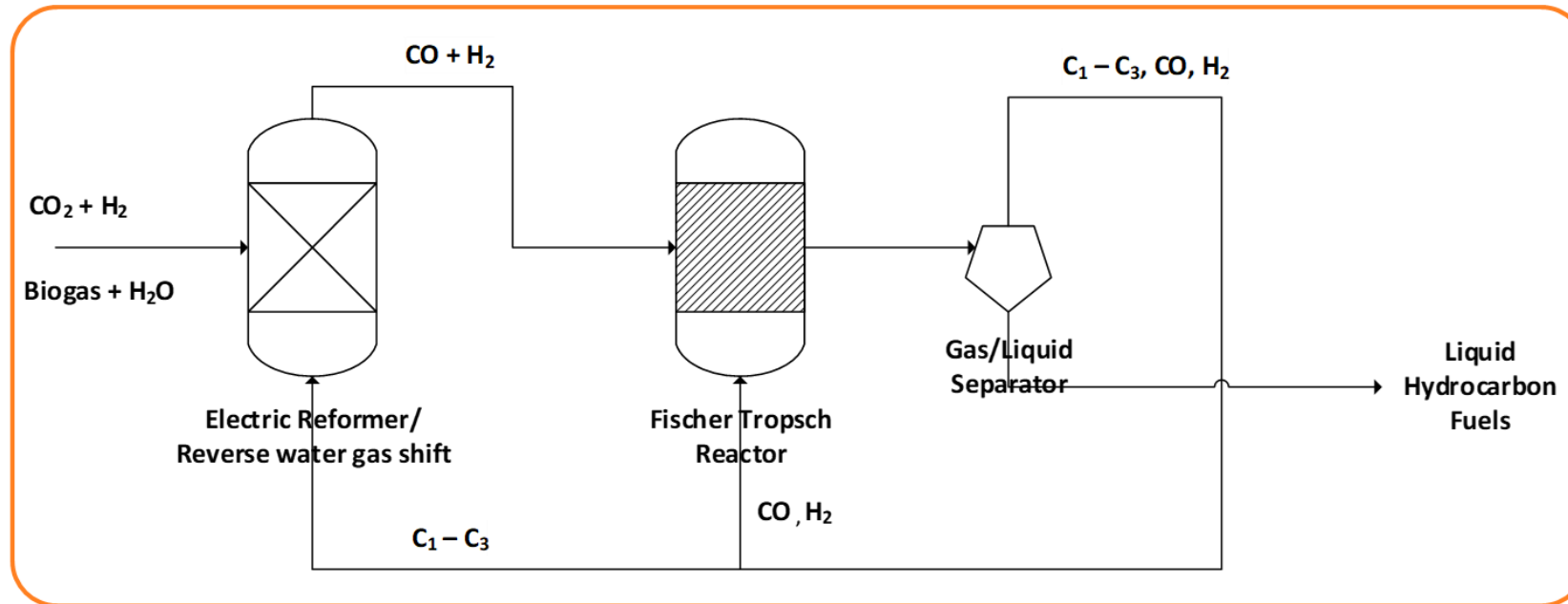
1 - Michigan Technological University 2 - GTI Energy, USA



**Michigan
Technological**
University



GTI Process Overview



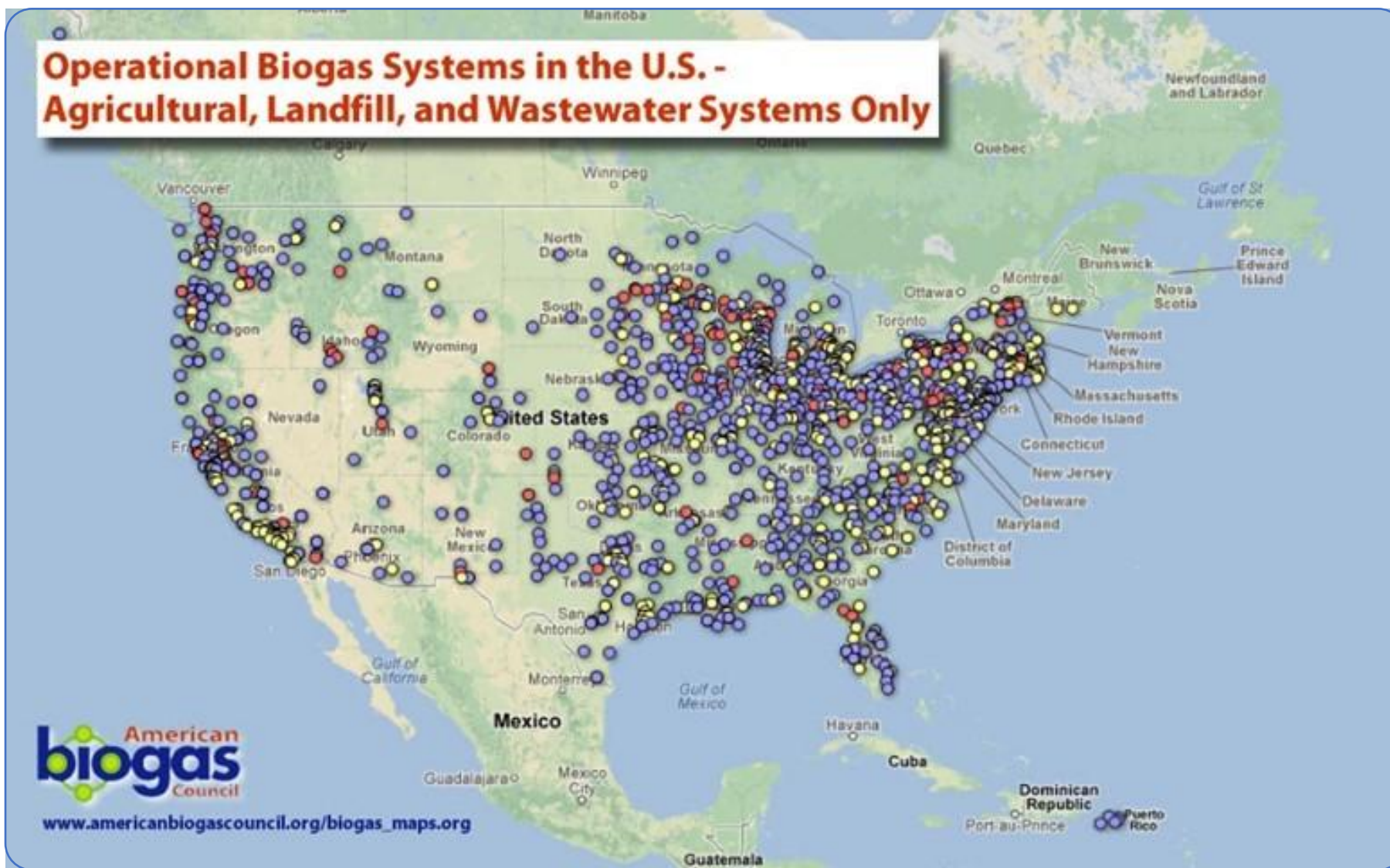
Two primary feedstock types

1) CO_2 feedstock –from EtOH plant or fossil sources

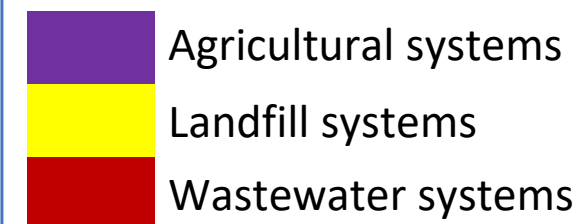
2) Biogas feedstock – mixture of CH_4 / CO_2

- Landfill Gas collected from Landfill
- Biogas generated from organic waste (MSW, manure)

Brief Overview – Biogas resource potential



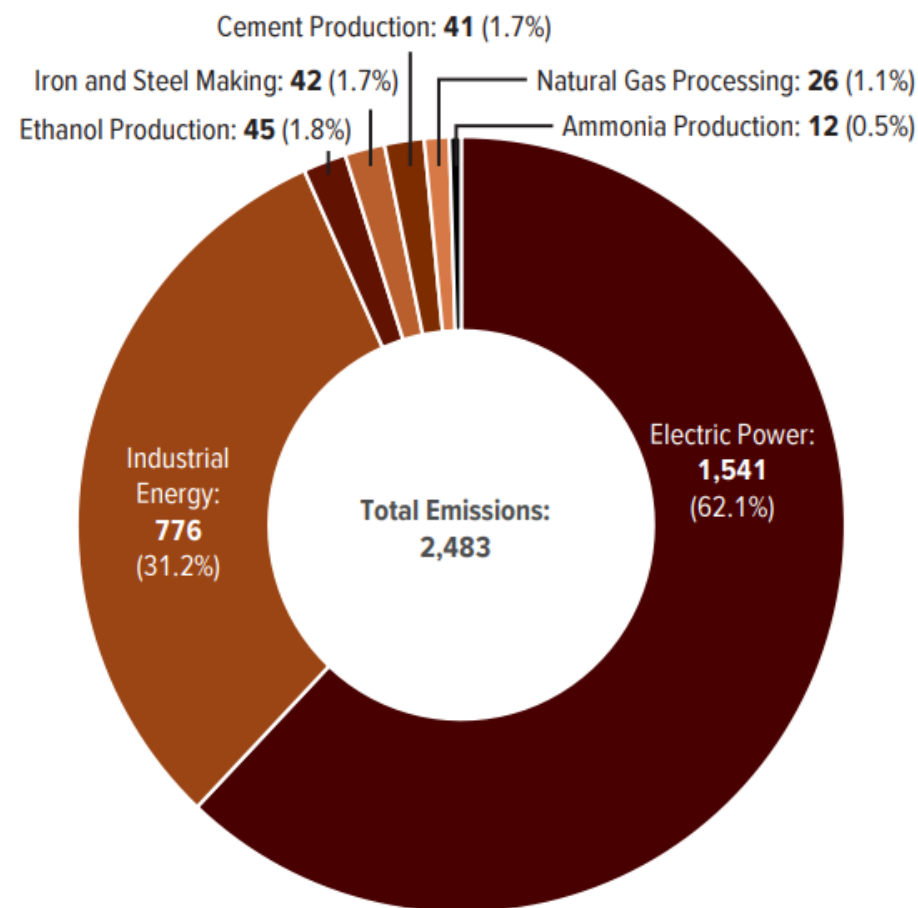
- 2,200 sites in the U.S.
- 13,500 future sites



Brief Overview – Carbon dioxide resource potential

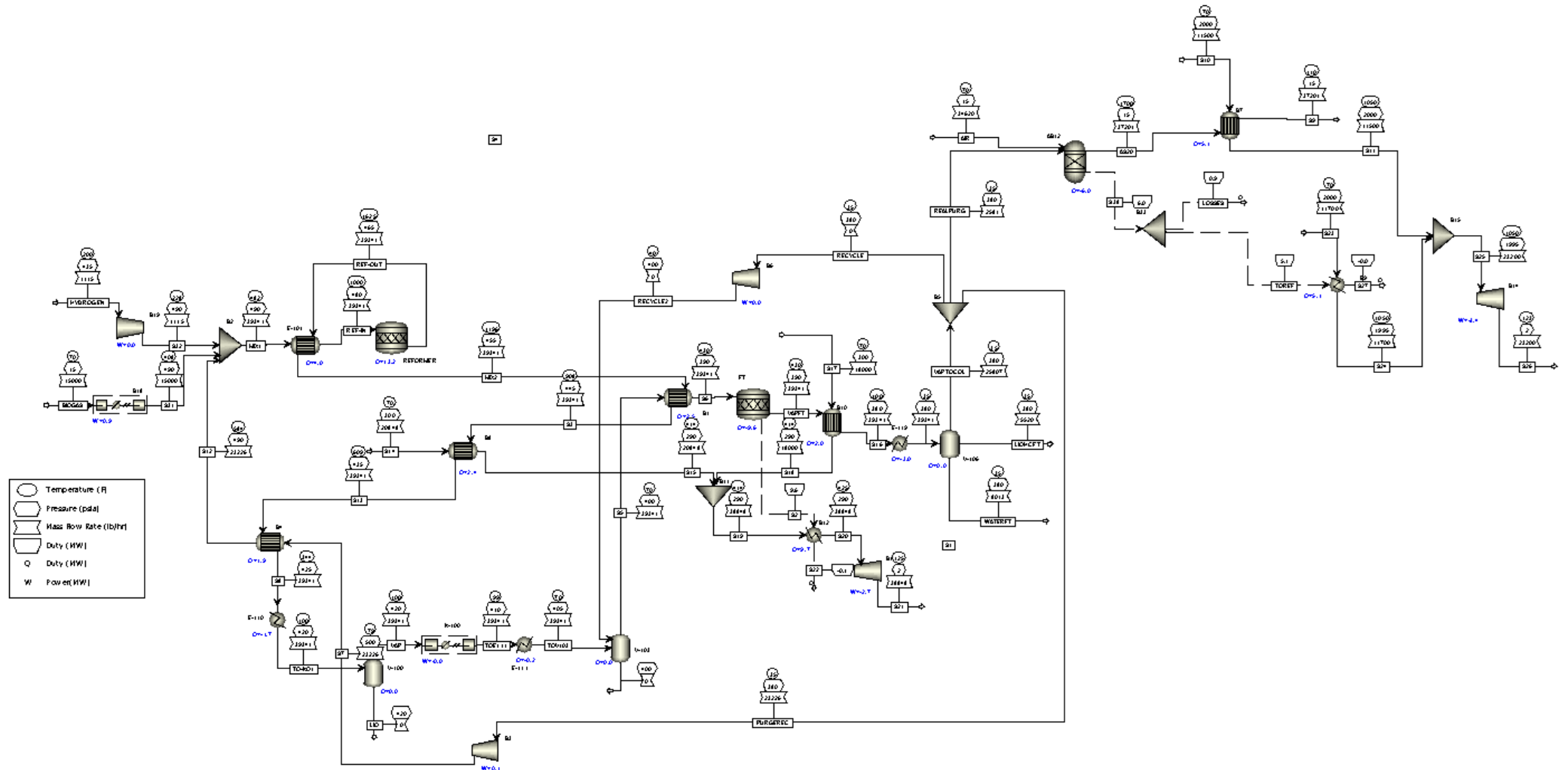
CO₂ Emissions in the United States in 2021 From Sources That Are Potential Candidates for Carbon Capture and Storage

Millions of Metric Tons



LCA Approach

Commercial-scale process model data from GTI



LCA Approach

Key inputs to LCA – basis of 1 hr operation

Inputs	Electric Reformer	Electric Reformer + H2
Item		
Biogas	5739 kg	6803 kg
Hydrogen	0	506 kg
Electricity	8.22 MW	8.72 MW
Output		
Biofuel	1244 kg	2504 kg

Inputs	CO2 Case
Item	Amount
Carbon dioxide	4536 kg
Hydrogen	642 kg
Water	218 kg
Electricity	8.78 MW
Output	
Biofuel	1466 kg

LCA Approach

Key inputs to LCA

Hydrogen – used GTI HyPEC tool as source of emissions estimates
3 different Hydrogen options and emissions impacts

- Solar PV electrolysis (2.36 kg CO_{2eq} / kg H₂)
- Low emissions grid electrolysis (5.19 kg CO_{2eq} / kg H₂)
- Steam methane reforming (11.68 kg CO_{2eq} / kg H₂)

LCA Approach

Key inputs to LCA

Electricity – used GTI HyPEC tool / EPA eGRID

3 different Electricity grid options and emissions impacts

- Solar PV (46 g CO_{2eq} / kWh)
- Low emissions grid electricity (~100 g CO_{2eq} / kWh)
- Recent national electricity grid (~400 g CO_{2eq} / kWh)



[Hydrogen Technology Center](#)

[Open Hydrogen Initiative](#)

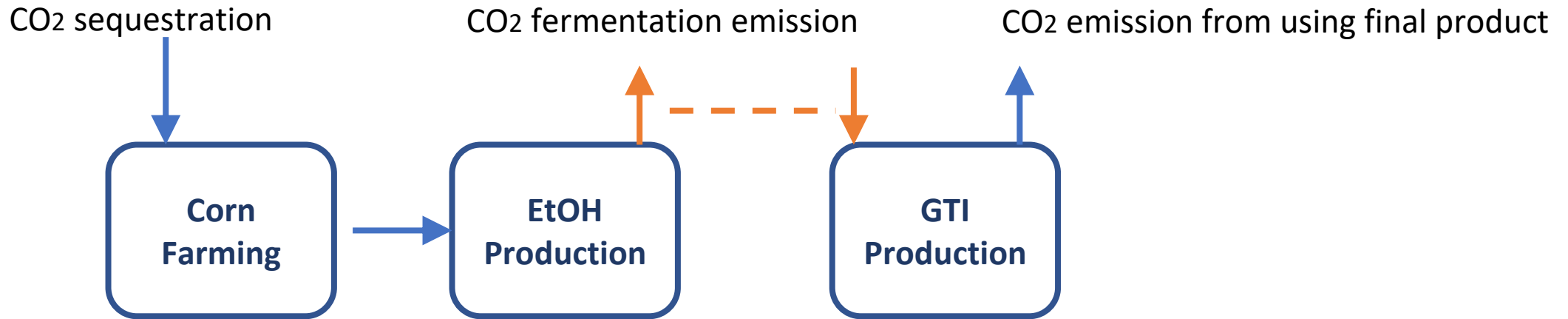
[Hydrogen Generation](#)

[Contact](#)

Hydrogen Production Emissions Calculator

LCA Approach: Corn Ethanol CO₂

CO₂ Scenario 1 – CO₂ comes from ethanol plant



CO₂ was previously being emitted

Now we are temporarily delayed that emission by routing it through the GTI process

Sequestration initially, release after fuel is burned

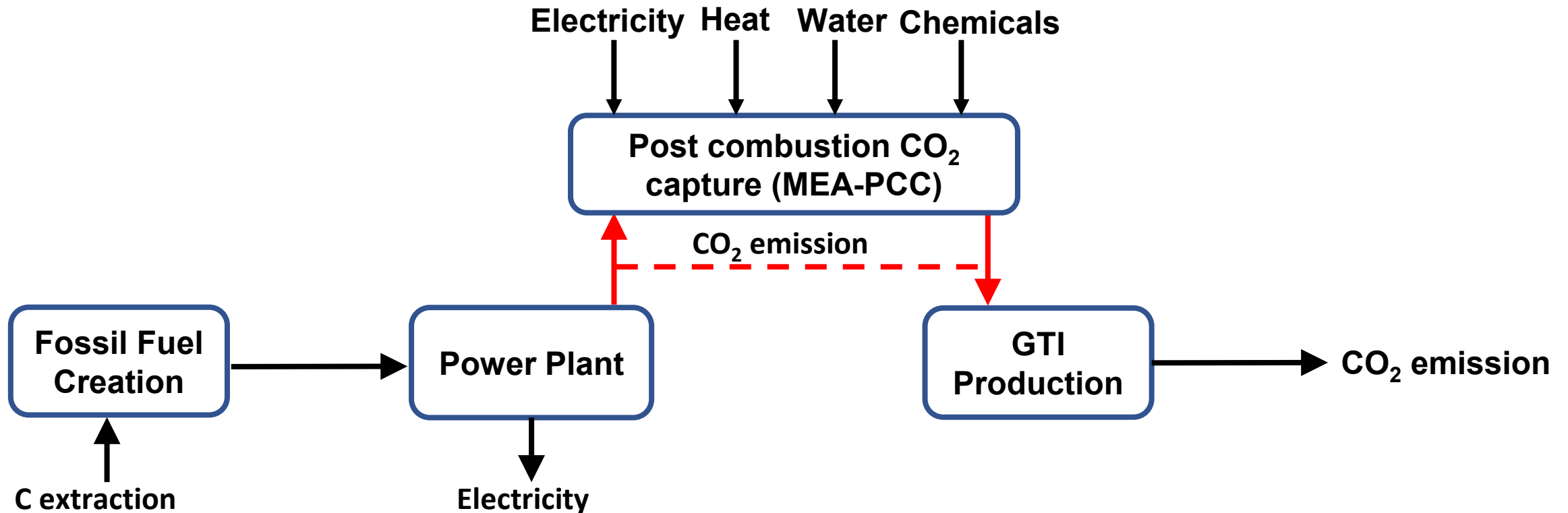
LCA Results: Corn Ethanol CO₂ Cases

	Biogenic CO ₂ – Case 1	Biogenic CO ₂ - Case 2	Biogenic CO ₂ Case 3	Biogenic CO ₂ Case 4
Feedstock source	Ethanol Plant	Ethanol Plant	Ethanol Plant	Ethanol Plant
Feedstock prior fate	Emission	Emission	Emission	Emission
Hydrogen source	Solar PV	Solar PV	Low-E Grid	SMR
Electricity source	Solar PV	National Grid	Low-E Grid	National Grid
Feedstock gas input	-71.0	-71.0	-71.0	-71.0
Hydrogen	23.0	23.0	51.2	115.3
Electricity	3.0	29.5	6.8	29.5
Water	0.04	0.04	0.04	0.04
Fuel combustion	71.0	71.0	71.0	71.0
Total GHG (g CO₂eq/MJ fuel)	26.1	52.8	58.0	144.9
% Reduction from fossil	69%	38%	32%	-70%

- **Case 1**, hydrogen (88%)
- **Case 2**, electricity (56%)

LCA Approach: Fossil CO₂

CO₂ Scenario 2 – CO₂ comes from fossil source



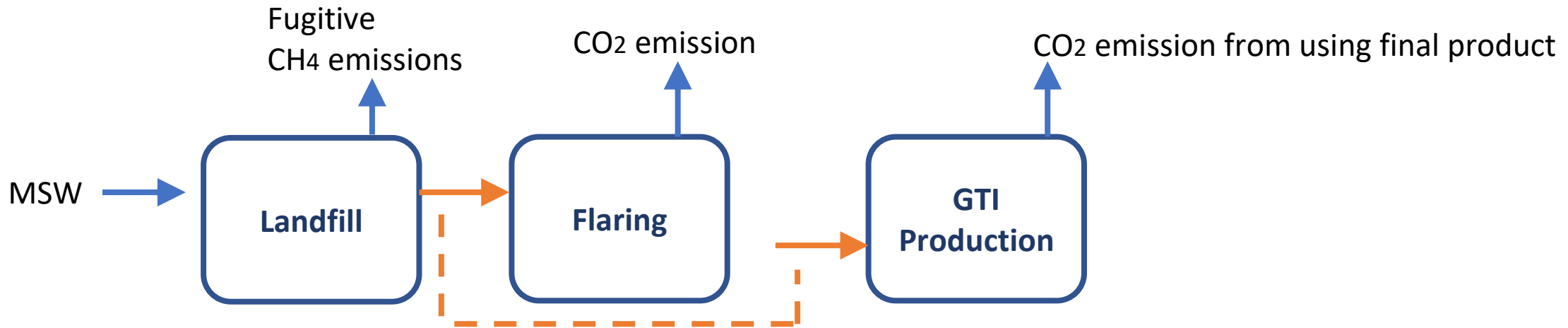
CO₂ emissions penalty is attributed to the electricity being generated
Exhaust gas treated as burden-free waste stream, credit for avoided emission to atmosphere
Sequestration initially, release after fuel is burned

LCA Results: Fossil CO₂ Cases

	Fossil CO ₂ Case 5	Fossil CO ₂ Case 6	Fossil CO ₂ Case 7	Fossil CO ₂ Case 8
Feedstock source	Fossil (MEA)	Fossil (MEA)	Fossil (MEA)	Fossil (MEA)
Feedstock prior fate	Emission	Emission	Emission	Emission
Hydrogen source	Solar PV	Solar PV	Low-E Grid	SMR
Electricity source	Solar PV	National Grid	Low-E Grid	National Grid
Feedstock gas input	-71.0	-71.0	-71.0	-71.0
Hydrogen	23.0	23.0	51.2	115.3
Electricity	3.0	29.5	6.8	29.5
Water	0.04	0.04	0.04	0.04
MEA – PCC Inputs	44.7	44.7	44.7	44.7
Fuel combustion	71.0	71.0	71.0	71.0
Total GHG (g CO₂eq/MJ fuel)	71.1	97.5	102.7	189.6
% Reduction from fossil	16%	-15%	-21%	-123%

LCA Approach: Landfill Biogas 1 (Avoid Flaring)

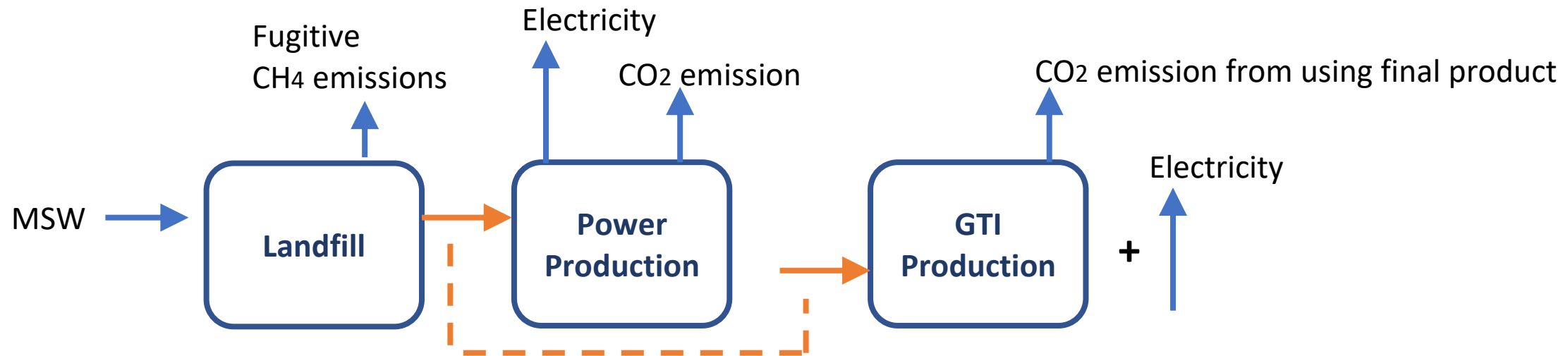
Biogas Scenario 1 – Biogas comes from landfill gas – gas was being flared



No ultimate change in outcomes – previously, biogas was converted to CO₂, also with GTI Credit for avoided CO₂ emissions, but penalty for fuel CO₂ emission.
Fugitive landfill emissions of CH₄ remain constant and are attributed to the landfill

LCA Approach: Landfill Biogas Case 2 (Avoid Power Production)

Biogas Scenario 2 – Biogas comes from landfill gas – gas is burned for power



This changes the situation, now we must account for the electricity produced during the prior fate of the biogas.

LCA Results: Biogas Cases – Gas Fired and E-Reformer (No H₂)

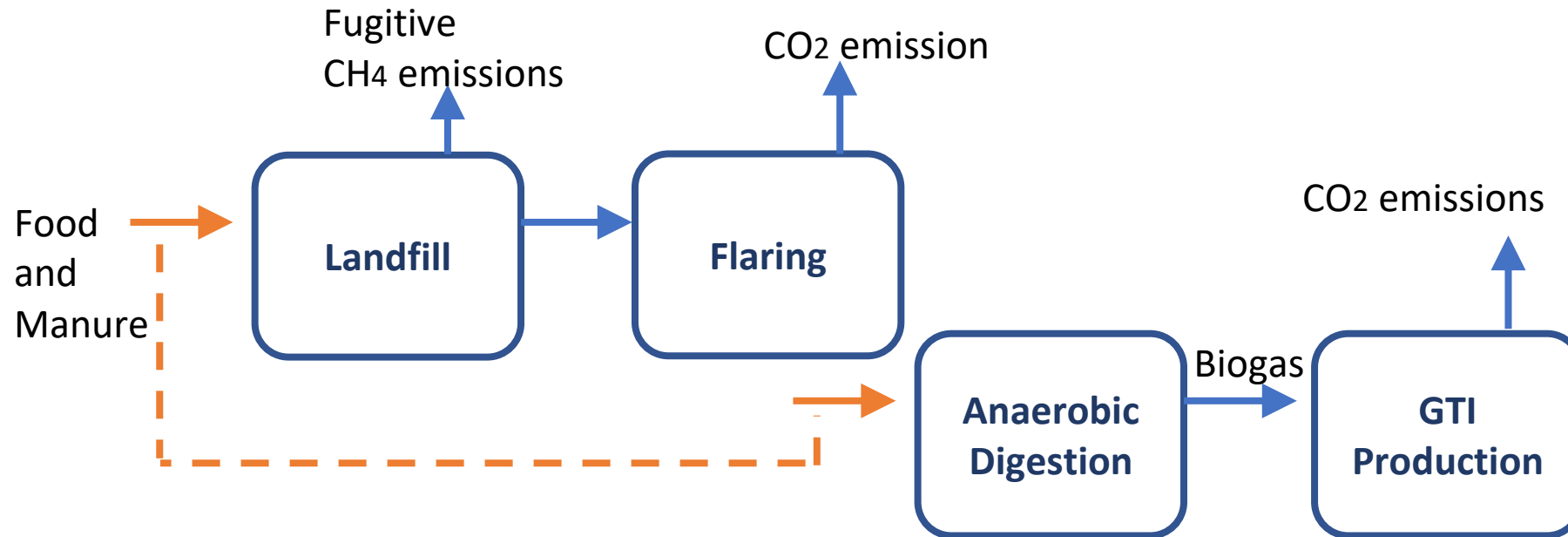
	Biogas Case 15	Biogas Case 16	Biogas Case 17
Feedstock source	Landfill gas E-Reformer	Landfill gas E-Reformer	Landfill gas E-Reformer
Feedstock prior fate	Flared	Flared	Power production
Hydrogen source	None	None	None
Electricity source	National Grid	Solar PV	Solar PV
Feedstock gas input	-71.0	-71.0	-71.0
Hydrogen	0.0	0.0	0.0
Electricity	67.6	7.0	7.0
Water	0.0	0.0	0.0
Replacement Electricity	0.0	0.0	23.1
Fuel combustion	71	71	71
Total GHG (g CO₂eq/MJ fuel)	67.6	7.0	30.1
% Reduction from fossil	21%	92%	65%

LCA Results: Biogas Cases – E-Reformer w/ added H2

	Biogas Case 18	Biogas Case 19	Biogas Case 20	Biogas Case 21	Biogas Case 22
Feedstock source	Landfill gas	Landfill gas	Landfill gas	Landfill gas	Landfill gas
Feedstock prior fate	Flared	Flared	Flared	Flared	Power production
Hydrogen source	SMR	Low-E Grid	Solar PV	Solar PV	Solar PV
Electricity source	National Grid	Low-E Grid	National Grid	Solar PV	Solar PV
Feedstock gas input	-71.0	-71.0	-71.0	-71.0	-71.0
Hydrogen	54.4	24.2	11	11	11
Electricity	34.3	7.9	34.3	3.5	3.5
Water	0.0	0.0	0.0	0.0	0.0
Replacement Electricity	0.0	0.0	0.0	0.0	27.8
Fuel combustion	71	71	71	71	71
Total GHG (g CO₂eq/MJ fuel)	88.7	32.1	45.3	14.5	42.3
% Reduction from fossil	-4%	62%	47%	83%	50%

LCA Approach: AD Biogas w Avoided Landfill Flaring

Biogas Scenario 3 – Biogas comes from organic waste – would have been landfilled with flaring previously

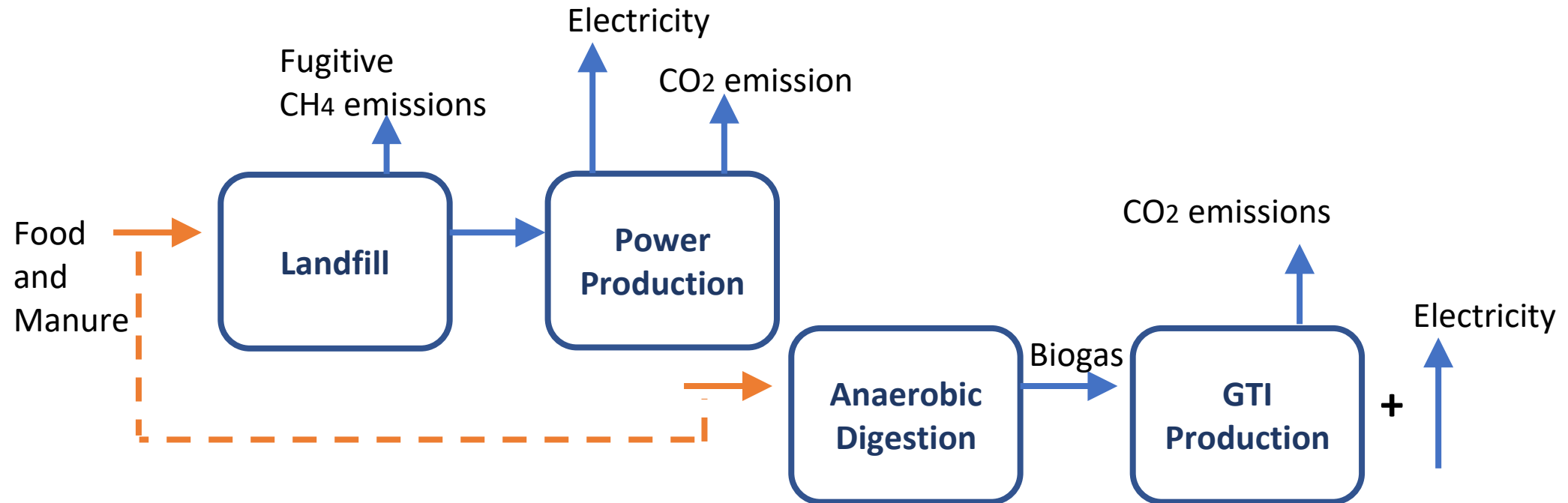


More drastic change – avoiding fugitive emissions from the landfill and avoiding the flaring emissions
Avoided fugitive methane emissions turn out to be pretty important!

Ankathi et al. 2018 for now, comparing other literature sources as well

LCA Approach: AD Biogas w Avoided Landfill Power Production

Biogas Scenario 4 – Biogas comes from food waste – would have been landfilled with gas collection and power generation



Similar to other LFG Scenario 2 where power was being produced

LCA Results: AD Biogas Cases – Gas Fired and E-Reformer (No H₂)

	Biogas Case 25	Biogas Case 26	Biogas Case 27
Feedstock source	F+M Biogas E-Reformer	F+M Biogas E-Reformer	F+M Biogas E-Reformer
Feedstock prior fate	Flared	Flared	Power production
Hydrogen source	None	None	None
Electricity source	National Grid	Solar PV	Solar PV
Feedstock gas input	-145.7	-145.7	-145.7
Hydrogen	0.0	0.0	0.0
Electricity	67.6	7.0	7.0
Water	0.0	0.0	0.0
Replacement Electricity	0.0	0.0	23.1
Fuel combustion	71	71	71
Total GHG (g CO₂eq/MJ fuel)	-7.1	-67.8	-44.7
% Reduction from fossil	108%	180%	153%

LCA Results: AD Biogas Cases – E-Reformer w/ added H2

	Biogas Case 28	Biogas Case 29	Biogas Case 30	Biogas Case 31	Biogas Case 32
Feedstock source	F+M Biogas	F+M Biogas	F+M Biogas	F+M Biogas	F+M Biogas
Feedstock prior fate	Flared	Flared	Flared	Flared	Power production
Hydrogen source	Solar PV	Low-E Grid	Low-E Grid	SMR	Solar PV
Electricity source	Solar PV	Low-E Grid	National Grid	National Grid	Solar PV
Feedstock gas input	-145.7	-145.7	-145.7	-145.7	-145.7
Hydrogen	11	24.2	24.2	54.4	11
Electricity	3.5	7.9	34.3	34.3	3.5
Water	0.0	0.0	0.0	0.0	0.0
Replacement Electricity	0.0	0.0	0.0	0.0	52.6
Fuel combustion	71	71	71	71	71
Total GHG (g CO₂eq/MJ fuel)	-60.2	-42.7	-16.3	14.0	-7.6
% Reduction from fossil	171%	150%	119%	84%	109%

Discussion, future work

- Large reductions in GHG emissions are possible!
 - Both feedstock types CO₂ and Biogas
- Avoiding fugitive methane emissions – huge potential benefit
 - Comparable to other bio-CH₄ LCA results
- CO₂ feedstocks can lower emissions
 - Paired with green H₂ and renewable electricity
 - Fossil CO₂ pathways are challenging – post-combustion

Thank you!
Questions?
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Other slides

Brief Introduction

- Pilot scale technology optimization / validation is ongoing
- Process modeling at larger scales has taken place
- Process model data used with other info to LCA scenarios
 - Feedstock types / production methods
 - Hydrogen sources
 - Electricity sources

LCA Approach

Commercial-scale process model outputs from GTI

Combined with several input data assumptions
Feedstock, Hydrogen, Electricity

LCA Modeling done in SimaPro

IPCC 2021 GWP 100a method for Global Warming Potential

Comparisons made to Fossil Jet Fuel ($\sim 85 \text{ g CO}_2\text{eq} / \text{MJ}$)

LCA Approach

Key inputs to LCA

Feedstock gas handling

- Compression power – estimated from Wiedebrook 2009
 - Equivalent to ~6% of process power requirement
- Conveyance power – estimated from GREET 2022 for CO₂ (algae)
 - Equivalent to ~1% of process power requirement



Undergraduate Journal of Mathematical
Modeling: One + Two

Volume 2 | 2009 Fall

Article 9

2009

Calculating Power of a CO₂ Compressor

Jennifer Wedebrook
University of South Florida



LCA Approach: Fossil CO₂

CO₂ Scenario 2 – CO₂ comes from fossil source

CO₂ capture method used

- Post-combustion capture using MEA absorption.

Electrical energy required

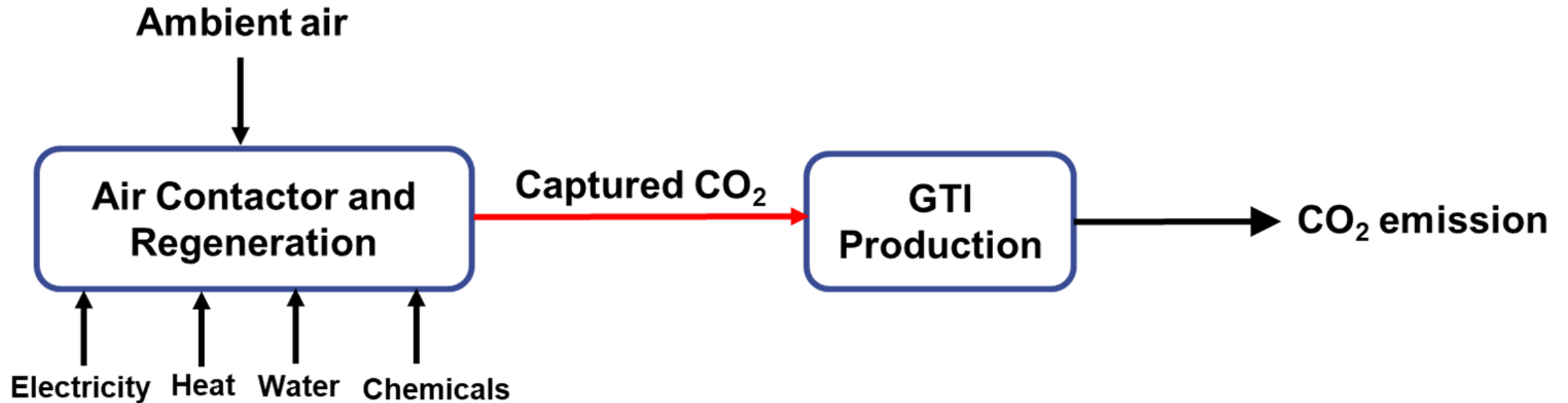
- 310 kWh/ton CO₂ for capture.
- 1000 kWh/ton CO₂ for heat requirements in solvent regeneration.
- 111 kWh/ton CO₂ for compression

Chemicals used

- 1.9 kg MEA/ton CO₂ for solvent absorption
- 0.13 kg NaOH/ton CO₂ and 0.075 kg activated carbon/ton CO₂
- 0.8 m³ water/ton CO₂ for solvent dilution and system operations.

LCA Approach: DAC CO₂

CO₂ Scenario 3 – CO₂ comes Direct Air Capture (DAC)



DAC removes CO₂ from the atmosphere

Inputs are required for DAC process – **early-stage research**

CO₂ sequestration initially, release after fuel is burned

LCA Results: DAC CO₂ Cases

	DAC CO ₂ Case 9	DAC CO ₂ Case 10	DAC CO ₂ Case 11	DAC CO ₂ Case 12
Feedstock source	DAC-Amine	DAC-Amine	DAC-Amine	DAC-Amine
Feedstock prior fate	Emission	Emission	Emission	Emission
Hydrogen source	Solar PV	Solar PV	Low-E Grid	SMR
Electricity source	Solar PV	National Grid	Low-E Grid	National Grid
Feedstock gas input	-71.0	-71.0	-71.0	-71.0
Hydrogen	23.0	23.0	51.2	115.3
Electricity	3.0	29.5	6.8	29.5
Water	0.04	0.04	0.04	0.04
DAC Inputs	31.6	31.6	31.6	31.6
Fuel combustion	71.0	71.0	71.0	71.0
Total GHG (g CO₂eq/MJ fuel)	58.0	84.4	89.6	176.5
% Reduction from fossil	32%	1%	-6%	-108%

Other DAC technologies also examined, but they fared poorly – higher utilities