Life Cycle Analyses of Point Source Carbon Capture and CO_2 Destinations at the National Energy Technology Laboratory

Innovations in Climate Resilience

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MISSION

Driving innovation and delivering solutions for an environmentally sustainable and prosperous energy future:

- Ensuring affordable, abundant and reliable energy that drives a robust economy and national security, while
- Developing technologies to manage carbon across the full life cycle, and
- Enabling environmental sustainability for all Americans.

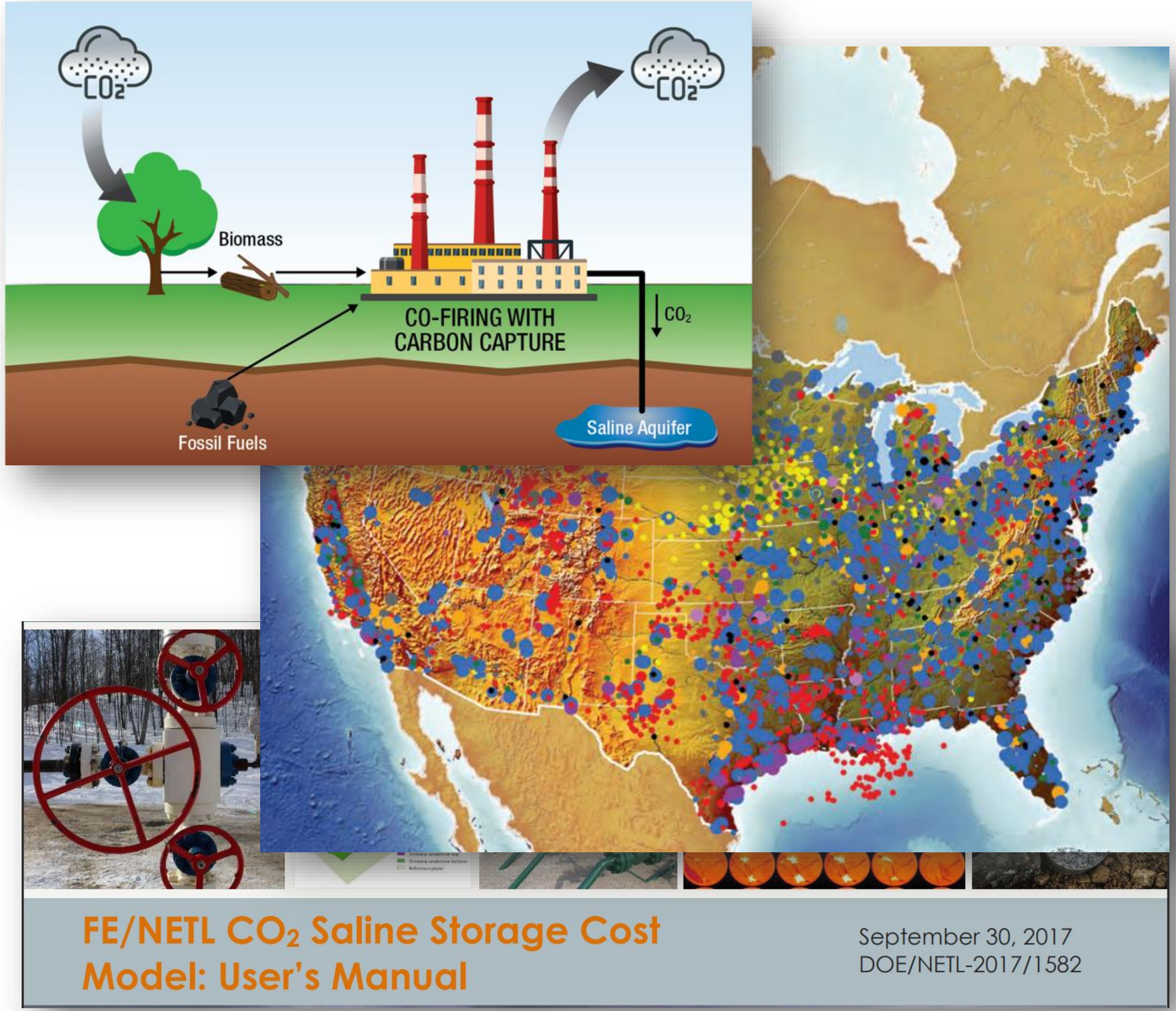
VISION

To be the nation's premier energy technology laboratory, delivering integrated solutions to enable transformation to a sustainable energy future.

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

Introduction

- **History of NETL CCUS products**
- **Techno-economics analysis and life cycle analysis**
  - Cost and Performance Baselines Pulverized coal, NGCC
  - Bio-Energy with Carbon Capture and Storage (BECCS)
- **Carbon capture retrofit databases**
- **Carbon storage**
  - FECM/NETL CO_2 Transport and Saline Storage Cost Models
  - Carbon Storage Atlas



Bio-energy with Carbon Capture and Storage

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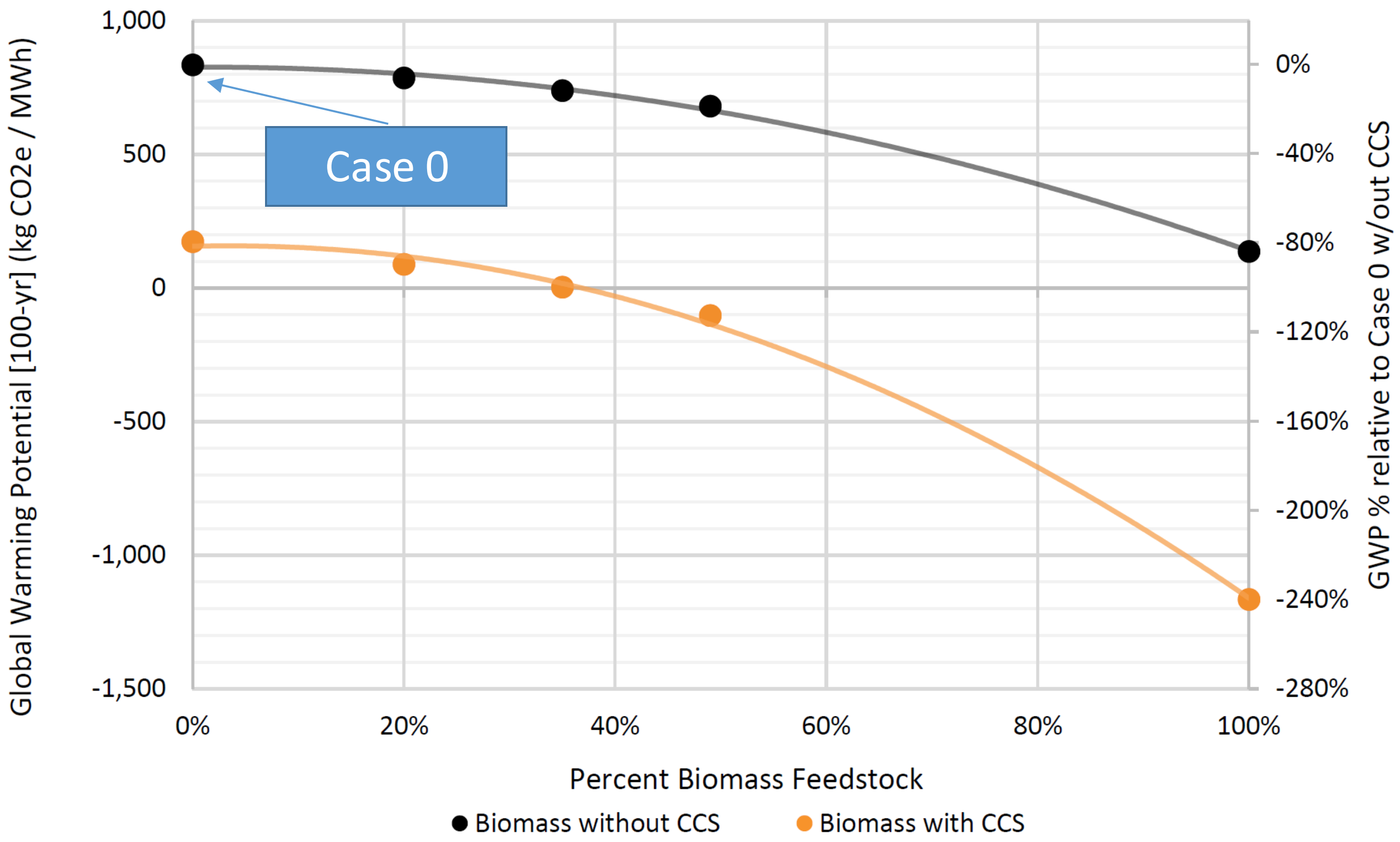
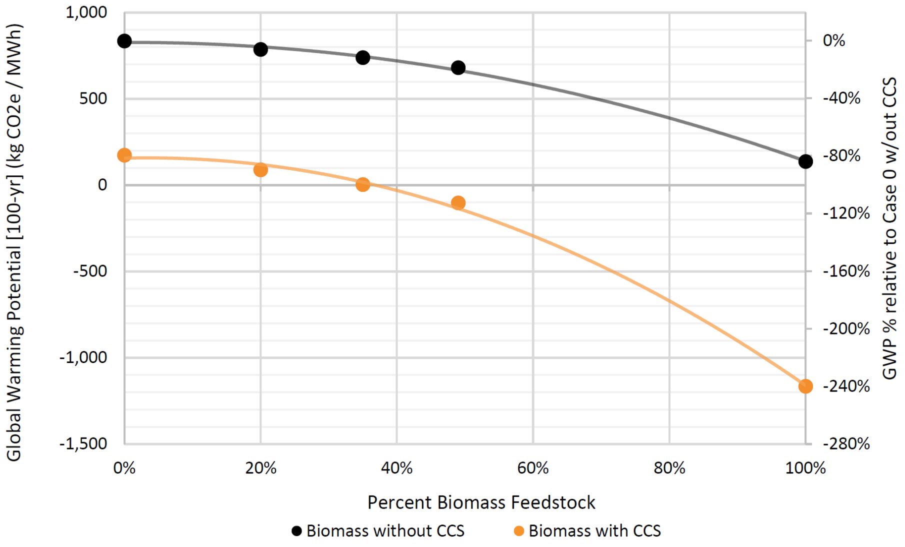
- **BECCS is one pathway to negative CO_2 emissions**

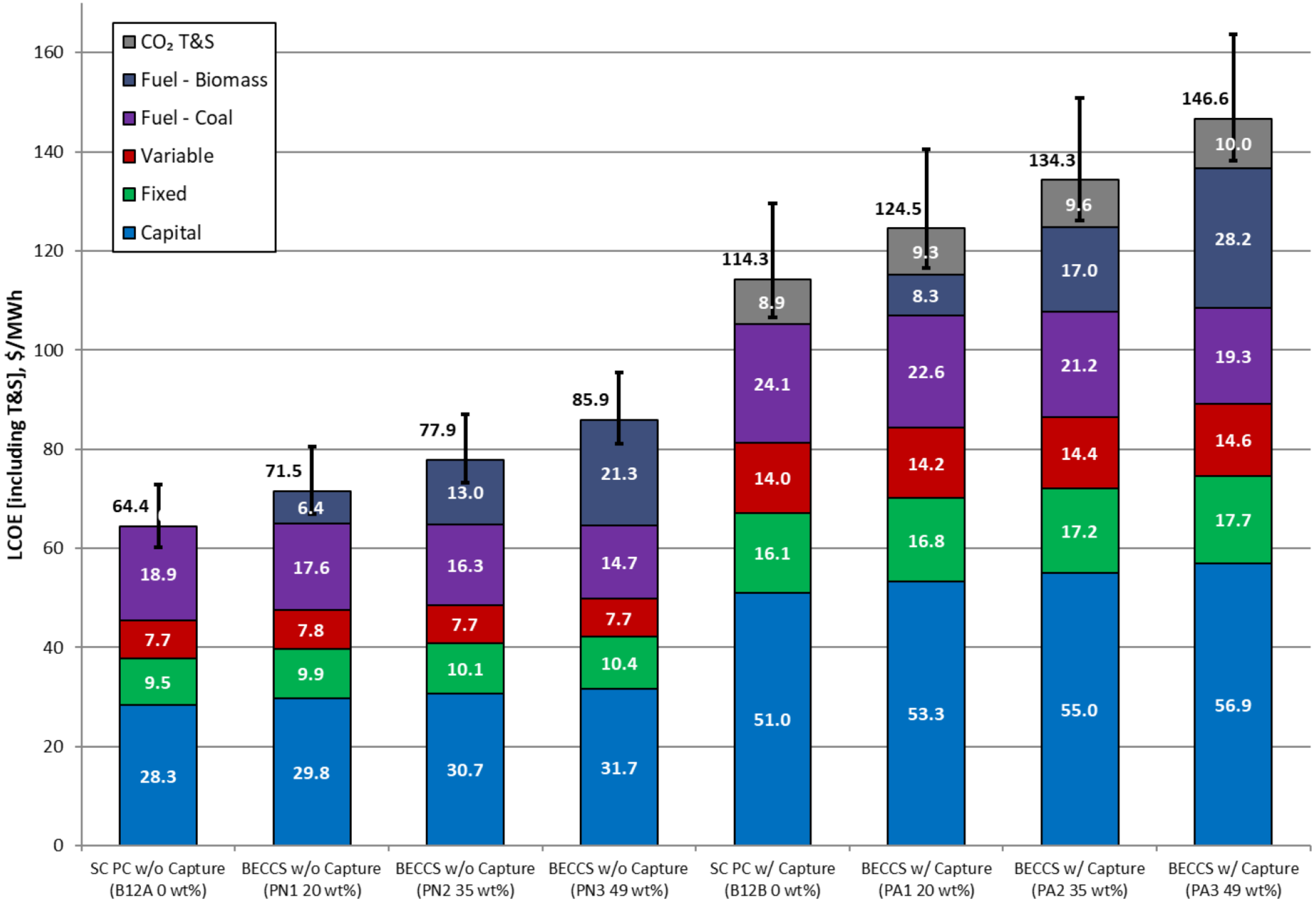


[Technoeconomic and Life Cycle Analysis for Bio-Energy with Carbon Capture and Storage (BECCS) Baseline]

Bio-energy with Carbon Capture and Storage

- **BECCS is one pathway to negative CO_2 emissions**
- **Co-firing coal can ease logistics and cost**





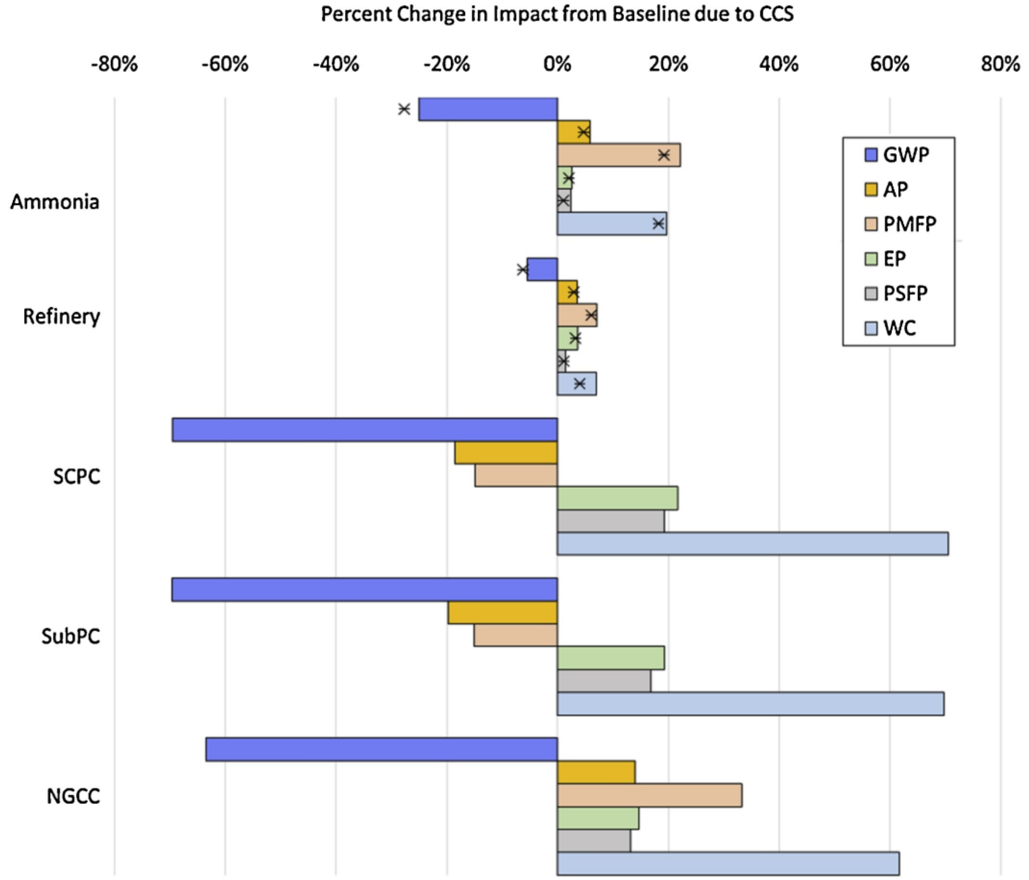
Bio-energy with Carbon Capture and Storage

- **The analysis also highlights the environmental tradeoffs for the GHG reductions**

Indicator	Unit	SC PC w/o Capture (B12A 0 wt%)	SC PC w/ Capture (B12B 0 wt%)	BECCS w/o Capture (PN1 20 wt%)	BECCS w/ Capture (PA1 20 wt%)	BECCS w/o Capture (PN2 35 wt%)	BECCS w/ Capture (PA2 35 wt%)	BECCS w/o Capture (PN3 49 wt%)	BECCS w/ Capture (PA3 49 wt%)
Acidification Potential	kg SO_2e	7.28E-01	5.04E-01	8.68E-01	7.18E-01	9.98E-01	9.19E-01	1.16E+00	1.17E+00
Eutrophication Potential	kg N e	2.25E-02	2.87E-02	5.33E-02	6.87E-02	8.41E-02	1.09E-01	1.22E-01	1.60E-01
Global Warming Potential [100-yr]	kg CO_2e	8.36E+02	1.75E+02	7.88E+02	9.09E+01	7.40E+02	5.66E+00	6.82E+02	-1.00E+02
Ozone Depletion Potential	kg CFC-11e	4.57E-09	5.87E-09	2.11E-08	2.73E-08	3.79E-08	4.95E-08	5.90E-08	7.76E-08
Particulate Matter Formation Potential	kg PM2.5e	1.30E-01	1.42E-01	1.34E-01	1.50E-01	1.37E-01	1.57E-01	1.41E-01	1.66E-01
Photochemical Smog Formation Potential-	kg O_3e	1.12E+01	1.31E+01	1.31E+01	1.57E+01	1.51E+01	1.83E+01	1.75E+01	2.16E+01
Water Consumption	kg	1.97E+03	2.82E+03	7.69E+03	1.02E+04	1.34E+04	1.77E+04	2.04E+04	2.70E+04

Industrial capture

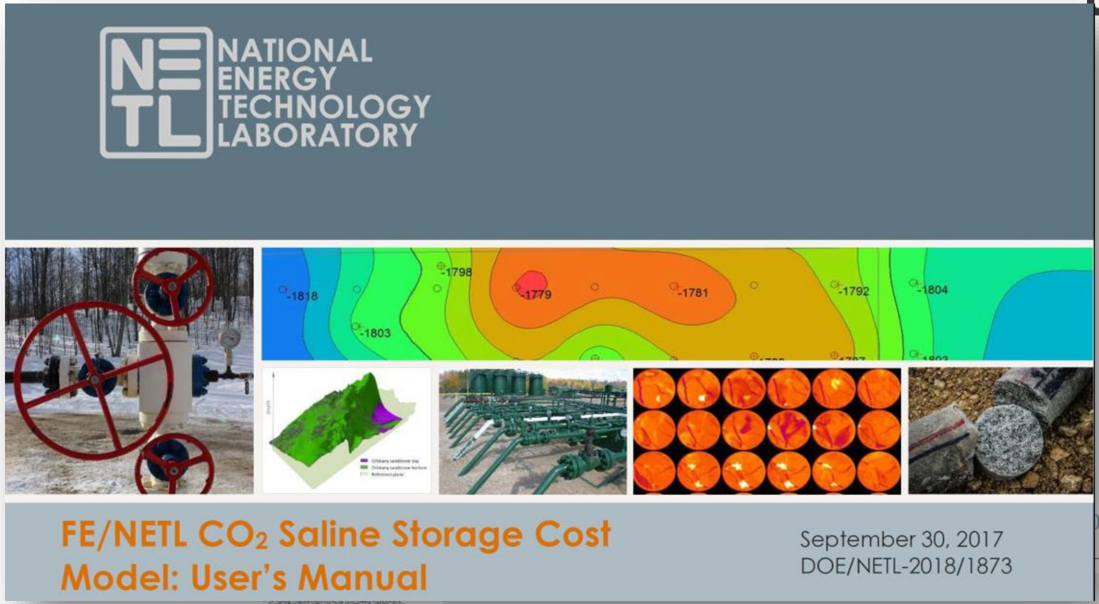
- **Previous work provided LCAs for industrial facilities with CCS:**
  - Petroleum refineries
  - Ammonia plants
- **We're continuing to add to that:**
  - Cement
  - Steel
  - Natural gas processing plants
- **Again, the implementation of capture has tradeoffs**



Young, B., Krynock, M., Carlson, D., Hawkins, T. R., Marriott, J., Morelli, B., Jamieson, M., & Cooney, G. (2017). *Comparative Environmental Life Cycle Assessment of Carbon Capture from Petroleum Refining, Ammonia Production, and Thermoelectric Power Generation*. https://www.sciencedirect.com/science/article/pii/S175058361830817X

Saline Aquifer Storage

- **Onshore storage LCA model**
- **Connects to FECM/NETL CO_2 Saline Storage Cost Model**
- **Formation-specific impacts**
- **Refined leakage rates**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FE/NETL CO_2 Saline Storage Cost Model: User's Manual

September 30, 2017
DOE/NETL-2018/1873

[Description and User's Manual](#)

[Model](#)

) 182–194

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Managing well leakage risks at a geologic carbon storage site with many wells

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https://www.sciencedirect.com/science/article/abs/pii/S1750583619302476?via%3Dihub

CO2 Utilization LCA Guidance Toolkit Update

- NETL first developed for CO_2 utilization projects using captured CO_2 from power plants
- Newer funding opportunities allow different CO_2 sources and for different end uses
- Version 2 of the Guidance Document addresses these changes
- Along with other updates to the database and other parts of the toolkit

NETL CO2U LCA GUIDANCE TOOLKIT

Version 2.0.0
Released 02/23/22

www.netl.doe.gov/LCA/CO2U

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Life Cycle Impact Assessment

Converts emissions to environmental impact equivalences (i.e., mid-point impacts).

Global	Air
Local	Water

- **Global Warming Potential (GWP):** is the heat absorbed by any greenhouse gas in the atmosphere, as a multiple of the heat that would be absorbed by the same mass of carbon dioxide (CO_2). GWP is dependent on the time horizon the greenhouse gas emission impacts are assessed; 20 and 100-year time frames are commonly reported, with 100-year being default time horizon. GWP values are defined by the Intergovernmental Panel on Climate Change (IPCC). IPCC 5th Assessment Report values applied in this study on a 20 and 100-year basis are:
  - Carbon Dioxide (CO2): 20-year: 1; 100-year: 1.
  - Methane (fossil) (CH4): 20-year: 87; 100-year: 36.
  - Nitrous oxide (N_2O): 20-year: 268; 100-year: 298.
  - Sulfur Hexafluoride (SF_6): 20-year: 17,500; 100-year: 23,500.
- **Acidification Potential:** is the increased concentration of hydrogen ions in a local environment. Substances, which cause acidification, can cause damage to building materials, paints, and other human-built structures, lakes, streams, rivers, and various plants and animals.
- **Eutrophication Potential:** is the enrichment of an aquatic ecosystem with nutrients (nitrogen, phosphorus) that accelerate biological productivity (growth of algae and weeds) and an undesirable accumulation of algal biomass. High levels of nitrogen and phosphorous can cause adverse effects on local water ways and other downstream destinations.
- **Ozone Depletion Potential:** is the deterioration of ozone within the stratosphere by chemicals such as chlorofluorocarbons (CFCs). Stratospheric ozone provides protection for people, crops, and other plant life from radiation.
- **Particulate Matter Formation Potential:** is the increased concentration of a mixture of solid particles and liquid droplets found in the air" that are smaller than 10 microns in diameter that have the potential to cause human respiratory effects.
- **Photochemical Smog Formation Potential:** is created by various chemical reactions, which occur between nitrogen oxides (NOx) and volatile organic compounds (VOCs) in sunlight. Ground level ozone can have both ecological impacts on crops and ecosystems as well as cause respiratory effects in humans.
- **Water Consumption:** volume of water consumed across the life cycle of the product or service. Increased water consumption in water scarce areas may restrict water availability for human, agricultural, and other uses.

LCIA methods for non-GWP indicators is based on the U.S. EPA "Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts (TRACI)" Bare, 2008; Bare 2011