

45Q Carbon Oxide Utilization LCA Training Workshop: Toolkit Overview

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Solutions for Today | Options for Tomorrow

¹National Energy Technology Laboratory (NETL)



By the end of this session we hope you'll be able to answer:

- What is LCA?
- What are the parts of the LCA development process?
 - How do I define my goal and scope
 - How do I perform an inventory analysis
 - How do I perform an impact assessment?
- What is the NETL LCA 45Q Toolkit?
 - What role does each part of the toolkit play in my LCA?
- What is required of my LCA for the 45Q LCA program?
- What additional tools and resources does NETL have for 45Q LCA?
- What are some common issues to look out for?

Regulatory basis

- **§ 1.45Q-4 Utilization of Qualified Carbon Oxide:**
- 26 CFR § 1.45Q-4 (hereby referred to as 45Q) requires a life cycle analysis (LCA) to be performed to document the amount of qualified carbon oxide for the utilization tax credit.
- Under the Internal Revenue Service's (IRS) regulations, LCAs must be prepared and documented in conformance with certain ISO standards.
- The Treasury Department and the IRS noted in its final rule that the Department of Energy (DOE) National Energy Technology Laboratory (NETL) CO₂ Utilization Guidance Toolkit is consistent with the ISO standards and directed taxpayers in the final rule to use such guidance when submitting LCAs under 45Q.
- LCAs only applicable to non-EOR utilization cases from 2018 on

- **§ 1.45Q-4 Utilization of Qualified Carbon Oxide.**
- **(a) In general.** For purposes of this section, *utilization of qualified carbon oxide* means -
 - **(1)** The fixation of such qualified carbon oxide through photosynthesis or chemosynthesis, such as through the growing of algae or bacteria,
 - **(2)** The chemical conversion of such qualified carbon oxide to a material or chemical compound in which such qualified carbon oxide is securely stored, or
 - **(3)** The use of such qualified carbon oxide for any other purpose for which a commercial market exists (with the exception of use as a tertiary injectant in a qualified enhanced oil or natural gas recovery project), as described in paragraph (d) of this section.

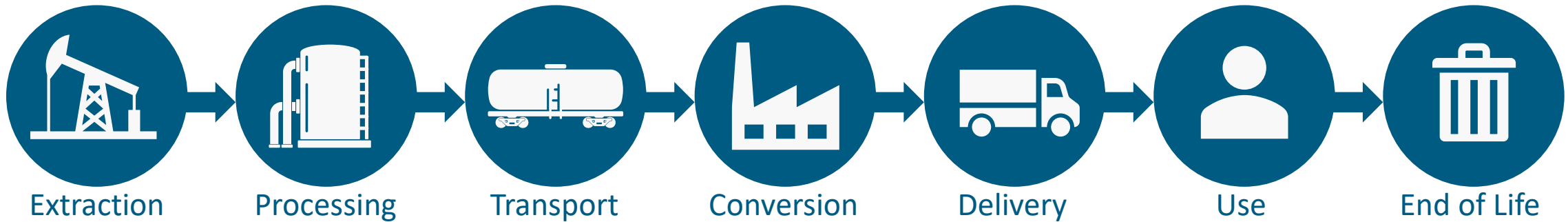
From: <https://www.ecfr.gov/current/title-26/chapter-I/subchapter-A/part-1/subject-group-ECFR321685e6a0496a0/section-1.45Q-4>

- **Amount utilized —**

- (1) **In general.** For purposes of [§ 1.45Q-1\(b\) \(ii\)](#) and [\(c\)\(2\)\(ii\)](#), the amount of qualified carbon oxide utilized by the taxpayer is equal to the metric tons of qualified carbon oxide which the taxpayer demonstrates, based upon an analysis of lifecycle greenhouse gas emissions (LCA), were—
 - (i) Captured and permanently isolated from the atmosphere through use of a process described in [paragraph \(a\)](#) of this section, or
 - (ii) Displaced from being emitted into the atmosphere through use of a process described in [paragraph \(a\)](#) of this section.
- (2) **Limitation.** The amount determined under [paragraph \(b\)\(1\)](#) of this section cannot exceed the amount of qualified carbon oxide measured at the source of capture.

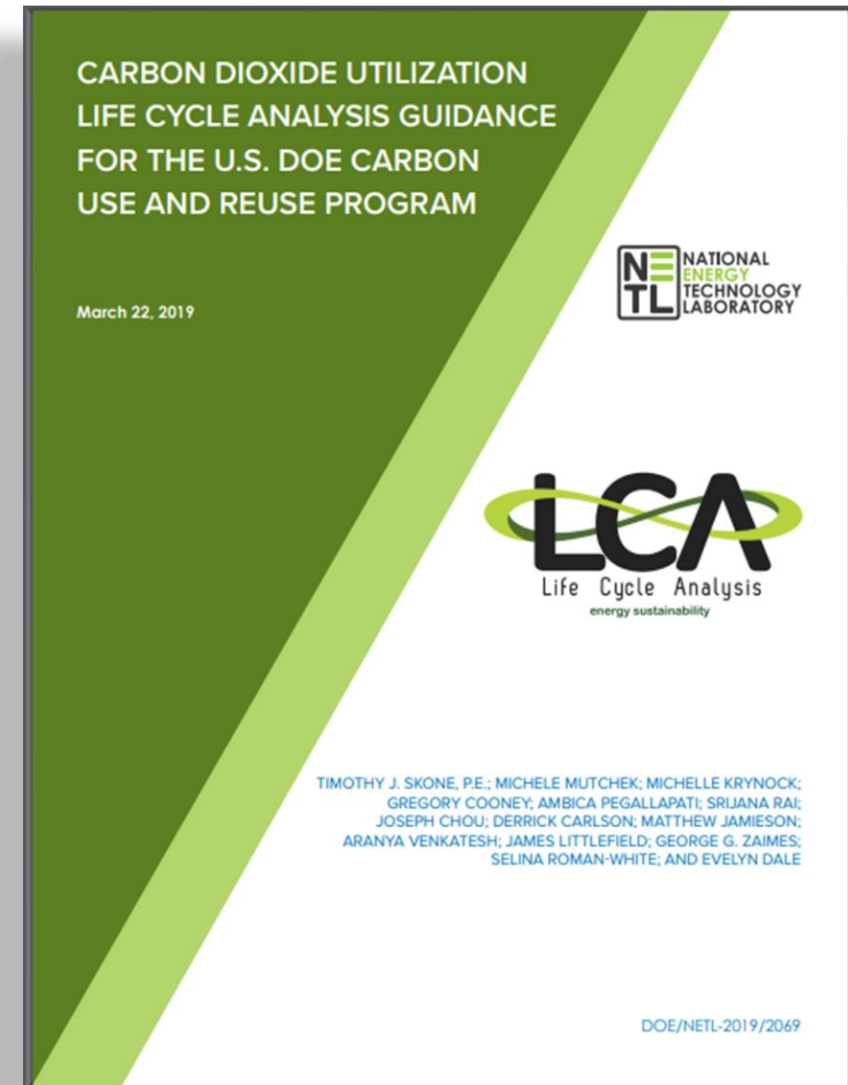
From: <https://www.ecfr.gov/current/title-26/chapter-I/subchapter-A/part-1/subject-group-ECFR321685e6a0496a0/section-1.45Q-4>

What is Life Cycle Assessment (LCA)?



LCA is a technique that helps people make better decisions to improve and protect the environment by accounting for the potential impacts from raw material acquisition through production, use, end-of-life treatment, recycling, and final disposal (i.e., cradle-to-grave).

CO2U LCA Guidance Document



CARBON DIOXIDE UTILIZATION

[LCA CO2U Quick Start](#) [NETL CO2U LCA Toolkit](#) [NETL CO2U LCA Training Resources](#) [NETL CO2U LCA Publications](#)

NETL CO2U LCA GUIDANCE TOOLKIT



GUIDANCE DOCUMENT

Analysis requirements and instructions for using the supporting data and tools



DOCUMENTATION SPREADSHEET

Excel file that can be used to document data when not using openLCA



TRAINING RESOURCES

Provided to funding recipients to aid in modeling an LCA



OPENLCA DATABASE

openLCA database that includes NETL unit process data and an example CO2U LCA



SUBJECT MATTER EXPERT SUPPORT

Available to funding recipients for all phases of the LCA from conception to documentation.
Email lca@netl.doe.gov for support



OPENLCA CONTRIBUTION TOOL

Excel template that translates openLCA results into required charts



NETL CO2U LCA REPORT TEMPLATE

Word report template for summarizing data and results

NETL ADDITIONAL DOWNLOADS

 [Download Full Toolkit](#)

 [Patches, Archives, and Version History](#)

NETL CO2U Guidance Toolkit

- First released in 2019
- Supports funding recipients with their LCA requirements
- Fosters better decision-making for the U.S. DOE Carbon Conversion Program by providing consistent and transparent analysis and reporting structure
- Provides LCA guidance, data, and tools to LCA practitioners in the area of carbon conversion
- Contributes to the global discussion on carbon conversion LCA and LCA methods
- Toolkit site:
netl.doe.gov/LCA/CO2U

NETL CO2U LCA GUIDANCE TOOLKIT Version 2.1.0

 <p>CO2U LCA GUIDANCE DOCUMENT FOR THE U.S. DOE OFFICE OF FECM, VERSION 2.0</p> <p>Analysis requirements and instructions for using the supporting data and tools</p>	 <p>NETL CO2U LCA DOCUMENTATION SPREADSHEET</p> <p>Excel file that can be used to document data when not using openLCA</p>	 <p>TRAINING RESOURCES</p> <p>Provided to funding recipients to aid in modeling an LCA</p>
 <p>NETL CO2U OPENLCA LCI DATABASE VERSION 2</p> <p>openLCA database that includes NETL unit process data and an example CO2U LCA</p>		<p>45Q ADDENDUM AND TOOLS</p> <p>Information pertaining to the use of this toolkit in performing life cycle analyses in support of the 26 CFR § 1.45Q tax credit, including an addendum to the Guidance Document.</p>
 <p>OPENLCA CONTRIBUTION TOOL</p> <p>Excel template that translates openLCA results into required charts</p>	 <p>NETL CO2U LCA REPORT TEMPLATE</p> <p>Word report template for summarizing data and results</p>	<p>NETL ADDITIONAL DOWNLOADS</p> <p> Download Full Toolkit</p> <p> Patches, Archives, and Version History</p>

45Q Addendum

- NETL refined the CO2U guidance for 45Q-specific purposes
 - Technology Readiness Level (TRL) 8/9+
 - Applicability to any conversion pathway, including any product in any market (e.g. food and beverage)
- Addition of regulatory-specific impact method to LCI database and documentation spreadsheet
- Updated Report Template with taxpayer-specific language Released Feb, 2022
- All products reviewed and approved by DOE and IRS

45Q LCA GUIDANCE TOOLKIT

To be used in conjunction with version 2.1.0 of the NETL CO2U Guidance Toolkit

Released 02/23/22

NEW RESOURCES COMING SOON – SEE FAQ AND RESOURCES SITE.



45Q ADDENDUM TO THE CO2U LCA GUIDANCE DOCUMENT

Summary of modifications to the CO2U Guidance Document to be used to meet 26 CFR part 1, Section 1.45Q-4 carbon oxide tax credit



NETL CO2U LCA DOCUMENTATION SPREADSHEET

Excel file that can be used to document data when not using openLCA



FREQUENTLY ASKED QUESTIONS AND ADDITIONAL RESOURCES



NETL CO2U OPENLCA LCI DATABASE VERSION 2.1

openLCA database that includes NETL unit process data and an example 45Q LCA



ADDITIONAL QUESTIONS?

Additional Questions should be directed to LCA45Q@hq.doe.gov



OPENLCA CONTRIBUTION TOOL

Excel template that translates openLCA results into required charts



NETL 45Q LCA REPORT TEMPLATE

Word report template for summarizing data and results

NETL ADDITIONAL DOWNLOADS



Patches, Archives, and Version History

45Q Addendum

- Shared tools highlighted in green
- CO2U Guidance Document and 45Q addendum to be read together

 <p>45Q ADDENDUM TO THE CO2U LCA GUIDANCE DOCUMENT</p> <p>Summary of modifications to the CO2U Guidance Document to be used to meet 26 CFR part 1, Section 1.45Q-4 carbon credit tax credit</p>	 <p>NETL CO2U LCA DOCUMENTATION SPREADSHEET</p> <p>Excel file that can be used to document data when not using openLCA</p>	 <p>FREQUENTLY ASKED QUESTIONS</p>
 <p>NETL CO2U OPENLCA LCI DATABASE VERSION 2.1</p> <p>openLCA database that includes NETL unit process data and an example 45Q LCA</p>		 <p>ADDITIONAL QUESTIONS?</p> <p>Additional Questions should be directed to LCA45Q@hq.doe.gov</p>
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LCA Methods Comparison

	CO2U	45Q	UPGrants
Program Origination	U.S. DOE Carbon Conversion Program FOAs	26 CFR § 1.45Q-4	Section 40302 of the Bipartisan Infrastructure Law
Terminology for LCA Submitter	Principal Investigator (PI)	Applicant	Vendor
LCA Submitter	DOE FOA recipient working on carbon conversion project	Owner of carbon capture equipment selling carbon oxide for utilization applying for 45Q tax credit	Carbon conversion product manufacturer intending to be available to Grant Applicants
Species Utilized	Carbon Dioxide	Carbon Oxide	Carbon Oxide
Expected TRL*	1-9	8-9	7-9
Review Scope	NETL provides critical and conformance review	NETL provides conformance review, third-party permitted to perform critical review (NETL provides if not)	NETL provides critical and conformance review
Approval	NETL works with PIs to bring LCA to sufficient quality	NETL provides conformance/critical review to IRS. IRS makes final decisions	NETL provides conformance/critical review to Carbon Conversion Program. Program makes final decisions

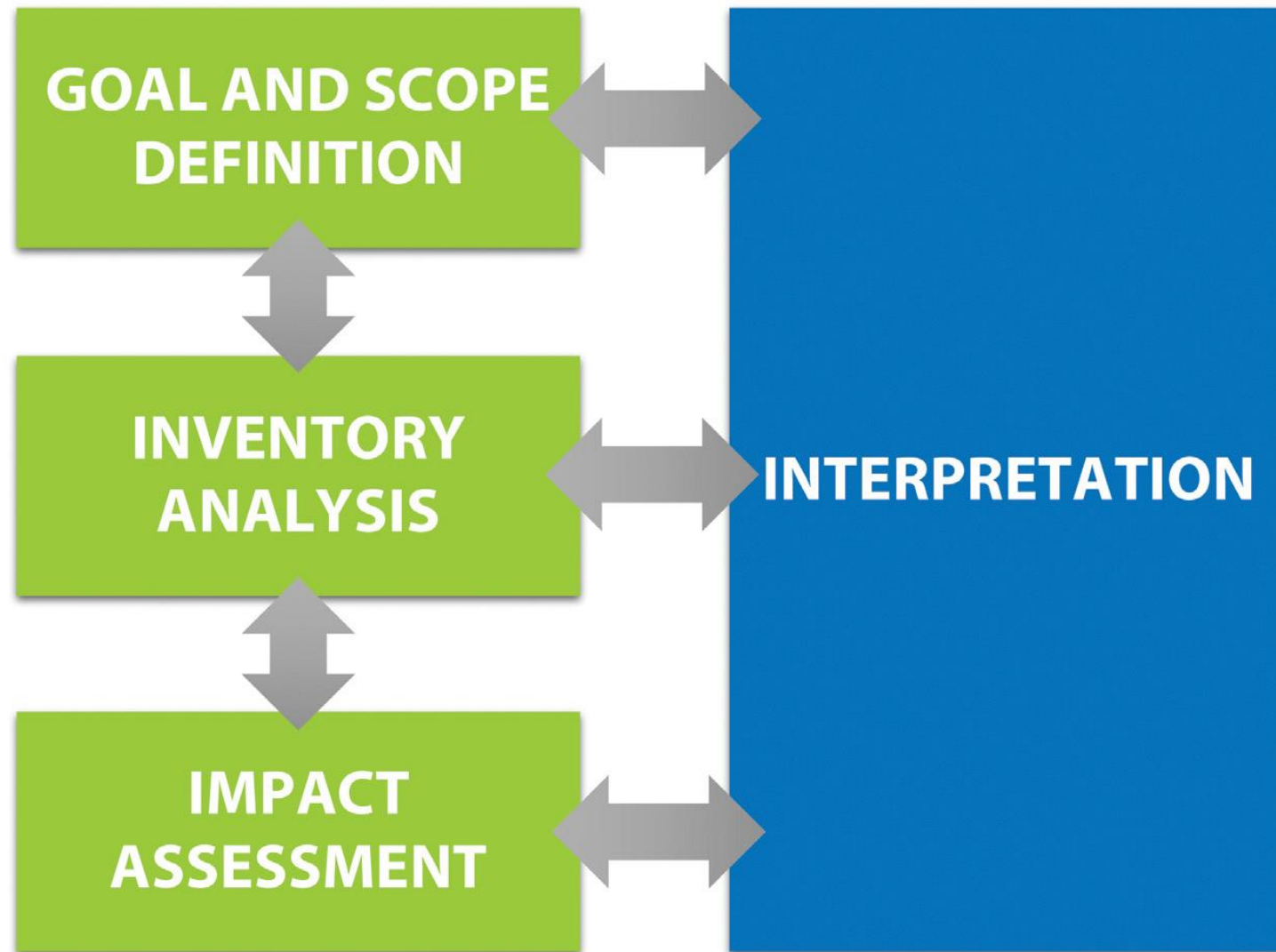
LCA Methods Comparison

	CO2U	45Q	UPGrants
Technological Scope	CO2U process based on data from FOA project	Carbon conversion Process based on applicant's sales to qualified utilization	Carbon conversion process based on product manufacturer's operations
Temporal Scope	Projected Start Year	Tax Year Relevant to Application	Most Recent Calendar Year to Submission
Geographical Scope	Default to US Average, PI to fill in information as they learn it	Applicant's real supply chain	US Average
NETL data usage	Required for CO ₂ upstream defaults and electricity inputs	Required, but third-party data acceptable with justification	Required where available
Downstream System Boundary	Cradle-to-grave encouraged	Truncation at the point of functional equivalence preferred	Truncation at the point of functional equivalence preferred
Carbon Oxide Source	Default required for comparability; alternates permitted	As is	As is
Sensitivity Analysis	Required	Required	Required (breakeven to 10% or 25% change instead of 0)
Uncertainty Analysis	Required	Not Required	Encouraged

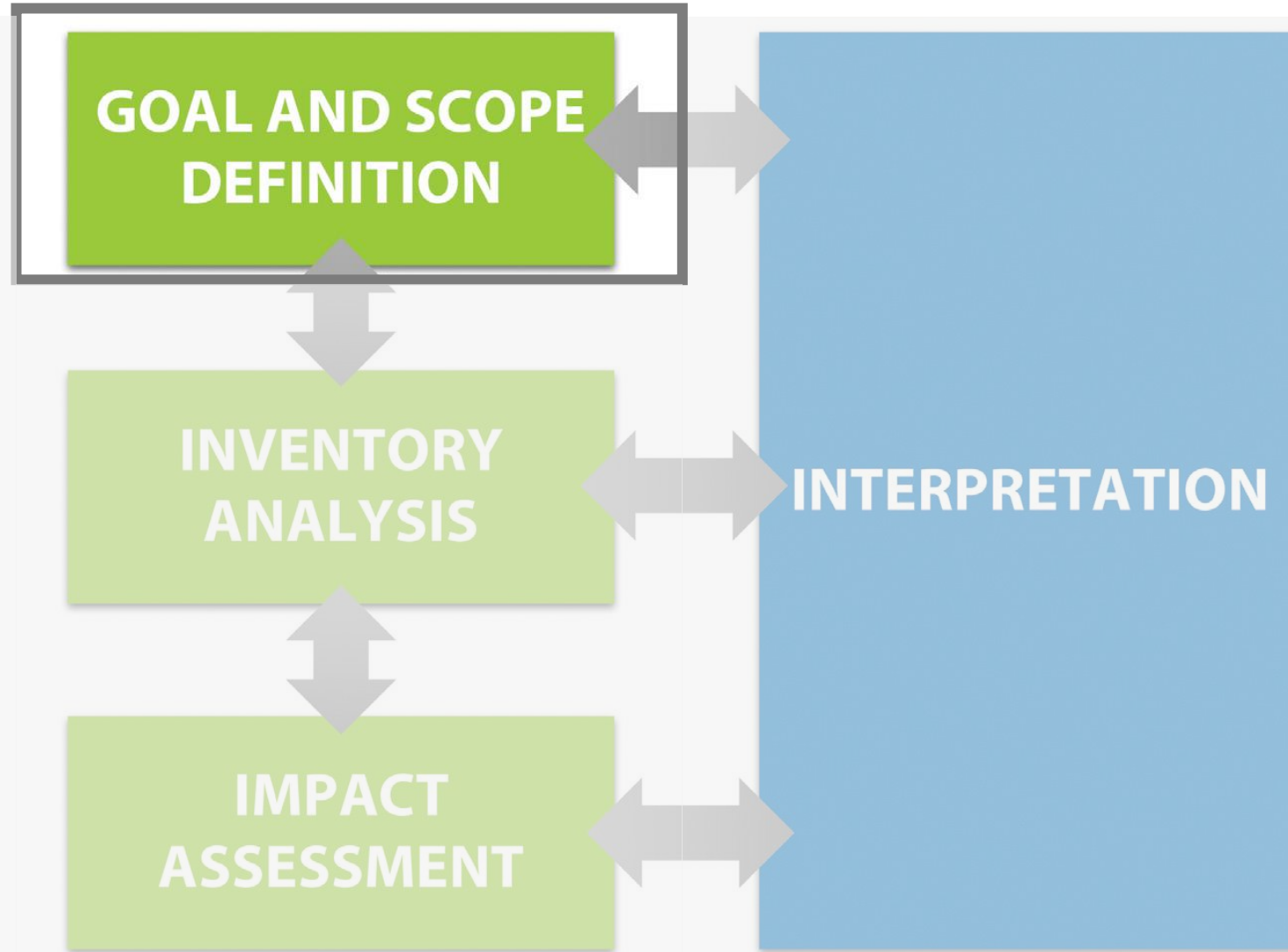
LCA Comparison

	CO2U	45Q	UPGrants
LCA Website	https://netl.doe.gov/LCA/CO2U	https://netl.doe.gov/LCA/CO2U/45Q	https://netl.doe.gov/LCA/UPgrants
Email address for support	LCA@netl.doe.gov Or your NETL project manager	General, including eligibility questions: LBI.EEF.45QLCA@irs.gov LCA-specific: lca45q@hq.doe.gov	FOA Questions must be submitted through the FedConnect Portal: http://www.fedconnect.net/FedConnect/?doc=DE-FOA-0002829&agency=DOE Vendor Questions: UPGrants-Vendors@netl.doe.gov
Helpful links	<ul style="list-style-type: none"> https://netl.doe.gov/LCA 	<ul style="list-style-type: none"> Regulatory Text (eCFR) IRS Final Rule (including preamble) ISO 14040:2006 ISO 14044:2006 	<ul style="list-style-type: none"> UPGrants Program General Information Information for Eligible Entities Funding Opportunity Announcement DE-FOA-0002829 ISO 14040:2006 ISO 14044:2006

The LCA Development Process



Inventory Analysis



Goals

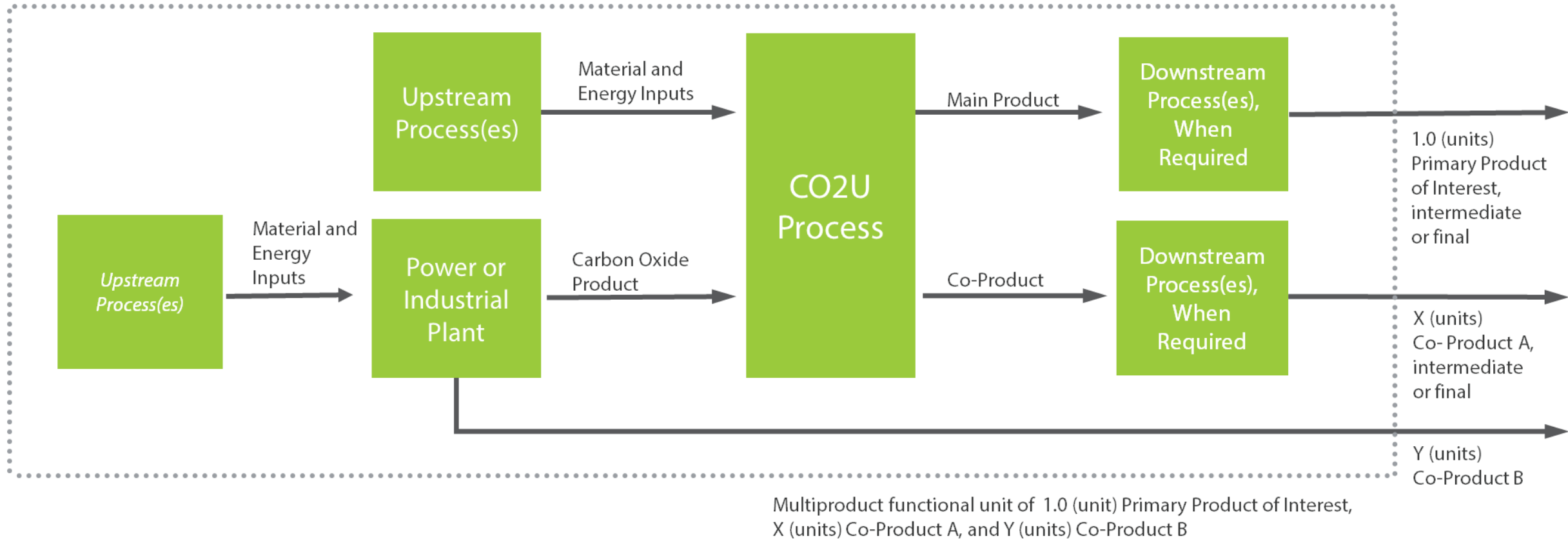
1. **Intended application** - to find the metric tons of qualified carbon oxide that the applicants demonstrate were captured and permanently isolated from the atmosphere or displaced from being emitted into the atmosphere through use in a qualified utilization process.

2. **Reasons for carrying out the study** - to determine the amount of qualified carbon oxide utilized by the applicants under paragraph (2)(B)(ii) or (4)(B)(ii) of subsection (a) of 26 CFR § 1.45Q-4.

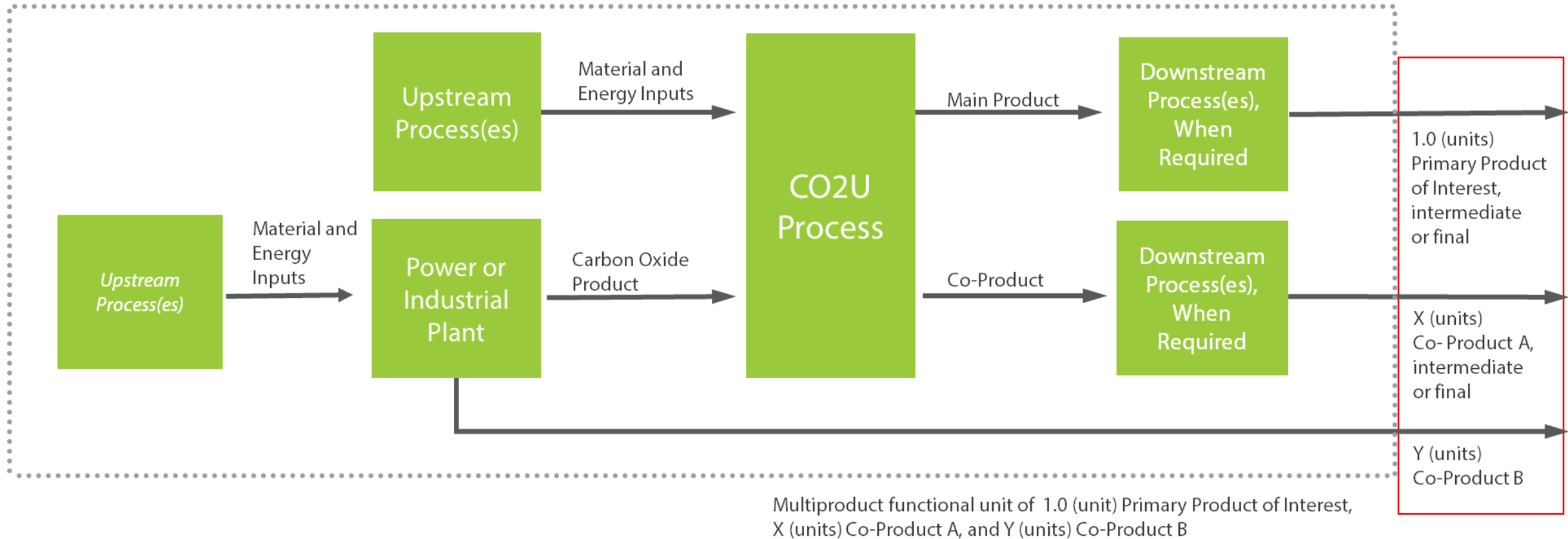
3. **Intended audience** - the U.S. IRS and DOE.

4. **Public disclosure** – the LCAs conducted as a requirement of qualification for the 45Q tax credit will not be published by DOE/NETL.

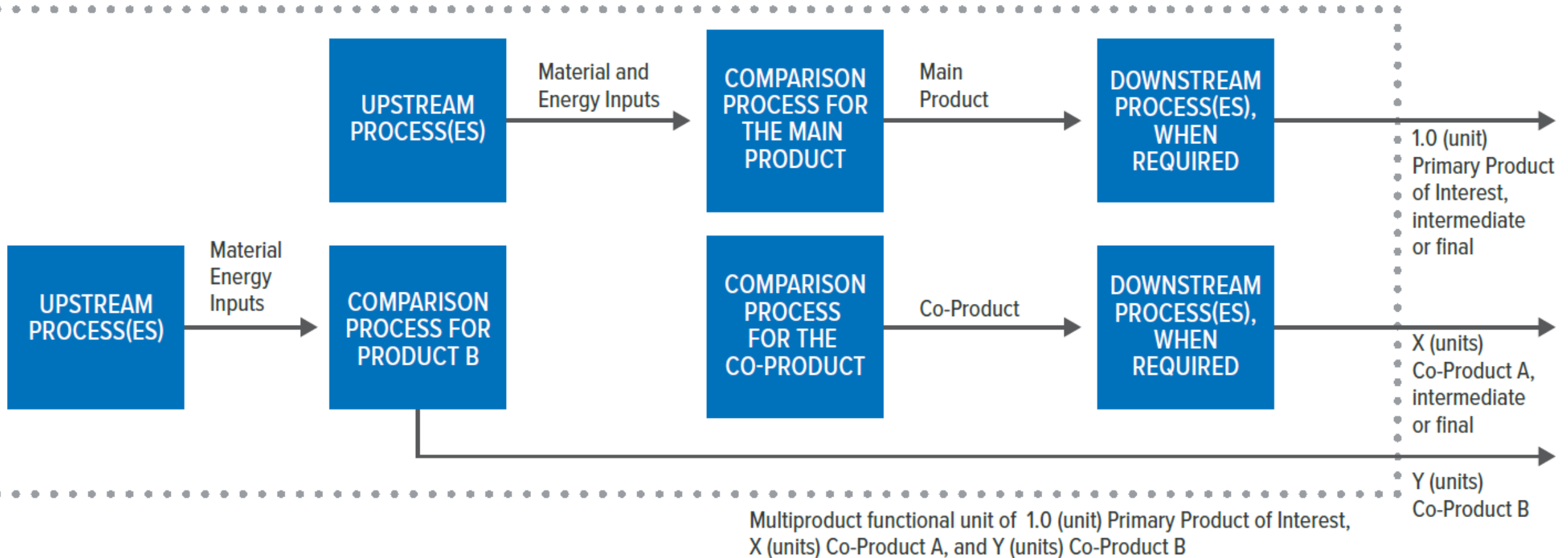
Proposed Product System

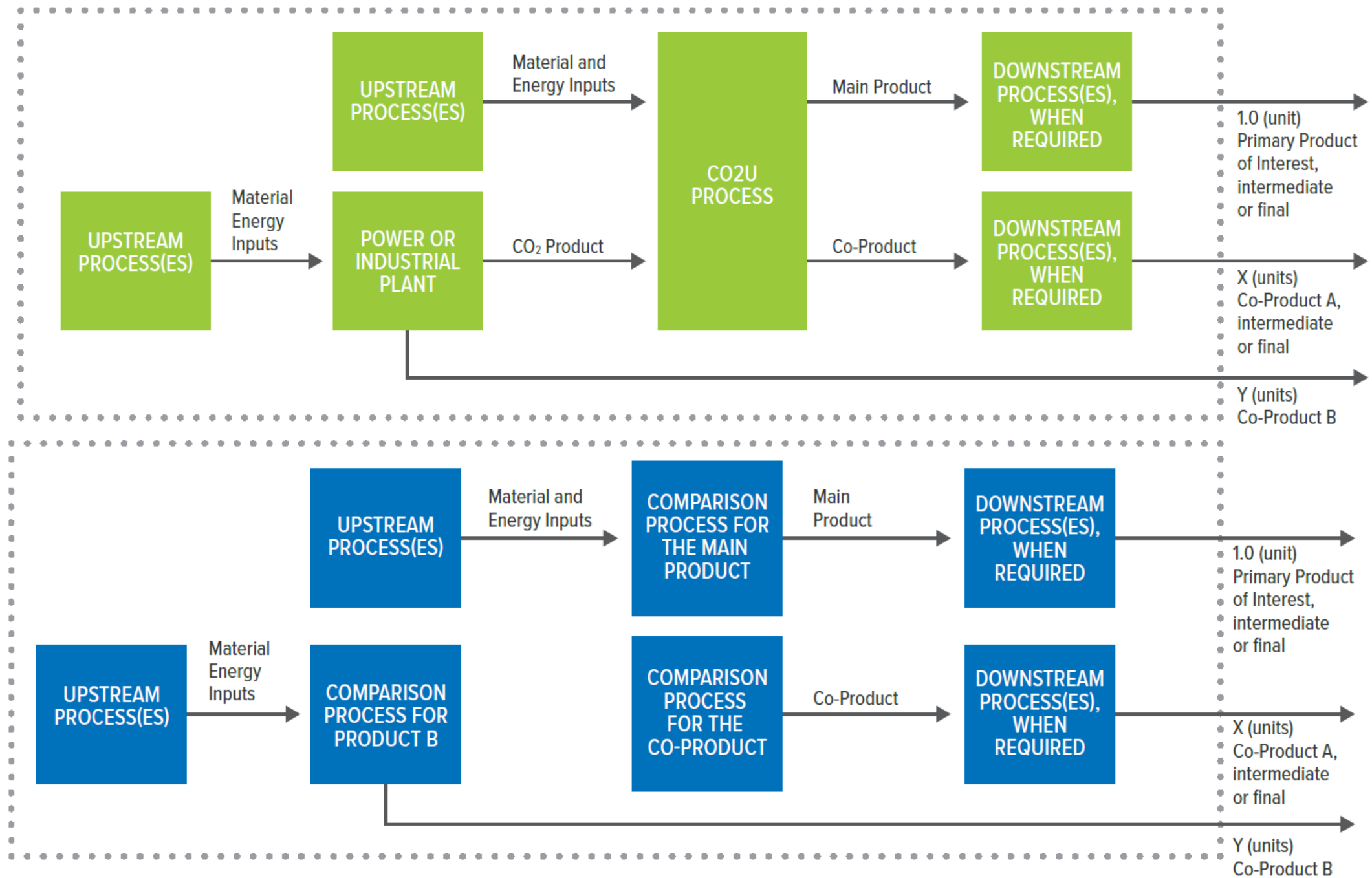


Proposed Product System

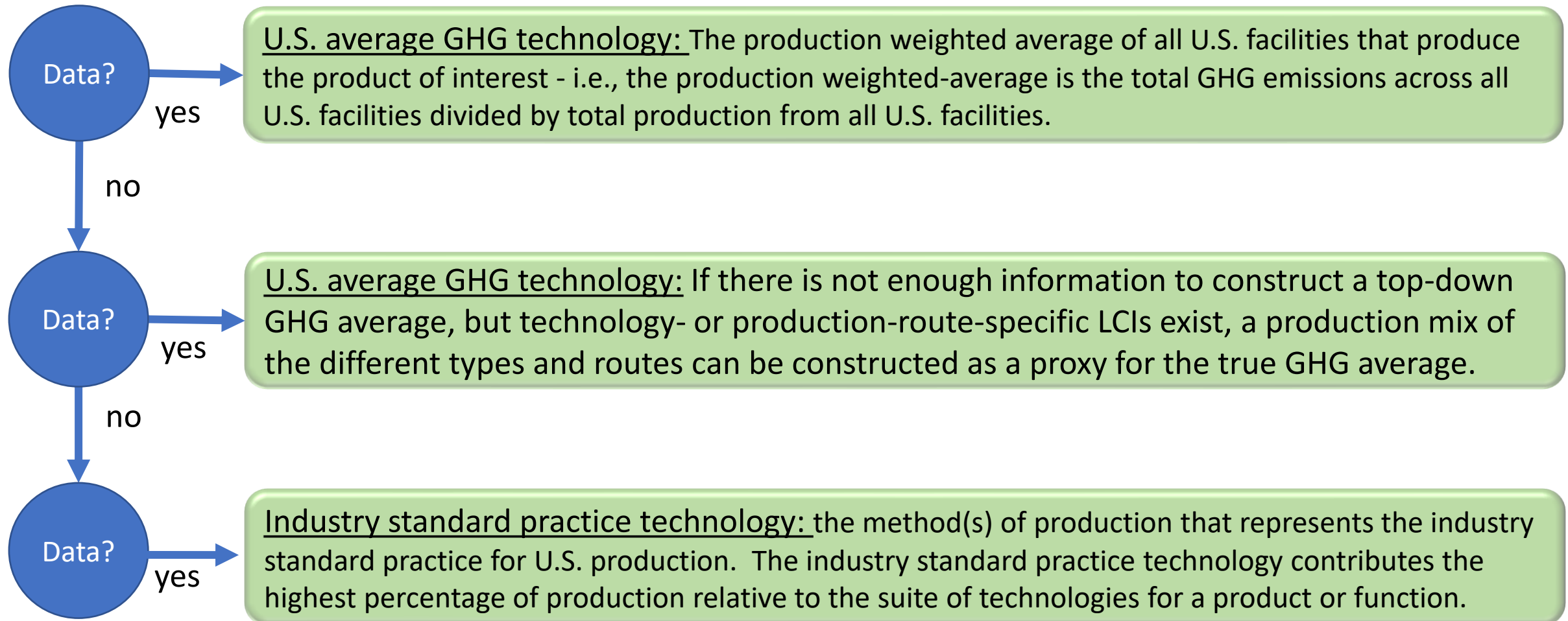


Comparison Product System





Comparison Product System Technology Choices



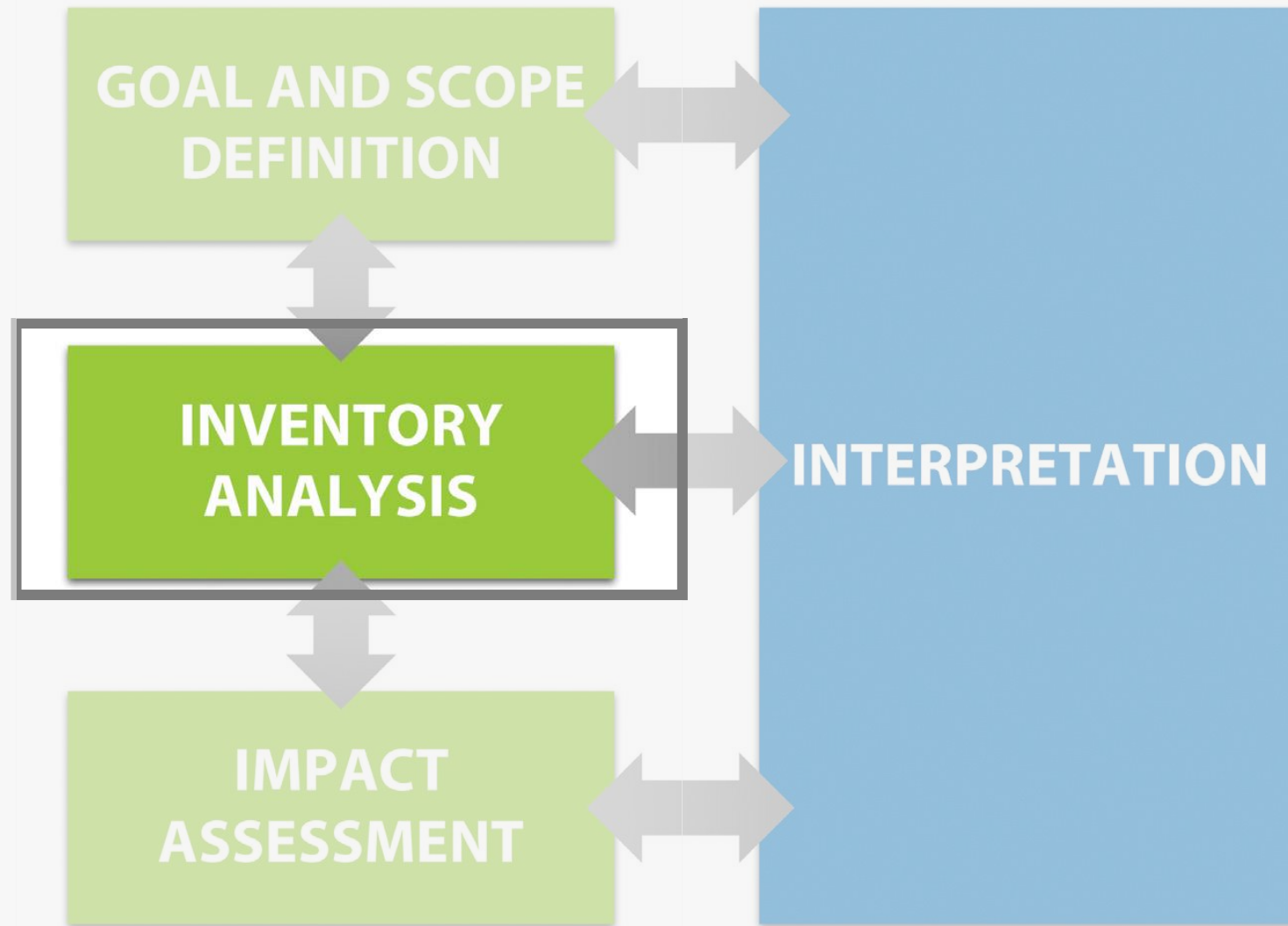
NEW! NETL U.S. Average Baseline Datasets



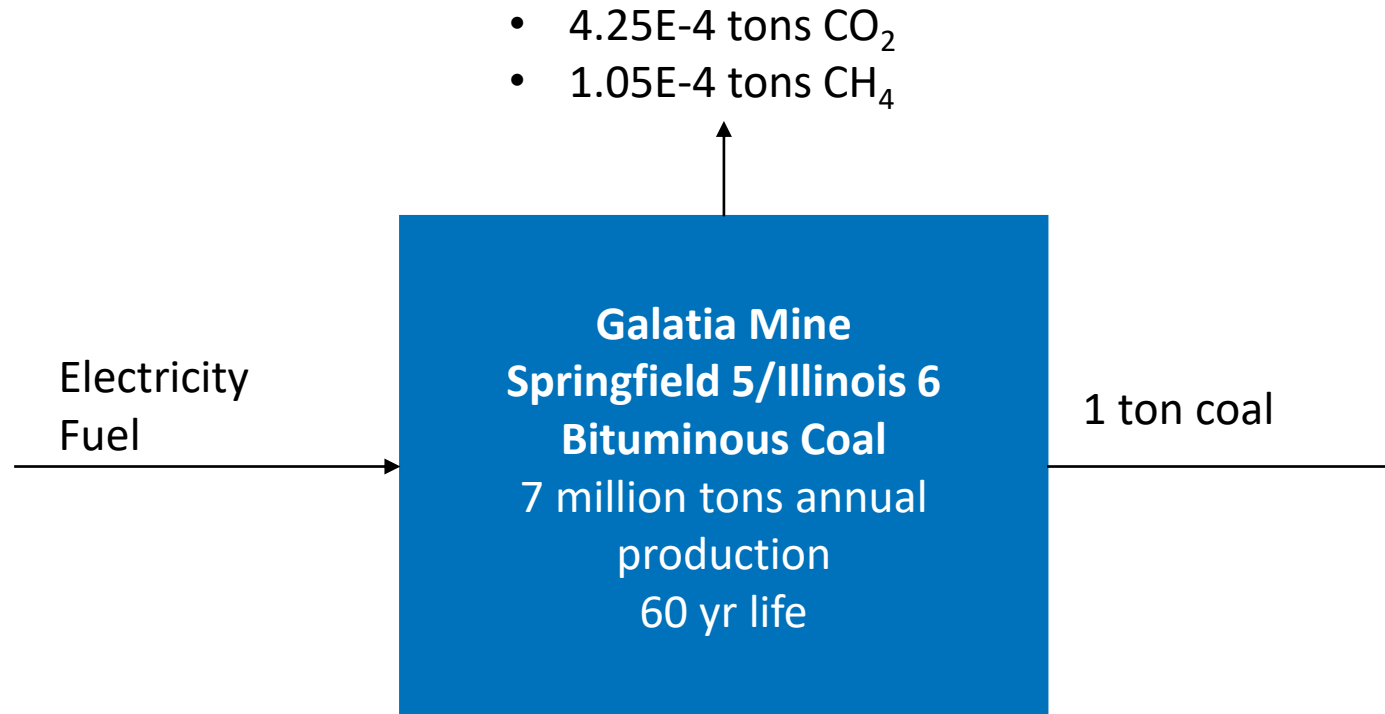
NETL U.S. Average Baseline Datasets

- Based on publicly available data
- Includes existing capture rates in industries
- Representing years 2018 – 2022
 - Will be updated as new data is available
- Documentation in complete report + supplemental data spreadsheet
- Data available in .zolca file compatible with CO2U LCI database
- Summary impact results will be available in next CO2U update

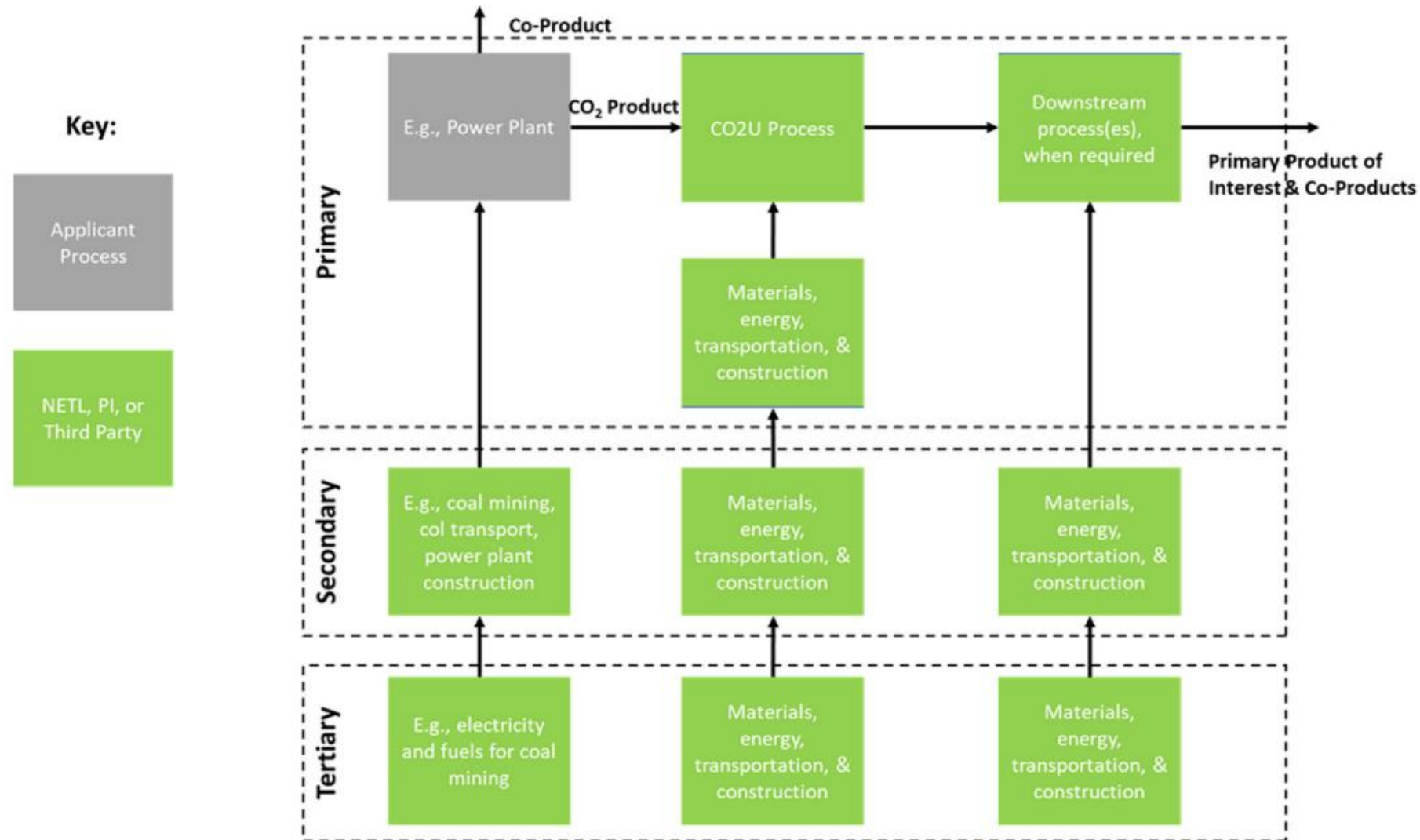
Inventory Analysis



Unit Process Development



Unit Process Sources

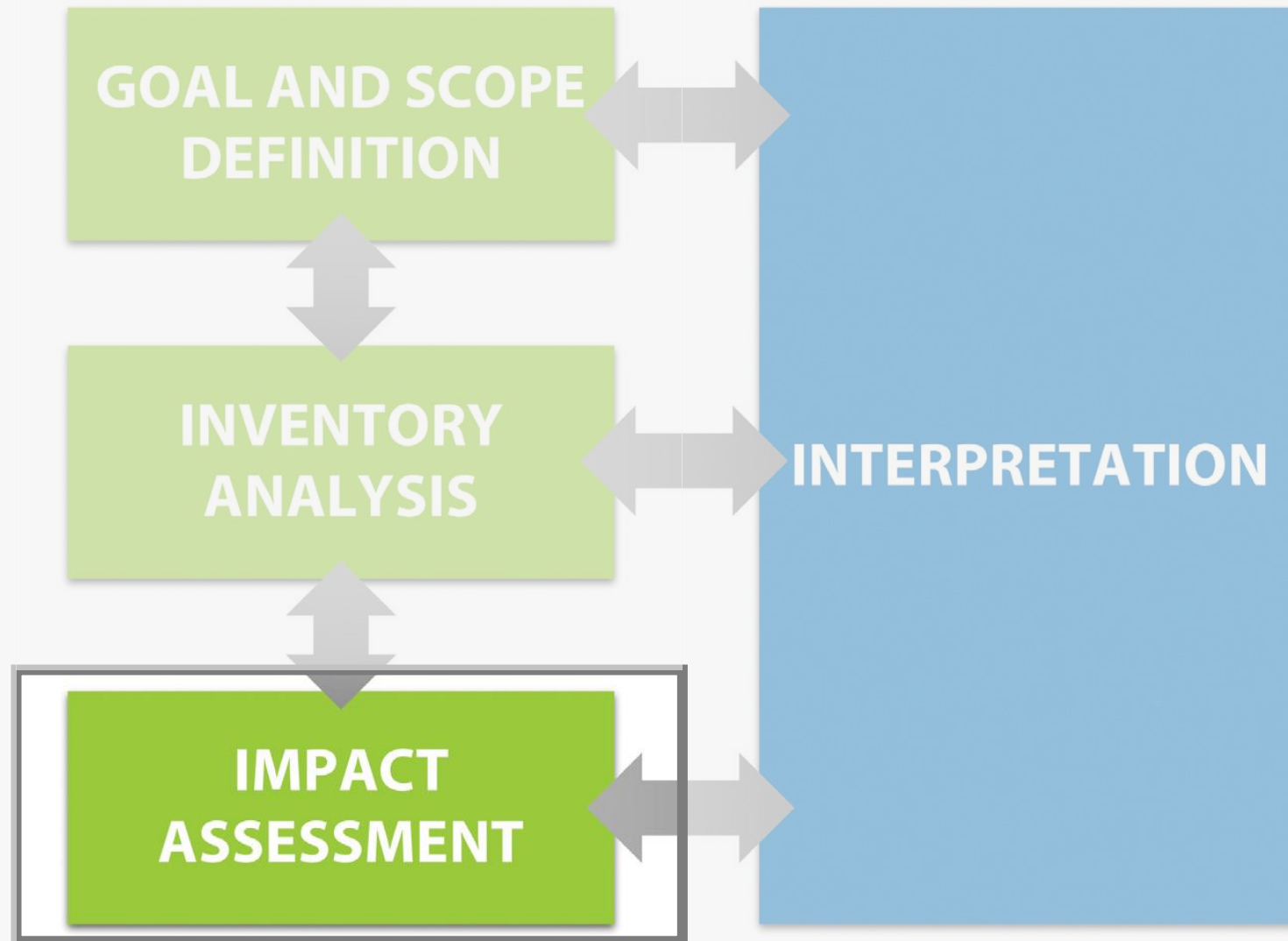


- openLCA
 - Free, opensource LCA development tool for data management and LCA calculations
 - Developed by GreenDelta in 2006
 - Version 1.9 released with many feature improvements
- Spreadsheet Models
 - May have to be built from scratch
 - Can be very flexible
- Other third Party LCA software
 - Often incorporate data management and LCA calculations
 - Often come with datasets

Documentation Requirements

- openLCA Software
 - NETL CO2U openLCA LCI Database
 - NETL CO2U openLCA Results Contribution Tool
 - NETL 45Q LCA Report Template
- PI Spreadsheet Model
 - Spreadsheet model and supporting material
 - NETL CO2U LCA Documentation Spreadsheet
 - NETL 45Q LCA Report Template
- Other Software
 - Final LCA model database file and supporting materials **OR**
 - NETL CO2U LCA Documentation Spreadsheet
 - NETL 45Q LCA Report Template

Impact Assessment



Required Global Warming Potential

- Use of the GWPs in Table A-1 of 40 CFR Part 98, Subpart A is required by 26 CFR 1.45Q-4(c)(1). 40 CFR Part 98 are the EPA's regulatory requirements for the Greenhouse Gas Reporting Program
- Version of table available in NETL CO2U LCI database as "GHGRP GWP"

[100-Year Time Horizon]

Name	CAS No.	Chemical formula	Global warming potential (100 yr.)
Chemical-Specific GWPs			
Carbon dioxide	124-38-9	CO ₂	1
Methane	74-82-8	CH ₄	^a 25
Nitrous oxide	10024-97-2	N ₂ O	^a 298
Fully Fluorinated GHGs			
Sulfur hexafluoride	2551-62-4	SF ₆	^a 22,800
...			
3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,11-Nonadecafluoroundecan-1-ol	87017-97-8	CF ₃ (CF ₂) ₈ CH ₂ CH ₂ OH	^b 0.19
Fluorinated GHGs With Carbon-Iodine Bond(s)			
Trifluoroiodomethane	2314-97-8	CF ₃ I	^b 0.4
Other Fluorinated Compounds			
Dibromodifluoromethane (Halon 1202)	75-61-6	CBR ₂ F ₂	^b 231
2-Bromo-2-chloro-1,1,1-trifluoroethane (Halon-2311/Halothane)	151-67-7	CHBrClCF ₃	^b 41

<https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-98#Table-A-1-to-Subpart-A-of-Part-98>

Results Calculations

Calculated using GWP impact values scaled to 1 metric ton carbon oxide captured and utilized:

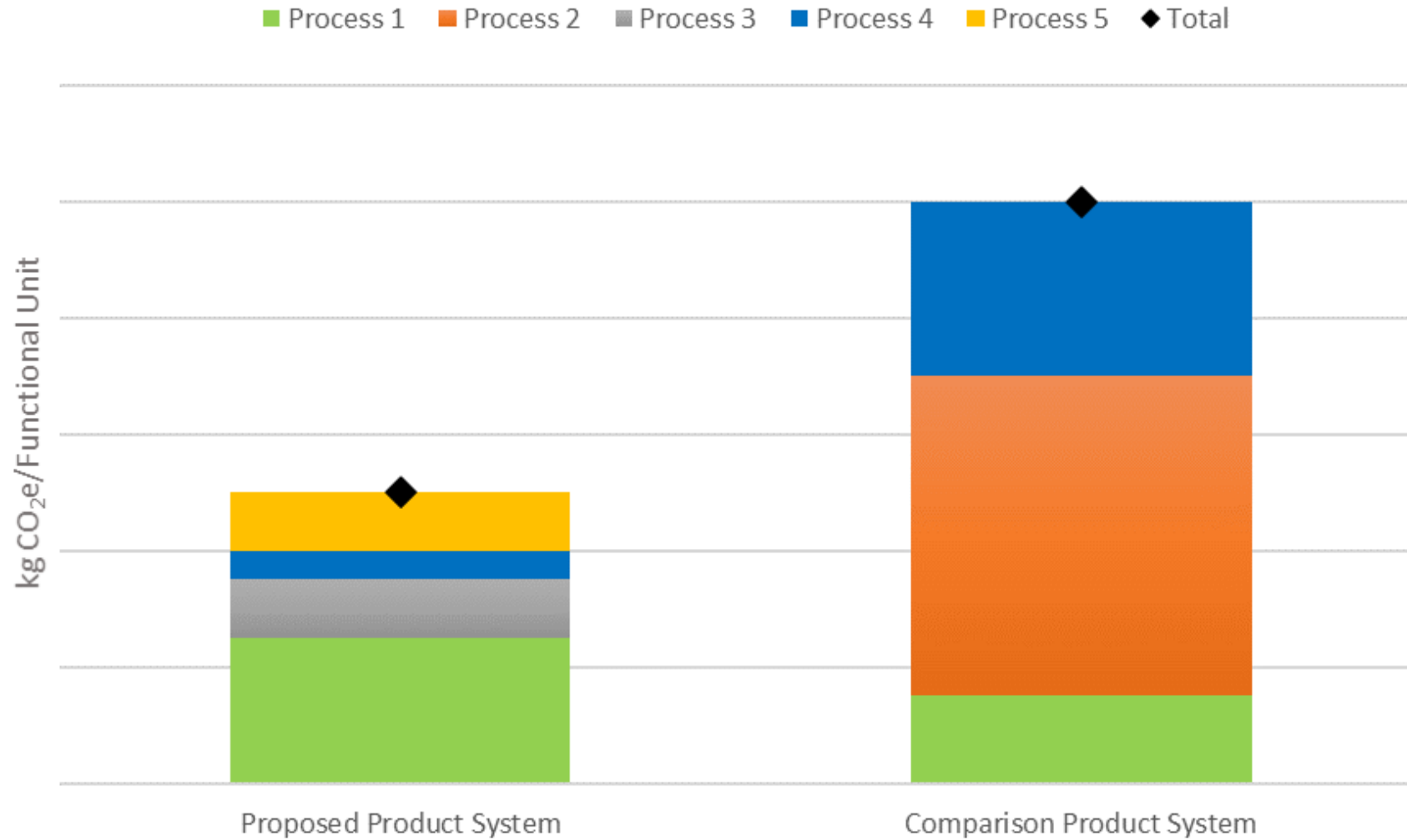
$$LC\ 45Q\ DF = \frac{\text{Proposed Product System GWP Impact} - \text{Comparison Product System GWP Impact}}{1\ \text{metric ton carbon oxide captured and utilized}} * -1$$

OR

Calculated using GWP impact values scaled to the functional unit:

$$LC\ 45Q\ DF = \frac{\text{Proposed Product System GWP Impact} - \text{Comparison Product System GWP Impact}}{\text{Amount of carbon oxide captured and utilized per functional unit}} * -1$$

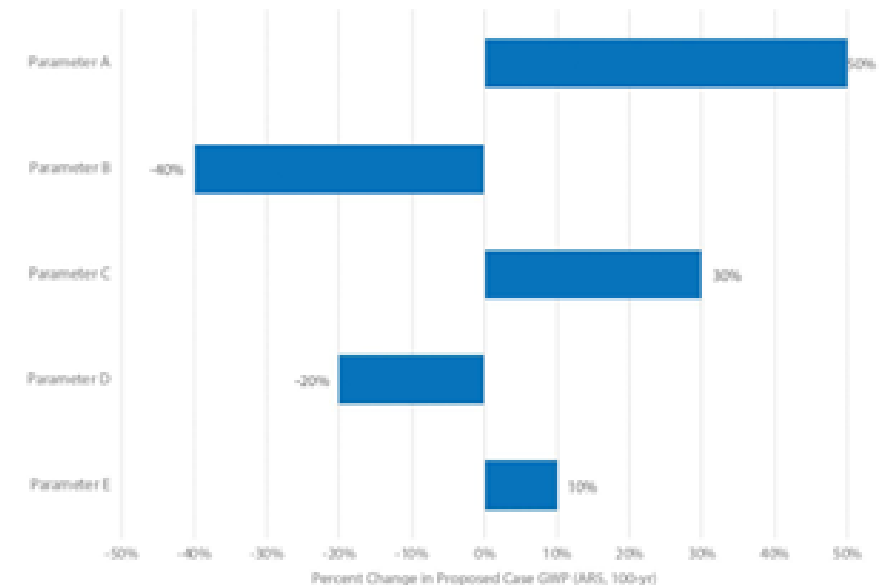
Results Visualization



Sensitivity Analysis

- Vary each model parameter by one increment (e.g. +10%) and record results to compare sensitivity of model to changes in parameters
- When using black box models, energy and material inputs must be used as parameters
- “one-at-a-time” sensitivity analysis required
- Break-even required for especially sensitive parameters

EXHIBIT 2-27. ONE-AT-A-TIME SENSITIVITY ANALYSIS EXAMPLE FIGURE




Contribution tree tool

Q19

	A	B	C	D	E	F	G	H	I	J
1	Cases to be compared:	Sheet name:	High (sheet name)	Low (sheet name)						
2	Proposed Product System: NETL Default	Prop-A-Exp	Prop-A-High	Prop-A-Low			Calculate!			
3	Comparison Product System: NETL Default	Comp-A-Exp	Comp-A-High	Comp-A-Low						
4							Graph!			
5										
6										
7										
8										
9										
10										
11	Impact Categories:									
12	Global Warming Potential (AR5, 100-yr)									
13										
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Comparison Keys Prop-A-Exp Prop-A-Low Prop-A-High Comp-A-Exp Comp ...

Results Reporting



The form is a white rectangular box with a green header bar at the top. The header bar contains a green geometric design. The main body of the form is white and contains the following text:

LCA REPORT TITLE

Company Name and Relevant Tax Year

SUBMISSION DATE

Author List

NEW! Review Checklist

- Provides quick summary of key checkpoints
- Includes summary for each report section and what is expected
- Gives some context to typical NETL critical review

NETL 45Q LCA REVIEW CHECKLIST

This review checklist is meant to be used as a guide for 45Q applicants. Applicants must reference the [NETL CO₂U LCA Guidance Document](#) and [45Q Addendum](#) for complete guidance on preparing LCAs for 45Q. The table below provides a high-level summary of the key checkpoints based on common issues in submitted LCAs reviewed to-date. The remainder of this document provides a thorough list of the items evaluated as part of the LCA technical review.

LCA Consideration	Key Checkpoint
Study Scope	✓ CPS represents the U.S. average GHG or industry standard practice technology per Section 2.1.3.2 of the 45Q Addendum.
Functional Unit	✓ Functional equivalence between the PPS and CPS.
System Boundary	✓ Clear and complete system diagrams for the PPS and CPS with consistent system boundaries.
Carbon Oxide Source and Utilization	✓ Captured CO ₂ co-product in the PPS must be produced in an equivalent amount in the CPS using the guidance in Section 2.1.10 of the 45Q Addendum.
Technology Representativeness	✓ The CPS uses Section 2.1.3.2 of the 45Q Addendum to represent the U.S. average GHG or industry standard practice technologies.
Geographical Representativeness	✓ PPS and CPS have equivalent geographical representativeness; CPS electricity unit processes represent the same geographical location as the PPS.
Temporal Representativeness	✓ PPS and CPS sufficiently represent the application tax year.
LCIA Methods for Results	✓ GWP impact calculations utilize characterization factors from Table A-1 of 40 CFR Part 98 subpart A.
Modeling Platform	✓ A complete model is included as part of the submission, or in the case of a report that has been externally reviewed by a third party, the description of the model is sufficient to completely recreate it. Inclusion of a model diagram is recommended for all reports.
Data Sources and Quality Assessment	✓ Description of the CPS data and unit processes includes U.S. average GHG or industry standard practice justification.
Sensitivity Check	✓ Sensitivity analysis results show the variation of individual model parameters and break-even analysis highlights key sensitive parameters.
Co-Product Management	✓ Description of the co-product management procedure is clear and complete, and functional equivalence was established.
Interpretation	✓ LC 45Q DF has been calculated according to Section 2.1.9.3 of the 45Q Addendum. LC 45Q DF is stated as 1 if initial calculated DF is greater than 1.

EXECUTIVE SUMMARY

- High-level, overview of the LCA. This should include brief descriptions of the following:

1

Toolkit Updates and Schedule

- The NETL 45Q LCA Guidance Toolkit will be updated as needed with additional tools and data, or revisions to guidance.
- The applicant must use the most current revision of this guidance as of the beginning of the year in which the LCA is to be submitted for review.
- This version of the guidance, Version 2.0, is optional for the remainder of 2024 and becomes required at the beginning of 2025.
- A detailed description of the revisions incorporated in this version of the guidance can be found in the [Toolkit Changelog](#)

Common Pitfalls

- Assuming the CPS is just “yourself minus carbon capture” instead of US GHG Average
- Providing insufficient documentation
- Using inappropriate pre-existing data or data with insufficient documentation to determine appropriateness
- Using inconsistent or inappropriate co-product management techniques
- Missing or insufficient sensitivity analysis

Questions?

VISIT US AT: www.NETL.DOE.gov



@NETL_DOE



@NETL_DOE



@NationalEnergyTechnologyLaboratory

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Or LCA45Q@HQ.DOE.GOV



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DISCLAIMER

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