

45Q ADDENDUM TO THE NETL CO₂U LCA GUIDANCE DOCUMENT

VERSION 2.0

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STRATEGIC SYSTEMS ANALYSIS AND ENGINEERING



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45Q Addendum Detailed Changelog – Version 2.0

1.0 Introduction (Additional Guidance)

- Provided additional clarification on the use of updated versions of the 45Q Addendum.

1.2 Document Goals (Direct Replacement)

- No modifications.

1.3 What Is Included in the NETL CO₂U LCA Guidance Toolkit (Direct Replacement)

- Provided additional clarification on the use of updated versions of the 45Q Addendum.

1.5 Modeling and Documentation Options for U.S. DOE Carbon Utilization Program Project PIs (Additional Guidance)

- Provided additional clarification.

2.1.1 LCA Study Goal (Direct Replacement)

- Provided additional clarification on the disclosure of information and materials submitted by applicants.

2.1.3 Functional Unit of the Study (Additional Guidance)

- Provided additional guidance on the representation of the function associated with the qualified carbon oxide or qualified carbon oxide utilization product in the functional unit.

2.1.3.2 Comparison Product System (Direct Replacement)

- Provided additional clarification on the use of the Comparison Product System hierarchy.
- Provided additional guidance on how to represent the U.S. average GHG and industry standard practice technologies.
- Introduced the NETL U.S. average GHG technology baselines for nitrogen fertilizers, ethanol, and CO₂.

2.1.4 System Boundary (Direct Replacement)

- Provided additional clarification on the truncation of the system boundary once functional equivalence has been established.
- Provided additional guidance on how the completeness requirements must be met and documented when/if truncation or omission of unit processes occurs.

2.1.5 Carbon Oxide Source (Direct Replacement)

- Updated example and figure with a more relevant case.

2.1.6.2 Geographical Representativeness (Direct Replacement)

- Provided additional clarification.

2.1.6.3 Temporal Representativeness (Additional Guidance)

- Provided additional clarification.

2.1.8 Life Cycle Impact Assessment Methods for Results Interpretation (Direct Replacement)

- Provided additional clarification.

2.1.9.2 Sensitivity and Uncertainty Analysis (Direct Replacement)

- Provided additional clarification on how to properly perform a sensitivity analysis.
- Provided additional guidance on performing a sensitivity analysis when a black box model is used.

2.1.9.3 Reporting Units and Methods of Comparison (Direct Replacement)

- Provided additional clarification on how to calculate the life cycle 45Q displacement factor (DF).
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- Provided an example DF calculation.

2.1.10 Co-product Management Procedures (Additional Section)

- This is a new section in the 45Q Addendum. This section does not exist in the NETL CO₂U Guidance Document.
- Provided additional guidance on how to manage co-products of Product Systems for 45Q LCAs.

2.2.2.2 Environmental Inventory Data (Direct Replacement)

- Provided additional clarification.

2.2.2.3 Unit Process Data Development Approaches (Direct Replacement)

- Provided additional clarification.
- Provided additional guidance on the construction of a black box unit process.

2.2.2.5 Land Use Change (Additional Guidance)

- Provided additional clarification.

2.2.3.1 Completeness Check (Direct Replacement)

- This is a new section in the 45Q Addendum. This section is a direct replacement for the parallel section in the NETL CO₂U Guidance Document.
- Provided additional guidance on performing a completeness check for 45Q LCAs.

2.3 Impact Assessment (Direct Replacement)

- Provided additional clarification.

2.3.1 Data Quality Assessment (Direct Replacement)

- Provided additional clarification.

2.4.5 Critical Review (Direct Replacement)

- Provided additional clarification.

3.0 Using openLCA for ~~CO₂U~~^a 45Q LCA (Direct Replacement)

- Provided additional clarification.

3.4 Performing a Product System Analysis (Direct Replacement)

- Provided revised guidance for openLCA 2.0.

5.0 Using the NETL ~~CO₂U~~ 45Q LCA Documentation Spreadsheet for Documentation (Direct Replacement)

- Provided additional clarification.

5.1 Overview (Direct Replacement)

- Provided additional clarification.

5.5 NETL Unit Process Data and GWP Impact Factors Worksheets (Direct Replacement)

- Provided additional clarification.

6.0 Completing the NETL ~~CO₂U~~ 45Q LCA Report Template (Direct Replacement)

- Provided additional clarification.

^a Strikethrough text in sections names refer to revisions from the NETL CO₂U LCA Guidance Document to the 45Q Addendum (this document) within the section titles themselves.

Appendix A: Accessing the NETL CO₂U 45Q LCA Toolkit and Resources For Assistance (Direct Replacement)

- Provided additional clarification.

Appendix B: U.S. DOE Technology Readiness Levels (Direct Replacement)

- Provided additional clarification.

Appendix C: Alternative Co-Product Management Methods (Additional Guidance)

- Provided additional clarification.

Appendix D: Electricity Mix Data Development (Direct Replacement)

- Provided additional clarification.

Appendix G: NETL CO₂U Guidance and 45Q Addendum Crosswalk (Additional Section)

- This is a new section in the 45Q Addendum. This section does not exist in the NETL CO₂U Guidance Document.
 - Provided a crosswalk for the NETL CO₂U Guidance Document and 45Q Addendum that shows the sections modified by the 45Q Addendum.
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1.0 INTRODUCTION (ADDITIONAL GUIDANCE)

26 CFR § 1.45Q-4 (hereby referred to as 45Q) requires a life cycle analysis (LCA) to be performed to verify the amount of qualified carbon oxide utilized for the 45Q tax credit. Under the Internal Revenue Service (IRS) regulations, LCAs must be prepared and documented in conformance with certain International Organization for Standardization (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 ISO 14040/14044 and directed taxpayers to use such guidance when submitting LCAs under 45Q. This toolkit, which includes the *Carbon Dioxide Utilization Life Cycle Analysis Guidance for the U.S. DOE Office of Fossil Energy and Carbon Management* (hereby referred to as the NETL CO₂U LCA Guidance Document), was originally written to guide projects in performing LCAs as part of their laboratory-funded project.

The purpose of this addendum is to guide taxpayers on how to perform LCA for the purposes of 45Q using the NETL CO₂U LCA Guidance Document. This addendum does not outline the requirements to qualify for a tax credit under 45Q, which are contained in IRS's regulations in 26 CFR Part 1.45Q. The key method of comparison outlined in this addendum (Section 2.1.9.3) is the life cycle 45Q displacement factor (LC 45Q DF). The LC 45Q DF calculates the percentage of captured carbon oxide that is allowable as qualified carbon oxide for the purposes of claiming the tax credit. For example, if an applicant calculates a DF of 0.75, for every 1 metric ton of carbon oxide captured and utilized, the applicant will have 0.75 metric tons of qualified carbon oxide according to 26 CFR 1.45Q-4(b).

All sections contained in this addendum are meant to serve as either direct replacement for the corresponding section in the NETL CO₂U LCA Guidance Document or provide recommendations on how to use the section for the purposes of LCA for 45Q. Each section is marked as either “direct replacement” or “additional guidance” in the heading for clarity. **These sections cannot be implemented in isolation as they stem from the entire approach and methodology within the NETL CO₂U LCA Guidance Document. Thus, applicants must refer to the approach and methodology presented in the NETL CO₂U LCA Guidance Document as well as this addendum.**

When using the NETL CO₂U LCA Guidance Document for purposes of applying under 45Q, all references to the “Principal Investigator” or “PI” within the larger CO₂U LCA Guidance Toolkit (e.g., the openLCA database) should instead refer to the “applicant”, and all references to the “U.S. DOE Carbon Utilization Program” should instead refer to “26 CFR § 1.45Q-4”.

45Q requires all greenhouse gases (GHGs) to be adjusted to account for the relative global warming potential (GWP) according to [Table A-1 of 40 CFR Part 98, Subpart A^b](#), which presents 100-year GWPs (hereby referred to as GWPs in this addendum). All references to GWPs in the NETL CO₂U LCA Guidance Document should be considered references to the GWPs contained in Table A-1 of 40 CFR Part 98, Subpart A. Note that GWP can refer to the “potential” of a single

^b 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.

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chemical species or of a process or product system. All GWP impact aggregations in the 45Q addendum also refer to the use of Table A-1 characterization factors to calculate that total.

The NETL CO2U LCA Guidance Document was also intended specifically for the use of carbon dioxide, which is reflected throughout the NETL CO2U LCA Guidance Document text. For the purposes of 45Q, any discussion of captured or utilized carbon dioxide in the NETL CO2U LCA Guidance Document or this addendum should be considered synonymous with carbon oxide.

The NETL 45Q LCA Guidance Toolkit will be updated as needed with additional tools and data, or revisions to this 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](#).

1.2 DOCUMENT GOALS (DIRECT REPLACEMENT)

All the guidance included herein complies with the ISO LCA standards (14040/14044) and ensures methodological consistency in applying the ISO standards. The ISO standards provide a broad framework for applying LCA to a wide range of applications which can lead to inconsistency in modeling choices and results interpretation.

The goals of this addendum are to modify the NETL CO2U Guidance Toolkit to:

1. Provide LCA guidance, data, and tools to 45Q applicants to complete the required LCA and documentation requirements; and
2. Foster better decision-making as part of the 45Q technical review process by providing an analysis and reporting structure that enables consistency and transparency for the applicants' LCAs.

1.3 WHAT IS INCLUDED IN THE NETL CO2U LCA GUIDANCE TOOLKIT (DIRECT REPLACEMENT)

The NETL CO2U LCA Guidance Toolkit and 45Q Addendum includes the following:

1. NETL CO2U LCA Guidance Document outlines the analysis requirements and how to use the supporting data and tools.
2. 45Q Addendum (this document) to the NETL CO2U LCA Guidance Document outlines the analysis requirements and how to use the supporting data and tools, and modifies the guidance provided in the NETL CO2U LCA Guidance Document for 45Q applicants.
3. NETL CO2U openLCA LCI Database is an openLCA database that includes NETL unit process data and an example CO2U LCA.
4. NETL CO2U openLCA Results Contribution Tool is an Excel template that translates openLCA results into required charts.

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5. NETL CO2U LCA Documentation Spreadsheet is an Excel file that can be used to document data when not using openLCA.
6. NETL 45Q LCA Report Template is a Word report template for summarizing data and results, including a modified version for 45Q applicants.

NETL CO2U LCA Subject Matter Expert Support and Training Resources are not available as part of the NETL 45Q LCA Guidance Toolkit. Therefore, all questions related to 45Q LCAs submitted to DOE shall be directed to LCA45Q@HQ.DOE.GOV with copy to LBI.EEF.45QLCA@IRS.GOV. Policy, eligibility, and other questions unrelated to LCA should be directed to LBI.EEF.45QLCA@IRS.GOV only. Please do not reach out to DOE or NETL staff for individual guidance, as those requests will not be addressed. [Frequently Asked Questions and Additional Resources](#) are available on the NETL website.

The NETL 45Q LCA Guidance Toolkit will be updated as needed with additional tools and data, or revisions to this 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.

1.5 MODELING AND DOCUMENTATION OPTIONS FOR U.S. DOE CARBON UTILIZATION PROGRAM PROJECT PIs (ADDITIONAL GUIDANCE)

If the submission includes an openLCA database, it shall be submitted using the “.zolca” file format (right click on the database in openLCA and select “Backup database”). Use of any third-party licensed data (e.g., ecoinvent, Sphera) shall include permission from the data providers for DOE review access. Use of third-party data that the applicant cannot share with DOE and NETL may result in additional review time for data verification.

A key component of the critical review is the ability to review the LCA models exactly as the applicant or third-party analysts have constructed and used them for LCA results. To this end, an entire database export is preferred for critical review, as this reduces the chances for missing data or processing steps required by NETL. For example if the LCA model is prepared in openLCA, we would prefer the model be submitted as a database backup (i.e., a .zolca file). Some other examples are: sphere GaBi - .gcd and SimaPro .SPBackup

2.1.1 LCA Study Goal (Direct Replacement)

The specific goals of the LCA as required by this document are described below:

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.

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4. Public disclosure — the LCAs conducted as a requirement of qualification for the 45Q tax credit will not be published by DOE/NETL. Federal employees are obligated to not disclose any confidential information under 18 U.S.C. 1905. As a Federal agency, DOE must comply with requests made under the Freedom of Information Act (FOIA) (5 U.S.C. 552). Under FOIA, Federal agencies are required to disclose agency records requested by a member of the public, including information received from outside parties, unless FOIA specifically exempts the information's disclosure. FOIA Exemption 4 (5 U.S.C. 552(b)(4)) exempts from FOIA disclosure confidential commercial and financial information obtained from a person outside the agency. Whenever a document submitted to DOE by a private business contains information which may be exempt from public disclosure, it will be handled in accordance with the procedures in 10 CFR 1004.11. While DOE is responsible for making the final determination with regard to the disclosure or nondisclosure of information contained in any requested documents, DOE will consider the submitter's views in making its determination. Therefore, if the submitter believes the information submitted would constitute trade secrets or commercial/financial information that is privileged and confidential, it is recommended that the submitter label the documents as such.

2.1.3 Functional Unit of the Study (Additional Guidance)

Section 2.1.1 of the 45Q Addendum states that the intended application of a LCA for 45Q is “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.” Section 4.2 of ISO 14044:2006 discusses at length how the intended application, goal and scope, and functional unit must be consistent. Thus, for the purposes of this guidance, the functional unit of the Proposed Product System must represent the function associated with the qualified carbon oxide or the function associated with the carbon oxide utilization product. The functional unit of the Comparison Product System must represent products and/or services that are functionally equivalent to the products and/or services of the Proposed Product System.

2.1.3.2 Comparison Product System (Direct Replacement)

There are likely multiple technologies that can produce the same products or functions as the Proposed Product System. Applicants shall use the following ordered hierarchy to model the processes and products related to the capture and utilization of carbon oxides in the Comparison Product System to ensure functional equivalence. The hierarchy shall be considered until comparison technologies have been identified for all products and/or functions in the Proposed Product System.

Step 1: U.S. average GHG technology: Identify the profile that represents the average GHG emissions for U.S. production. This should be a production weighted average of all U.S. facilities that produce the product of interest - i.e., the production weighted-average is the total GHG emissions across all U.S. facilities divided by total production from all U.S. facilities. There may not be an appropriate profile in existing LCI databases that represents the U.S. average GHG technology. However, if there is data available to construct a profile representative of the U.S.

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average GHG technology, this must be considered by the applicant. Additionally, if there is not enough information to construct a top-down GHG average, but technology- or production-route-specific LCIs exist, a production mix of the different types and routes can be constructed as a proxy for the true GHG average.

If sufficient data is not available to determine the U.S. average GHG technology for a comparison process, proceed to step 2.

Step 2: Industry standard practice technology: Identify the method(s) of production that represents the industry standard practice for U.S. production. The industry standard practice technology contributes the highest percentage of production relative to the suite of technologies for a product or function. The applicant must justify the selection of the industry standard practice technology with evidence such as peer-reviewed literature citations, industry reports, or government publications. As with the U.S. average GHG technology, if there is not an existing unit process to represent the industry standard practice technology, the applicant must leverage any available data to construct a custom unit process.

Repeat these steps until comparison technologies have been identified for all the products/services from the Proposed Product System. Relevant data that must be considered in developing the Comparison Product System unit processes include the industry prevalence of carbon oxide capture and the average carbon oxide capture rate. To construct a U.S. average GHG technology model, U.S. industrial production technology shares and GHG emissions data may be obtained from publicly available models and databases published by entities such as Argonne National Laboratory (ANL), Energy Information Administration (EIA), Environmental Protection Agency (EPA), National Renewable Energy Laboratory (NREL), NETL, and published academic literature. U.S. average GHG technology models are expected to reflect recorded/reported operational data from the majority of industry facilities, while industry standard practice data may have lower resolution and can originate from modeled/simulated data or guidelines from equipment and facility specifications. Additional guidance on the products produced from the carbon oxide source is provided in Section 2.1.5.

To provide additional support for 45Q applicants, NETL has developed U.S. average GHG technology baselines for several common applicant products, including nitrogen fertilizer production, corn ethanol production, and CO₂ production. The applicant should use NETL U.S. average GHG technology baselines for products and/or functions in their Comparison Product System wherever possible. If the applicant identifies data that better represent the U.S. average GHG technology for the products and/or functions in their Comparison Product System, justification and documentation (including references to peer-reviewed, industry, or government sources) must be provided to validate the decision to not use NETL unit processes. These provided baselines should preclude the need to use Step 2 (industry standard practice) for those products.

Details regarding the background data, unit process development approach, and assumptions can be found in the accompanying documentation provided in the NETL 45Q LCA Toolkit as part of the FAQ and Additional Resources section. NETL will continue to develop additional U.S. average GHG technology baselines to support applicants as trends in applications identify key CO₂ sources and utilization products.

2.1.4 System Boundary (Direct Replacement)

A complete LCA is a cradle-to-grave analysis, with a boundary that begins with the extraction of raw materials (cradle) and ends with the consumption or disposal of the final product (grave). However, when comparing two systems that produce the same products or functions, portions of the life cycle may be equivalent. To avoid unnecessary complication from downstream unit processes, modeling the fate of carbon oxide utilization products should end when complete functional equivalency with comparison products has been reached such that all downstream unit processes, emissions, and life cycle impacts are the same (i.e., cradle-to-gate). Such truncation is permissible under the ISO standards 14040/14044 for a comparative LCA. For the purposes of this guidance, the key metric (the LC 45Q DF) is a life cycle GHG reduction potential of the Proposed Product System relative to a Comparison Product System on an absolute basis. The LC 45Q DF metric is not based on a stated percentage reduction in life cycle GHG emissions, therefore, truncation of the system boundary is allowed in LCA for 45Q.

An example of cradle-to-gate analysis that meets functional equivalency may be a carbon oxide utilization process and a Comparison Product System that make functionally equivalent fuel. The two systems make a fuel with the exact same performance for the same vehicles and thus, the unit processes downstream of fuel production will be identical. In this example, the life cycle stages downstream of the production gate would represent equivalent emissions and life cycle impacts for both systems and, mathematically, the results would cancel each other out in the comparison. Thus, in a 45Q LCA, when the emissions and subsequent life cycle impacts of a life cycle stage are equivalent in both the Comparison and Proposed Product Systems, that stage may be omitted without affecting the results of the study.

However, this cannot be done if the downstream process and corresponding emissions are not identical. For example, if the fuel produced by the carbon oxide utilization process has a different chemical composition which would result in different emissions upon combustion than the comparison, this must be included in the system boundary. Similarly, if one fuel produces biogenic carbon emissions upon combustion and another produces fossil carbon emissions, the use-phase must be modeled. If the unit process being considered for omission is the unit process that creates the functional unit, then the functional unit must be revised and must be valid. In the case of LCA for 45Q, if the carbon oxide utilization process is equivalent for both systems (i.e., dry ice production), this unit process may be omitted so long as the revised functional units are functionally equivalent between the Proposed and Comparison Product Systems.

All system boundary truncation must satisfy completeness requirements (see Section 2.1.9.1 of the NETL CO₂U LCA Guidance Document) and must be justified to NETL. The applicant shall explain the decision to omit any unit processes and justify either mathematically or by referencing peer-reviewed, industry, or government sources. It is also acceptable to implement a cut-off criteria, where the exclusion of a unit process is permissible for a product system, provided that the cumulative change in total GWP impact as a result of all excluded unit processes is less than 1% of the total. Use of cut-off criteria is important to maintain

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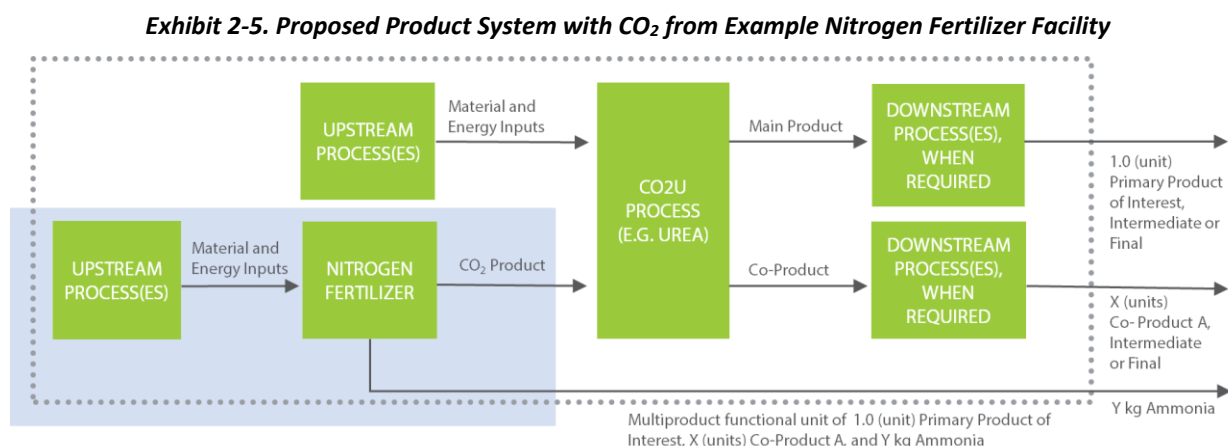
manageable Product Systems and avoid unnecessary complexity by allowing for the exclusion of unit processes that have negligible effects on the life cycle impact results.

Applicants shall illustrate diagrams for the Proposed Product System and the Comparison Product System based on the goals and scope of the LCA study (see Section 2.1 of this addendum) while ensuring equivalent functions are provided by both product systems. These diagrams will inform the data development and life cycle boundary development processes. Quantities of inputs and outputs for parts of the life cycle may or may not be known at this stage. If either the Proposed Product System or the Comparison Product System includes an input that is a waste product, the alternative fate of that waste product needs to be included in the other product system. For example, if mining waste is an input in the Proposed Product System, the Comparison Product System must model the alternative fate of the mining waste such as the U.S. average impacts of disposal following the hierarchy in Section 2.1.3.2.

Applicants shall illustrate the final system boundary of the Proposed Product System and the Comparison Product System based on any changes that have occurred during the data development process, such as the addition of life cycle stages or additional co-products/functions.

2.1.5 Carbon Oxide Source (Direct Replacement)

An applicant's carbon oxide source strongly influences the goal and scope of the study and the Comparison Product System. Most 45Q LCAs will have a minimum of two products exiting the system boundary because the carbon oxide source likely co-produces carbon oxide and other products (i.e., fossil-based ammonia production with carbon capture). Applicants shall model the Proposed Product System inclusive of the carbon oxide source, capture of carbon oxide, and all non-carbon oxide co-products produced from the carbon oxide source. Exhibit 2-5 demonstrates the Proposed Product System for an example nitrogen fertilizer facility with an ammonia co-product.



The Comparison Product System shall account for the same non-carbon oxide co-products produced by the carbon oxide source in the same quantities. Applicants shall construct the Comparison Product System using the guidance provided in Exhibit 2-8. For example, if CO₂

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capture has been applied to an existing nitrogen fertilizer facility, then the comparison system shall include nitrogen fertilizer products produced by the U.S. average GHG or industry standard practice technology (see Section 2.1.3.2 of this addendum). The Comparison Product System plant must be scaled such that the amount of non-carbon oxide co-product is the same in both systems. Additional detail on co-product management can be found in Section 2.1.5.3 of this addendum.

For the purposes of this guidance, Exhibits 2-6 and 2-7 in the NETL CO2U LCA Guidance Document do not apply. Exhibit 2-8 is modified below to reflect this revised guidance. The revised exhibit is applicable to all carbon oxide source types, such as power plants, industrial plants, and direct air capture sources.

Exhibit 2-8. Summary of Proposed Guidelines for Considering Carbon Oxide Source Co-Product Based on Type of Carbon Oxide Input to the Utilization Project

PLANT TYPE	PROPOSED PRODUCT SYSTEM	COMPARISON PRODUCT SYSTEM
Greenfield	Applicant carbon oxide plant	Average GHG performance for equivalent products/services, see hierarchy in Section 2.1.3.2.
Retrofit with de-rate	Same plant with carbon oxide capture, possibly producing less non-carbon-oxide co-product due to de-rate (e.g., less co-product generation at a plant)	Average GHG performance for equivalent products/services, see hierarchy in Section 2.1.3.2.
Retrofit with no de-rate	Same plant with carbon oxide capture	Average GHG performance for equivalent products/services, see hierarchy in Section 2.1.3.2.

The remainder of Sections 2.1.5.1 and 2.1.5.2 of the NETL CO2U LCA Guidance Document do not apply as the guidance therein is superseded by the above.

2.1.6.2 Geographical Representativeness (Direct Replacement)

Geographical boundaries specify the locations of parts of, or all of, the supply chain. This allows calculation of the transport distances between points in the supply chain, the origins of electricity and other energy sources used by unit processes, and specification of other parameters that may change depending on location. It can also serve as the basis for evaluating the extent of interactions among the domestic and global markets of products.

The geographical boundaries of the unit processes are determined by the supply chains required (modeled) to meet the goal and scope of the LCA. It is important to recognize that

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while the geographical boundary specified in the goal and scope of the LCA and reaffirmed in the long description of the functional unit may vary from the geographic boundary of individual product systems (supply chains). This is acceptable and common when noted as a data limitation in study documentation. It is important that the inventory data for the modeled product system represent the product that will be delivered to the geographical boundary of the goal and scope of the LCA study.

The modeled applicants' projects, products, and supporting supply chains shall represent the real-world geographical origins as closely as possible. Differences in this representativeness due to data limitations shall be noted in the data quality assessment accompanying the results interpretation section of the study findings.

2.1.6.3 Temporal Representativeness (Additional Guidance)

The Proposed and Comparison Product Systems temporal boundaries shall reflect the single tax year for which the applicant is filing for the 45Q credit. Specifically, all operational facility data, including inputs, outputs, and emissions, must reflect the relevant tax year.

2.1.8 Life Cycle Impact Assessment Methods for Results Interpretation (Direct Replacement)

LCAs submitted for the 45Q tax credit are required to perform life cycle impact assessment using the GWPs in [Table A-1 of 40 CFR Part 98, Subpart A](#), which are incorporated in the "GHGRP GWP" impact assessment method in the NETL CO2U openLCA LCI Database of the NETL 45Q LCA Guidance Toolkit. No other impact categories are required for this 45Q LCAs. Sections 2.1.8.1 and 2.1.8.2 of the NETL CO2U LCA Guidance Document are superseded by this guidance.

2.1.9.2 Sensitivity and Uncertainty Analysis (Direct Replacement)

Applicants shall complete a sensitivity analysis in which each model parameter is varied by one increment at a time to determine the degree of influence on the life cycle impact assessment results. Changing the percentage of the parameters all at once and presenting a single result does not satisfy the requirements for the sensitivity analysis, which instead should test the individual contribution of uncertain parameters to the overall impacts. It is recommended that parameter values are varied +/- 10%, but other percentage values may be used. It is recommended that the sensitivity analysis be presented in a tornado graph. Section 2.2.3.2 of the NETL CO2U LCA Guidance Document, which is not superseded by a corresponding section in this addendum, contains additional details regarding sensitivity analysis.

According to Section 2.2.2.3 of this addendum, the expectation is that applicants will develop custom, parameterized unit processes for the capture and utilization facilities. However, in the case of "black box" models (see Section 2.2.2.3 of this addendum), sensitivity analysis can still be performed by varying the input quantities of the black box process. For example, the quantity of material inputs can be adjusted by a set percentage individually the same way a parameter would change. Notably, the use of proxy data may require additional sensitivity analysis (see Section 2.2.2.6 of the NETL CO2U LCA Guidance Document). Applicants shall describe under what modeling conditions the results of the LCA study would change the

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outcome of the comparison. To do so, highly sensitive parameters (i.e., the parameters that result in the largest changes to the GWP impact when varied) identified in the sensitivity analysis shall be further evaluated to determine the level of variation that would result in the same GWP impact for the Proposed and Comparison Product Systems. This is referred to as a break-even analysis. Both a sensitivity analysis and break-even analysis are required.

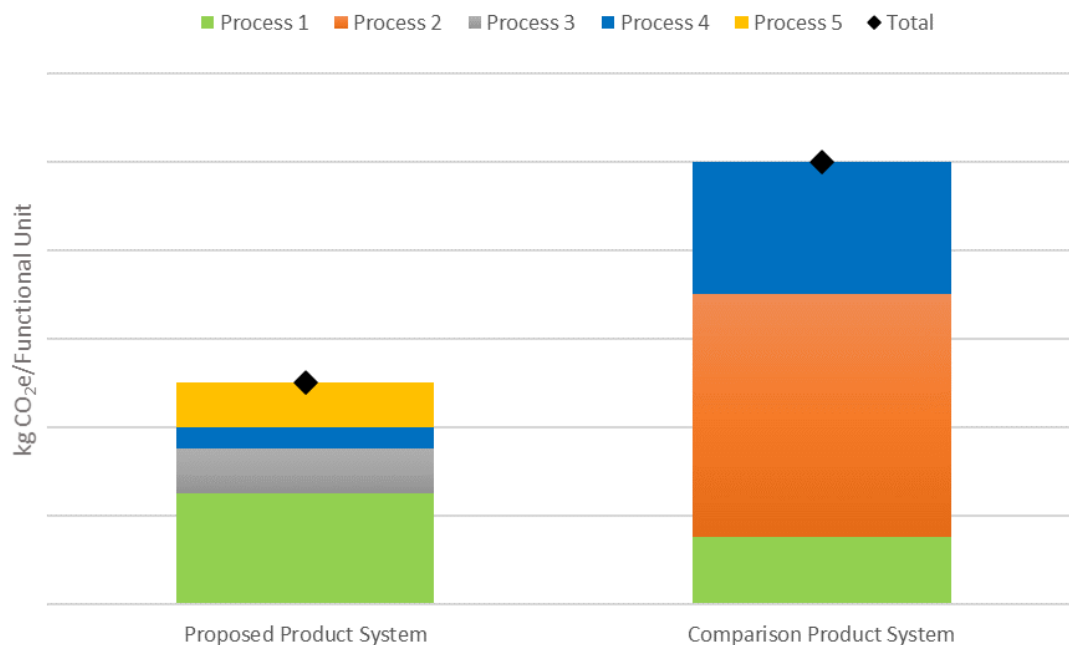
Additionally, Section 2.2.2.6 of the CO2U Guidance, which is not superseded by this addendum, provides information on when the use of proxy data requires a sensitivity analysis. This section states that documentation and a sensitivity analysis are required to evaluate data gaps.

Uncertainty analysis is not required for the 45Q LCAs. However, if the applicants choose to use a stochastic modeling method, such as Monte Carlo analysis, they must be consistent in using the mean or the median as the expected value for all product systems. For example, if the applicants choose to use the median value for the Proposed Product System, they must also use the median value for the Comparison Product System.

2.1.9.3 Reporting Units and Methods of Comparison (Direct Replacement)

All results shall be documented in the report according to the guidance outlines in Section 6.0 of this addendum. Applicants shall generate a contribution analysis and display results as a stacked bar chart that includes the Proposed Product System and the Comparison Product System as shown in Exhibit 2-26.

Exhibit 2-26. Stacked Bar Example Figure



See Section 4.0 of the NETL CO2U LCA Guidance Document for information on how to use the contribution tree provided in openLCA results to display the contribution analysis in a stacked bar chart. For the purposes of this guidance, applicants shall generate a stacked bar chart that is

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delineated by unit process and include at least unit processes that contribute 10 percent or more to the total life cycle GWP impacts.

In addition to the stacked bar chart, applicants shall report the life cycle GWP results in a table. The organization of the table should make clear the organization of the contribution analysis in the stacked bar chart (e.g., the aggregation is at the same level or clearly indicates how more granular data is aggregated). Applicants shall calculate the difference between the Proposed Product System and the Comparison Product System life cycle GWP results and display the value in the table. The difference shall be calculated as follows for the life cycle GWP:

$$\text{Difference} = \text{Total Proposed Product System GWP Impact} - \text{Total Comparison Product System GWP Impact}$$

A negative difference value indicates a decrease in emissions from the Proposed Product System relative to the Comparison Product System. A positive difference value indicates an increase in emissions from the Proposed Product System relative to the Comparison Product System, and indicates that there is zero qualified carbon oxide.

The key metric of 45Q LCAs is the LC 45Q DF, which represents a ratio of the amount of CO₂ equivalents (CO₂e) displaced to the amount of carbon oxides captured and utilized. The LC 45Q DF may be determined using one of the equations below. Equation 1 should be used if the GWP impact results presented in the bar chart and table (described above) have been scaled to 1 metric ton of captured and utilized carbon oxide. Equation 2 should be used if the GWP impact results presented in the bar chart and table are scaled to the functional unit.

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

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

2. Calculated using GWP impact values scaled to the functional unit.

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

Once the LC 45Q DF has been calculated, the minimum of 1 and the calculated DF value will represent the amount of qualified carbon oxide an applicant will receive a tax credit for (i.e., the maximum DF value is 1). In the example below, which uses Equation 2 above, the calculated DF of 1.5 is greater than 1, thus the DF is reported as the maximum value of 1. If the DF value is less than 1, the DF is reported as calculated. To further explain the application of the LC 45Q DF, if an applicant calculates a DF of 0.75, for every 1 metric ton of carbon oxide captured and utilized, the applicant will have 0.75 metric tons of qualified carbon oxide and will therefore receive a 45Q credit for the 0.75 metric tons qualified carbon oxide.

$$LCA\ 45Q\ DF = \frac{150,000\ MT\ CO_2e - 250,000\ MT\ CO_2e}{100,000\ MT\ CO_2} * -1$$

$$LCA\ 45Q\ DF = 1.50; \text{ if } LCA\ 45Q\ DF > 1, \text{ final } LCA\ 45Q\ DF = 1$$

2.1.10 Co-product Management Procedures (Additional Section)

Product systems that produce more than one product require co-product management, such as partitioning, system expansion, or allocation. ISO 14044 Section 4.3.4.2 directs practitioners to avoid allocation wherever possible. The first option is to partition all unit processes in the Product System into sub-processes, and to assign a product to each sub-process. For complex systems that have a high degree of integration, partitioning is often not feasible. The next option to avoid allocation is system expansion. With system expansion, the Product System includes all co-products, resulting in a multi-product functional unit, and one product is assigned as the primary product of interest upon which the system is based. The co-products are thereby scaled to the main product of the Product System. (e.g., 1 kg of primary product A, X kg co-product B, and Y kg co-product C). For the purposes of this guidance and LCA for 45Q, the primary product does not have to be scaled down to 1 unit (i.e., 1 kg or 1 kWh) and the co-products do not have to be scaled according to 1 unit of the primary product. For example, the multi-product functional unit may be left as the total production of the primary product and co-products from the Proposed Product system for the relevant tax year (i.e., 500 kg primary product A, 250 kg co-product B, and 200 kg co-product C, as produced by the Proposed Product System in 2020).

System expansion is the recommended co-product management procedure for 45Q LCAs and is the co-product management method described throughout this guidance. The products and/or functions of the expanded Proposed Product System are used to define the products and/or functions of the Comparison Product System.

Notably, this presents a challenge for carbon oxide utilization systems that have captured CO₂ as a co-product. Many Proposed Product Systems in 45Q LCAs will produce CO₂ as a co-product in larger quantities than the Comparison Product System and must expand the Comparison Product System to match the function of this additional CO₂ co-product. This is often the result of a carbon oxide capture rate in the Proposed Product System that is higher than the carbon oxide capture rate in the Comparison Product System. In this case, system expansion may be challenging due to the complexity of carbon oxide production. For example, market CO₂ is produced from many industrial sources that are difficult to characterize and produce additional products that must also be managed with system expansion or other co-product management approaches.

To overcome this challenge, NETL has developed a market CO₂ production unit process that represents the U.S. average GHG technology. This unit process can be used to expand the Comparison Product System and produce an additional amount of CO₂ co-product such that the Comparison and Proposed Product System produce an equal amount of CO₂ co-product.

An alternative system expansion approach, referred to as substitution, involves the subtraction or displacement of the impacts associated with producing a co-product. In the case of CO₂ co-product, substitution can be applied to the Proposed Product System, using the same U.S. average GHG market CO₂ production unit process, but instead of “adding” its impacts to the Comparison Product System, the impacts of the CO₂ co-product are “subtracted” from the Proposed Product System. Both approaches to system expansion can be applied to achieve

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functional equivalence (equal amounts of CO₂ co-product) for the Proposed and Comparison Product Systems.

Substitution may also be used to “subtract” CO₂ co-product from the Proposed and Comparison Product Systems such that it is no longer part of either systems’ functional unit. However, it’s important to note that substitution or displacement is a method that assumes that an existing market product will be substituted with the product from the carbon oxide utilization process, so the products must be comparable, and the substitution must be justified.

For the purposes of this guidance, the use of the term “waste” should be avoided when referring to carbon oxide. Carbon oxide emitted into the atmosphere should be referred to as an emission and should be modeled as an elementary flow. Carbon oxide that is captured and utilized, as is the case for 45Q, must be referred to as a product and modeled as a technosphere flow. Carbon oxides that are captured but not utilized or emitted into the atmosphere must be treated as a technosphere co-product and must be considered in the multi-product functional unit.

Carbon oxides used as a tertiary injectant in enhanced oil recovery (EOR) or natural gas recovery should be treated as a co-product and should follow the appropriate co-product management methods described in the NETL CO₂U LCA Guidance Document and this addendum (i.e., system expansion). The expanded system, which includes the carbon oxides destined for EOR, may be truncated at carbon oxide production. This truncation assumes that the use phase (i.e., injection) is the same in the Proposed and Comparison Product Systems. The carbon oxides in the Comparison Product System may be from another source such as natural well CO₂ which is frequently used in EOR operations. Carbon oxides sent to be disposed of in secure geological storage (i.e., saline aquifer) should be treated as a waste with the waste management operations, including energy used for storage, included in the system boundary.

The denominator of the LC 45Q DF calculation (see Section 2.1.9.3) of this addendum should only include the carbon oxide that is captured and utilized as noted in 26 CFR § 1.45Q-4. It should not include any carbon oxide that is used as a tertiary injectant or sent to secure geological storage, which are reported separately for the purposes of 45Q.

If system expansion cannot feasibly be applied, allocation may be performed. All co-product management decisions must be documented and justified. Allocation methods must be consistent within a unit process and applicants should strive for reasonably consistent allocation methods across a product system.

2.2.2.2 Environmental Inventory Data (Direct Replacement)

Emissions and other output data in unit processes are ultimately linked to an impact assessment method (see Section 2.1.8) to calculate environmental impacts, so it is imperative to report all relevant outputs in each unit process. For the purposes of this guidance, applicants shall report the relevant GHG emissions in [Table A-1 of 40 CFR Part 98, Subpart A](#) for each unit process created for their LCA. Additionally, significant direct and indirect land use should be reported in land area (e.g., m²) to determine the global warming potential derived from it.

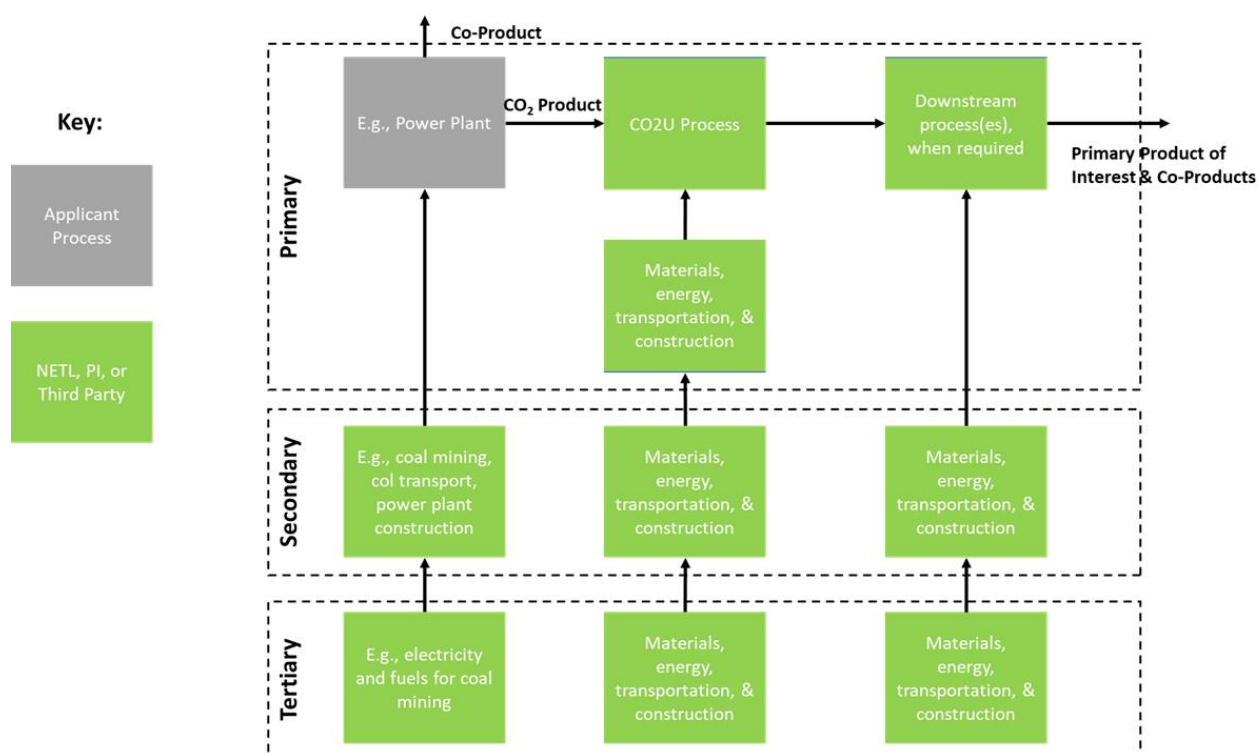
2.2.2.3 Unit Process Data Development Approaches (Direct Replacement)

The development of data for life cycle models is a time-consuming process that requires knowledge to understand the product system and unit processes within the product system (background in science and engineering is an added advantage in this case), the willingness to gather information from disparate sources and normalize it to a common basis, and the ability to translate real-world phenomena into mathematical relationships.

Development and selection of unit process data is a balance between data quality, utility, and time and resources to create custom models. In the field of LCA, there is no distinction between “good” and “bad” data, only “fit for purpose” based on the goal and scope of the study. For this addendum, the expectation is that the applicants will develop custom, parameterized unit process or unit processes of all operations within the operational control of the applicant.

Exhibit 2-23 illustrates this point and defined nomenclature related to primary, secondary, and tertiary unit processes within a typical LCA study. Four general methods for data development are described in the following sections.

Exhibit 2-23. Unit Process Development Minimum Expectations and Nomenclature



Process Based (Bottom Up)

The bottom-up approach uses engineering and other relationships to calculate the energy or material flows of an activity. For example, a bottom-up calculation of the CO₂ emissions from pipeline compressors would factor variables for the thermodynamic properties of fluid compression, compressor efficiency, spacing between compressors, pipeline pressure drop, split between natural gas and electricity use by pipeline compressors, combustion chemistry for natural gas, and flow rate of natural gas through the pipeline.

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In the NETL CO₂ compression unit process, the power required to pump the CO₂, is calculated using the Equation 2-3 found in literature [21]. [22]

$$Power = \frac{1000 * 10}{24 * 3600} * \frac{CO_2 \text{ flow rate} * (Pressure_{final} - Pressure_{cut-off})}{CO_2 \text{ density} * pump \text{ efficiency}}$$

The energy used for compression uses a set of equations with similar parameters from the same reference. Water use and CO₂ emissions were calculated using emissions factors and data from existing cooling towers. By tying these calculations to a common basis — 1 kg CO₂ ready for pipeline transport — a complete unit process is developed. Additionally, the various components and assumptions as part of the bottom-up calculation can be parameterized for the purposes of sensitivity and uncertainty analysis.

System Based (Top Down)

The top-down approach uses data from outside the boundaries of a process to calculate energy and material flows. In contrast to the bottom-up calculation of pipeline emissions described above, a top-down calculation of CO₂ emissions from pipeline compressors could use national inventories or corporate CO₂ emissions reported by pipeline operators, divided by the corresponding carbon dioxide throughput, to arrive at a similar emission profile.

The top-down method is accurate (presuming that the source data are accurate). However, top-down unit processes are not as flexible as bottom-up unit processes as they lack parameters. If the goal of an LCA is to calculate total burdens for a product, then top-down unit processes are sufficient. But if the goal of an LCA is to drill down to the sub-process level and use parameters to test system dynamics, then top-down data will not be sufficient.

Black Box

A black box unit process is developed from a set of data that completely describes the inputs and outputs of a process. The black box approach is the most straightforward approach to developing a unit process. Black box unit processes often represent a series of integrated processes that have been aggregated to avoid complexity or to obfuscate proprietary data. For example, carbon capture from a concentrated CO₂ stream and the process that produces the CO₂ stream will often be aggregated into a black box unit process. The black box approach results in obscured unit process details as individual flows and values are not shown, and in the case of process aggregation, some flows are internal to the black box and are not represented in input and output flows. Therefore, proper documentation is essential to maintain transparency and consistent interpretation of the data, and to allow for a thorough LCA review.

One limitation of the black box approach is that complete data sets that align exactly with the boundaries of a unit process are rarely available. Another limitation of black box unit processes is that they have limited applicability. They are based on specific technologies and do not have parameters that allow them to be adapted to other technologies. Therefore, the use of a black box approach should be limited to the Comparison Product System unless details of the process in the Proposed Product System are truly unknown. Concerns of confidential and proprietary data are not reasonable justifications to exclude details from the Proposed Product System via a black box unit process. Section 2.1.1 of this addendum contains additional information on the handling of LCA materials submitted for 45Q.

Economic Input-Output Data

Unit processes may also be developed using an economic input-output (EIO) model. One example of an EIO model that may be used for LCA is the [U.S. Environmentally-Extended Input-Output \(USEEIO\) model](#) published by the EPA. If the amount and relative cost of a material, feedstock, or fuel needed for a unit process is known, the EIO model calculates the LCI data for that unit process based on its impact through the U.S. economy. The advantage of this method, besides being publicly available and relatively easy to use, is that when the EIO method is used to collect data for a secondary or tertiary unit process, all subsequent high-order flows are also captured in that data giving a conservative estimate of impacts. Thus, the EIO model provides the most efficient method to capture data as close to the elementary flows for a system as possible.

The disadvantage of the EIO approach is the large range of uncertainty associated with flow values due to data vintage and vague descriptions, which are often not specific enough for LCA. Because of this, EIO models are not permitted for primary or secondary unit processes.

2.2.2.5 Land Use Change (Additional Guidance)

The NETL unit processes for modeling land use change are not required to be used by applicants, but the choice of land use change modeling shall be justified in the report. Unit processes for modeling land use change may be found in [NETL's Unit Process Library](#). Additionally, GHG emissions resulting from land use change should be documented as a separate category of emissions for the graphs and tables specified Section 2.1.9.3.

2.2.3.1 Completeness Checks (Direct Replacement)

An engineering-based carbon and energy balance must be conducted across the life cycle system boundary of the Proposed and Comparison Product Systems to determine the level of completeness. Completeness shall be demonstrated by the inclusion of at least 99% of the carbon inputs and outputs to the Product System. Though it is not explicitly required to include at least 99% of the energy inputs and outputs to the Product System, the applicant must document all energy inputs and outputs, and the completeness of the energy balance. In addition, completeness shall be tested by determining if the omission of secondary or tertiary unit processes from the system boundary would change the environmental impact result for the Product System by more than 1%. If more than one unit process is excluded, the sum of the exclusions shall change the result less than 1%.

Noted deficiencies in completeness shall be resolved through additional data collection and/or documented as a key data limitation to inform the results interpretation. The results of the completeness check, including the carbon and energy balances, shall be documented and shall contain a statement describing that the completeness was tested and the degree to which the completeness does or does not affect the results of the LCA. It's important to note that the critical review may identify errors or data which are not of sufficient quality or representativeness but changing these items does not change the GWP impact results by greater than 1%. Such errors would be considered "immaterial" and would not affect the acceptance of the submitted LCA.

2.3 IMPACT ASSESSMENT (DIRECT REPLACEMENT)

LCAs submitted for the 45Q tax credit are required to measure impacts based on the global warming potential factors in [Table A-1 of 40 CFR Part 98, Subpart A](#). These factors are used in the Greenhouse Gas Reporting Protocol (GHGRP) by the U.S. Environmental Protection Agency. Within the NETL CO2U LCA Guidance Toolkit openLCA Database the corresponding GWP values from [Table A-1 of 40 CFR Part 98, Subpart A](#) as “GHGRP GWP” factors. No other impact categories are required for this analysis. The elementary flows from the openLCA version 1.10.3 reference flows were matched to the table using first Chemical Abstract Service (CAS) number where provided, then flow name, and then chemical formula where provided. The resulting impact factors are included in the openLCA database.

2.3.1 Data Quality Assessment (Direct Replacement)

A critical component of the life cycle impact assessment is an evaluation of the data quality. The applicant must document the source of all data used in the LCA and must describe the source and how it is representative of the relevant unit process. The applicant must describe how the data is representative of the geographical and temporal boundaries identified in the goal and scope of the LCA. The applicant shall describe any known data limitations or omissions of inventory data that may affect the GWP impact result. Noted deficiencies shall be resolved through additional data collection and/or documented as a key data limitation to inform the results interpretation.

2.4.5 Critical Review (Direct Replacement)

ISO Technical Specification (ISO/TS) 14071 (Environmental management – life cycle assessment – Critical review processes and reviewer competencies: Additional requirements and guidelines to ISO 14044:2006) provides additional guidance regarding the ISO 14044 critical review statements. Specifically, ISO/TS 14071 addresses the scope of reviews and competencies of the reviewer(s). For the purposes of 45Q, all applicant LCAs will be subject to a critical review in accordance with ISO/TS 14071 as modified by the additional guidance below.

- Per 26 CFR § 1.45Q-4(c)(4), this critical review can be provided by an independent third party. If the critical review is not provided by an independent third party, then the U.S. DOE NETL will perform the critical review pursuant to § 1.45Q-4(c)(6).
- ISO 14044 specifies two different types of critical reviews: expert review (Section 6.2) or a panel review (Section 6.3). An expert review satisfies the critical review requirement for 45Q. A panel review may also be used but will be treated the same as an expert review.

Further, the following items shall also be included in the scope of the review and confirmed in the critical review report:

- An assessment of the LCA model and an assessment of the individual datasets, including an assessment of the geographical, temporal, and technological representativeness relative to the stated goal and scope of the LCA.

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- Calculation and reporting to confirm adequate closure of the carbon and mass balances are defined by the CO2U LCA Guidance Document. This means that the input-output gap in the carbon and mass balances can be related to potential changes in the DF. A mass balance should ensure a table of process flows relating to the system boundary diagram. An energy balance is optional but can be included for transparency. Closure requirements for mass and energy balances do not necessarily need to be met but reasoning should be provided.

In addition to the reviewer competencies defined in ISO/TS 14071, reviewers shall be familiar with the requirements of the NETL CO2U LCA Guidance Document as modified by this addendum. In addition to the scope of the review defined in ISO/TS 14071, the critical review shall ensure that the LCA conforms with the requirements of the NETL CO2U LCA Guidance Document as modified by this addendum. Applicant reports that are submitted with independent, third-party critical reviews will still be subject to a technical review by the DOE, in accordance with 26 CFR § 1.45Q-4(c)(6). For these reports, DOE will perform a conformance review to determine whether the LCA conforms to the standards of ISO 14040/14044 and the NETL CO2U LCA Guidance Document as modified by this addendum and that the critical review conforms to ISO 14044/14071. Note that the IRS may still request a more in-depth critical review by the DOE.

If the applicant is resubmitting after receiving comments on a previous submission, they must include a table at the beginning of the LCA report that contains a "Response to Previous Comments". The table shall consist of the original Reviewer Comments, Reviewer Recommendations, and a column with the Applicant Responses. Each Applicant Response will address how each of the comments have been resolved. This table will be referenced by reviewers when determining if the applicant's response to the reviewer comment and recommendation is sufficient.

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Exhibit Addendum-1. IRS/DOE Technical Review Type for Independent, Third-Party Critical Review Scenarios

Who Performs the LCA?	Independent Third-Party Statement Required?	Who Can Sign the Independent Third-Party Statement?	IRS/DOE Technical Review Requirement
Applicant or Claimant (in-house)	Yes	Professional license not affiliated with the Applicant or Claimant	Conformance
Consultant hired by applicant or claimant	Yes	Professional license with the Consulting company that performed the LCA	Critical
Consultant hired by applicant or claimant	Yes	Professional license not affiliated with the Applicant or Claimant or Consultant hired to perform the LCA	Conformance

Note, per the regulation, Applicant LCA reports must be performed or verified by an independent third party before submission to the IRS/DOE for review.

3.0 USING OPENLCA FOR CO2U 45Q LCA (DIRECT REPLACEMENT)

openLCA is an LCA software platform. openLCA makes it easier to include more inventory data, apply an impact assessment method, and include uncertainty and sensitivity parameters in an analysis than it would be in a spreadsheet model. NETL has created an openLCA database, referred to as the “NETL CO2U openLCA LCI Database,” that includes an example LCA and NETL unit processes. Appendix A provides instructions on where to download a free copy of the openLCA software and the NETL CO2U LCI Database. Details on accessing openLCA modeling support are also available in Appendix A.^c

The openLCA [website](https://openlca.org/) provides free resources such as manuals and presentation on openlca.org/learning for general openLCA support. This section will only include CO2U-specific mechanics and the conventions necessary to ensure submissions are useful and consistent. The following sections will describe how to organize the database, utilize NETL-provided processes, build and run CO2U product systems and projects, and display and compare results.

3.4 PERFORMING A PRODUCT SYSTEM ANALYSIS (DIRECT REPLACEMENT)

After creating product systems in openLCA for the Proposed Product System and Comparison Product System, open the product system in an editor window. Check the “Model graph” and “Parameters” tabs to ensure the information in the product system is correct. On the “General information” tab, click the “Calculate” button. When the pop-up window appears, select the following options:

- For the Impact assessment method, select “GHGRP GWP”
- For the Calculation type, select “Analysis”
 - If the applicant is using openLCA 2, select “Eager/All”
- Then select “Finish”

The analysis required by this guidance does not include selecting an allocation method or normalization and weighting set. Choosing these options without having previously modeled these methods can result in errors and null values that should not be null. See Exhibit 3-8 for available choices in the pop-up window.

The resulting analysis will have several tabs with results, and easy-to-use automatic tables and graphs useful for exploring and understanding the modeled Product System. Assess the Inventory results, Impact results, Process results, and Sankey diagram to check for any results which could point to errors in the model. The Contribution tree presents a breakdown of the major contributors to the selected flow or impact category that can be further expanded if

^c Note that real-time training on openLCA and the NETL CO2U LCA Guidance Toolkit is only available to U.S. DOE Carbon Utilization Program Pls. Applicants under 26 CFR § 1.45Q-4 are not eligible for these trainings unless they are also a U.S. DOE Carbon Utilization Program Pl. Any requests or questions regarding 45Q LCA applications must be submitted to 45QLCA@hq.doe.gov.

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more resolution is required. The Contribution tree can be copied into the NETL CO2U LCA openLCA Results Contribution Tool to generate figures for the 45Q LCA Report.

Exhibit 3-8. Pop-up Window Choices for Product System Calculation in openLCA Version 1 (left) and Version 2 (right).

The image displays two side-by-side screenshots of the 'Calculation properties' dialog box in openLCA, comparing Version 1 (left) and Version 2 (right).

Version 1 (Left):

- Allocation method:** None
- Impact assessment method:** GHGRP GWP
- Normalization and weighting set:** (empty)
- Calculation type:** ☐ Quick results ☒ Analysis ☐ Regionalized LCIA ☐ Monte Carlo Simulation
- ☐ Include cost calculation
- ☐ Assess data quality

Version 2 (Right):

- Allocation method:** None
- Impact assessment method:** GHGRP GWP
- Normalization and weighting set:** (empty)
- Calculation type:** ☐ Lazy/On-demand ☒ Eager/All ☐ Monte Carlo Simulation
- ☐ Regionalized calculation
- ☐ Include cost calculation
- ☐ Assess data quality

5.0 USING THE NETL ~~CO2U~~ 45Q LCA DOCUMENTATION SPREADSHEET FOR DOCUMENTATION (DIRECT REPLACEMENT)

If an applicant elects to not use openLCA or another LCA modeling software, a spreadsheet model may be used. This section provides guidance on how to use the NETL CO2U LCA Documentation Spreadsheet to provide unit process and Product System documentation when the applicant uses a spreadsheet model. See Section 1.5 of the NETL CO2U Guidance Document and Section 1.5 of this addendum for details on modeling options and required methods to ensure study transparency.

5.1 OVERVIEW (DIRECT REPLACEMENT)

The following guidance applies only when the NETL CO2U LCA Documentation Spreadsheet is being submitted in place of an openLCA model or a model from another LCA modeling software. An NETL CO2U LCA Documentation Spreadsheet shall be completed for each Product System. The NETL CO2U LCA Documentation Spreadsheet includes a “Product System Overview” worksheet, “UP Template” worksheet, “NETL Unit Process Data” worksheet, and “GWP Impact Factors” worksheet. One “Product System Overview” worksheet shall be completed for each NETL CO2U LCA Documentation Spreadsheet completed. The “UP Template” worksheet is for documenting each unit process in the Product System that is not an accessible, third-party unit process. For each unit process, a copy of a blank UP Template shall be made and completed. The “NETL Unit Process Data” worksheet represents the NETL unit process data that applicants may use, which is also available in the NETL CO2U openLCA database. The “NETL Unit Process Data” worksheet should not be modified as it is a data repository for applicant use and does not require applicant input. The “GWP Impact Factors” worksheet contains two tables: one for NETL CO2U LCA and one for 45Q. For the purposes of this guidance, the table for 45Q applicants (GHGRP GWP Impact Factors) must be used for impact assessment as the factors provided are from [Table A-1 of 40 CFR Part 98, Subpart A](#).

5.5 NETL UNIT PROCESS DATA AND GWP IMPACT FACTORS WORKSHEETS (DIRECT REPLACEMENT)

The “NETL Unit Process Data” worksheet contains life cycle impacts using alternative GWP factors (AR5 100-yr, for NETL CO2U LCA). The worksheet also contains life cycle impacts using the GWPs from [Table A-1 of 40 CFR Part 98, Subpart A](#). The applicant must use the life cycle GWP impacts that were calculated using the GWPs from [Table A-1 of 40 CFR Part 98, Subpart A](#) (GHGRP GWP).

6.0 COMPLETING THE NETL ~~CO2U~~ 45Q LCA REPORT TEMPLATE (DIRECT REPLACEMENT)

Documenting the LCA study in a clear and consistent manner is important to effectively communicating the results. There are various strategies and approaches to documenting LCA results. To ensure consistency, a standardized report template is provided. The goal is to ensure a minimum level of documentation to effectively communicate the goal of the study, how the study was conducted, and how the results should be interpreted. The NETL 45Q LCA Report Template is provided to assist in the documentation process. Applicants shall consider the report template a “guide” and add additional documentation or analysis necessary to effectively communicate the study results.

The following sections describe what to include in each section of the NETL 45Q LCA Report Template. The basis for this report is Section 5.2 of ISO 14044. Where applicable, default text that aligns with 45Q guidance stated in this addendum is recommended within the report template. As defined within this addendum, the applicants shall document and report the Proposed and Comparison Product Systems. Any alternative Product Systems recommended by the applicants for consideration by NETL must be accompanied by justification for why NETL should consider these alternatives. The proceeding sections describe the reporting requirements for the Proposed and Comparison Product Systems, any additional Product Systems recommended by the applicants shall follow the same level of documentation.

APPENDIX A: ACCESSING THE NETL CO2U 45Q LCA TOOLKIT AND RESOURCES FOR ASSISTANCE (DIRECT REPLACEMENT)

The NETL 45Q LCA Guidance Toolkit includes the following:

1. NETL CO2U LCA Guidance Document outlines the analysis requirements and how to use the supporting data and tools.
2. 45Q Addendum to the NETL CO2U LCA Guidance Document outlines the analysis requirements and how to use the supporting data and tools, and modifies the guidance provided in the NETL CO2U LCA Guidance Document for 45Q applicants.
3. NETL CO2U openLCA LCI Database is an openLCA database that includes NETL unit process data and an example CO2U LCA.
4. NETL CO2U openLCA Results Contribution Tool is an Excel template that translates openLCA results into required charts.
5. NETL CO2U LCA Documentation Spreadsheet is an Excel file that can be used to document data when not using openLCA.
6. NETL 45Q LCA Report Template is a Word report template for summarizing data and results, including a modified version for 45Q applicants. The template includes guidance on completing each section of the report that is in conformance with this addendum.

NETL CO2U LCA Subject Matter Expert Support and Training Resources are not available as part of the NETL 45Q LCA Toolkit. Therefore, all questions related to 45Q LCAs submitted to DOE shall be directed to LCA45Q@hq.doe.gov. Requests to DOE or NETL staff directly will not be addressed. [Frequently Asked Questions and Additional Resources](#) are available on the NETL website.

The entire contents of the NETL 45Q LCA Toolkit can be accessed at the following URL:

<https://netl.doe.gov/LCA/CO2U/45Q>

The openLCA software can be downloaded at the following URL:

<https://www.openlca.org/download/>

APPENDIX B: U.S. DOE TECHNOLOGY READINESS LEVELS (DIRECT REPLACEMENT)

Appendix B of the NETL CO2U LCA Guidance Document does not apply for the purposes of this guidance and 45Q LCAs.

APPENDIX C: ALTERNATIVE CO-PRODUCT MANAGEMENT METHODS (ADDITIONAL GUIDANCE)

Appendix C of the NETL CO2U LCA Guidance Document is provided for information only. For the purposes of this guidance and 45Q, system expansion must be used wherever possible (see Section 2.1.7 of this addendum). Any use of the allocation methods covered in this Appendix C of the NETL CO2U LCA Guidance Document must be justified in the 45Q LCA report.

APPENDIX D: ELECTRICITY MIX DATA DEVELOPMENT (DIRECT REPLACEMENT)

Appendix D NETL CO2U LCA Guidance Document, Sections D.1-D.3 do not apply for the purposes of this guidance and 45Q LCAs. Section D.4 NERC Region Electricity Consumption Mix LCI Data remains unchanged.

APPENDIX G: NETL CO2U GUIDANCE AND 45Q ADDENDUM CROSSWALK (ADDITIONAL SECTION)

Exhibit G-1. Summary of modifications to the NETL CO2U Guidance Document by the 45Q Addendum. shows a summary of the sections in the NETL CO2U Guidance Document and the modifications to those sections by this guidance, the 45Q Addendum. Sections of the NETL CO2U Guidance Document modified by the 45Q Addendum are highlighted in green. Sections labelled as “no modification” must be adhered to for the purposes of LCA for 45Q and can be referred to in the NETL CO2U Guidance Document.

Exhibit G-1. Summary of modifications to the NETL CO2U Guidance Document by the 45Q Addendum.

Section Number	Section Header	Modification to CO2U Guidance by 45Q Addendum
1.0	INTRODUCTION	Additional Guidance
1.1	INTRODUCTION TO LCA	No Modification
1.2	DOCUMENT GOALS	Direct Replacement
1.3	WHAT IS INCLUDED IN THE NETL CO2U LCA GUIDANCE TOOLKIT	Direct Replacement
1.4	HOW TO USE THIS DOCUMENT AND TOOLKIT	No Modification
1.5	MODELING AND DOCUMENTATION OPTIONS FOR U.S. DOE CARBON UTILIZATION PROGRAM PROJECT PIS	Additional Guidance
2	OVERVIEW OF THE LCA STEPS AND METHODS REQUIRED FOR U.S. DOE CARBON UTILIZATION PROGRAM PROJECTS	No Modification

NETL 45Q ADDENDUM TO THE CO2U LCA GUIDANCE TOOLKIT

Section Number	Section Header	Modification to CO2U Guidance by 45Q Addendum
2.1	GOAL AND SCOPE DEFINITION	No Modification
2.1.1	LCA STUDY GOAL	Direct Replacement
2.1.2	PRODUCT SYSTEM DESCRIPTION	No Modification
2.1.3	FUNCTIONAL UNIT OF THE STUDY	Additional Guidance
2.1.3.1	PROPOSED PRODUCT SYSTEM	No Modification
2.1.3.2	COMPARISON PRODUCT SYSTEM	Direct Replacement
2.1.4	SYSTEM BOUNDARY	Direct Replacement
2.1.5	CARBON DIOXIDE SOURCE	Direct Replacement
2.1.5.1	FLUE GAS DIVERSION OPTION	No Modification
2.1.5.2	CAPTURED CO2 OPTIONS	No Modification
2.1.6	DATA REPRESENTATIVENESS	No Modification
2.1.6.1	TECHNOLOGY REPRESENTATIVENESS	No Modification
2.1.6.2	GEOGRAPHICAL REPRESENTATIVENESS	Direct Replacement
2.1.6.3	TEMPORAL REPRESENTATIVENESS	Additional Guidance
2.1.7	ALLOCATION PROCEDURES	No Modification
2.1.8	LIFE CYCLE IMPACT ASSESSMENT METHODS FOR RESULTS INTERPRETATION	Direct Replacement
2.1.8.1	GLOBAL WARMING POTENTIAL	No Modification
2.1.8.2	ADDITIONAL IMPACT CATEGORIES FOR CONSIDERATION	No Modification
2.1.9	DATA REQUIREMENTS, ASSUMPTIONS, AND LIMITATIONS	No Modification
2.1.9.1	COMPLETENESS REQUIREMENTS	No Modification
2.1.9.2	SENSITIVITY AND UNCERTAINTY ANALYSIS	Direct Replacement
2.1.9.3	REPORTING UNITS AND METHODS OF COMPARISON	Direct Replacement
2.1.9.4	STUDY LIMITATIONS - DATA QUALITY ASSESSMENT	No Modification
2.1.10	CO-PRODUCT MANAGEMENT PROCEDURES	Additional Section
2.2	INVENTORY ANALYSIS	No Modification
2.2.1	MODELING PLATFORM	No Modification
2.2.1.1	OPTION 1: OPENLCA	No Modification
2.2.1.2	OPTION 2: PI SPREADSHEET MODEL	No Modification
2.2.1.3	OPTION 3: ANOTHER LCA SOFTWARE PLATFORM OR TOOL	No Modification
2.2.2	DATA COLLECTION	No Modification
2.2.2.1	UNIT PROCESS STRUCTURE	No Modification
2.2.2.2	ENVIRONMENTAL INVENTORY DATA	Direct Replacement

NETL 45Q ADDENDUM TO THE CO2U LCA GUIDANCE TOOLKIT

Section Number	Section Header	Modification to CO2U Guidance by 45Q Addendum
2.2.2.3	UNIT PROCESS DEVELOPMENT APPROACHES	Direct Replacement
2.2.2.4	EXISTING UNIT PROCESS DATASETS	No Modification
2.2.2.5	LAND USE CHANGE	Additional Guidance
2.2.2.6	PROXY DATA	No Modification
2.2.3	DATA CALCULATION AND QUALITY ASSESSMENT	No Modification
2.2.3.1	COMPLETENESS CHECK	Direct Replacement
2.2.3.2	MODEL SENSITIVITY CHECK	No Modification
2.2.3.3	ALLOCATION PROCEDURES	No Modification
2.3	IMPACT ASSESSMENT	Direct Replacement
2.3.1	DATA QUALITY ASSESSMENT	Direct Replacement
2.4	INTERPRETATION	No Modification
2.4.1	PRODUCT SYSTEM COMPARISON METHODS	No Modification
2.4.2	UNCERTAINTY AND SENSITIVITY ANALYSIS	No Modification
2.4.3	STUDY LIMITATIONS	No Modification
2.4.4	STUDY CONCLUSIONS AND RECOMMENDATIONS	No Modification
2.4.5	CRITICAL REVIEW	Direct Replacement
3.0	USING OPENLCA FOR CO2U LCA	Direct Replacement
3.1	DATABASE STRUCTURE AND ORGANIZATION	No Modification
3.2	BUILDING NEW UNIT PROCESSES	No Modification
3.3	BUILDING PRODUCT SYSTEMS	No Modification
3.4	PERFORMING A PRODUCT SYSTEM ANALYSIS	Direct Replacement
3.5	BUILDING PROJECTS	No Modification
3.6	DISPLAYING AND COMPARING RESULTS	No Modification
4	USING THE CONTRIBUTION TREE EXCEL TOOL TO TRANSLATE OPENLCA RESULTS INTO THE REQUIRED GRAPHS	No Modification
4.1	COPYING SHEET 1 FOR EACH SCENARIO	No Modification
4.2	MOVING THE CONTRIBUTION TREE TO THE EXCEL TEMPLATE	No Modification
4.3	CALCULATING RESULTS	No Modification
4.4	DETERMINING THE CONTENTS OF THE GRAPH	No Modification
4.5	GRAPHING	No Modification
4.6	CLEANING UP THE UNIT PROCESS NAMES IN THE GRAPH	No Modification
5	USING THE NETL CO2U LCA DOCUMENTATION SPREADSHEET FOR DOCUMENTATION	Direct Replacement

NETL 45Q ADDENDUM TO THE CO2U LCA GUIDANCE TOOLKIT

Section Number	Section Header	Modification to CO2U Guidance by 45Q Addendum
5.1	OVERVIEW	Direct Replacement
5.2	PRODUCT SYSTEM OVERVIEW WORKSHEETS	No Modification
5.3	UP TEMPLATE WORKSHEET	No Modification
5.4	SCREENSHOTS AND ACCOMPANYING FILES	No Modification
5.5	NETL UNIT PROCESS DATA AND GWP IMPACT FACTORS WORKSHEETS	Direct Replacement
5.6	REPORTING FOR IMPACT ASSESSMENT	No Modification
6	COMPLETING THE NETL CO2U LCA REPORT TEMPLATE	Direct Replacement
6.1	EXECUTIVE SUMMARY	No Modification
6.2	GOAL OF THE STUDY	No Modification
6.3	SCOPE OF THE STUDY	No Modification
6.4	LIFE CYCLE INVENTORY ANALYSIS	No Modification
6.5	LIFE CYCLE IMPACT ASSESSMENT	No Modification
6.6	LIFE CYCLE INTERPRETATION	No Modification
6.7	CRITICAL REVIEW	No Modification
6.8	REFERENCES	No Modification
7	REFERENCES	No Modification
Appendix A	ACCESSING THE NETL CO2U LCA TOOLKIT AND RESOURCES FOR ASSISTANCE	Direct Replacement
Appendix B	U.S. DOE TECHNOLOGY READINESS LEVELS	Direct Replacement
Appendix C	ALTERNATIVE CO-PRODUCT MANAGEMENT METHODS	Additional Guidance
Appendix D	ELECTRICITY MIX DATA DEVELOPMENT	Direct Replacement
Appendix E	NETL CO2U OPENLCA LCI DATABASE	No Modification
Appendix F	NOTES ON READING THE OPENLCA CONTRIBUTION TREE	No Modification
Appendix G	NETL CO2U GUIDANCE AND 45Q ADDENDUM CROSSWALK	Additional Section

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