LCA carbon footprint summary report for Eastman carbon renewal technology

Authors: Ben Coleman, Randy Waymire, Neil Brown, C. Jason Pierce (Eastman)

Date: June 10, 2020

BACKGROUND

Eastman is dedicated to building a circular economy that creates value from plastic waste. We are leading the way by advancing innovative recycling technologies and products, forging collaborations at local and global levels, and identifying solutions to lessen our environmental footprint. Our commitment to material circularity is grounded in the belief that plastic and textile waste can be not only eliminated but reinvented by a prescriptive, closed-loop process supported by companies, consumers, manufacturers, policymakers, and governments—working together to ensure a better world in which waste is reduced and materials are used, reused, recycled, and recreated over and over again.

Advancing material technologies and circular solutions are central to Eastman's commitment to deliver change now. Through Eastman's Advanced Circular Recycling technologies, including carbon renewal technology (CRT), we are creating value from waste. These technologies break down waste plastics into molecular building blocks and rebuild them into new materials—enabling circularity for materials that were previously destined to be discarded. We are creating new products derived from recycled content that enable companies across industry sectors to meet their sustainability commitments. We are dedicated to reducing our own environmental impact as part of our commitment to create a sustainable future by delivering value from waste and, as a result, lessening our use of fossil-based resources.

INTRODUCTION

In 2019, Eastman started commercial operation of CRT, a molecular recycling technology for waste plastics. CRT enables a diverse variety of mixed waste plastics to be chemically recycled into synthesis gas by using reforming technology. Synthesis gas (abbreviated as syngas) is a mixture of carbon monoxide and hydrogen. It is an important intermediate building block material that is further processed by Eastman to create a variety of plastic resins, fibers, and acetyl chemical products, including cellulose acetate plastics and Eastman Naia™ cellulosic fiber.

CRT breaks mixed waste plastics down to the molecular level, and Eastman recycles these molecules into new plastic and fiber products. Illustrative examples of suitable waste feedstocks for recycling in CRT include post-consumer polyester carpet fiber, pre-consumer cross-linked polyethylene scrap, and postindustrial cellulose acetate plastic scrap. These materials are not suitable for conventional recycling, and they are typically disposed of in landfills. CRT enables a new option to recycle these materials to produce new specialty plastic and fibers with no compromise in quality. CRT is currently capable of recycling a variety of waste plastic materials, including resin identification codes 1, 2, 4, 5, 6, and 7. Recycling of other materials—including waste textile fibers—is under development.

CRT is a modification which enables recycling to occur at the front end of Eastman's world-scale manufacturing system to produce syngas. CRT uses coprocessing and substitutes waste plastic for a portion of coal feedstock. Eastman's goal is to significantly increase the CRT processing capacity to transition toward maximum use of waste plastic feedstocks.

The CRT process utilizes reforming technology. Presently, coprocessing is used to allow CRT recycling operations to occur in a world-scale material production system. The basic pathway of waste plastic through reforming to make building blocks for cellulosics is shown in Figure 1.

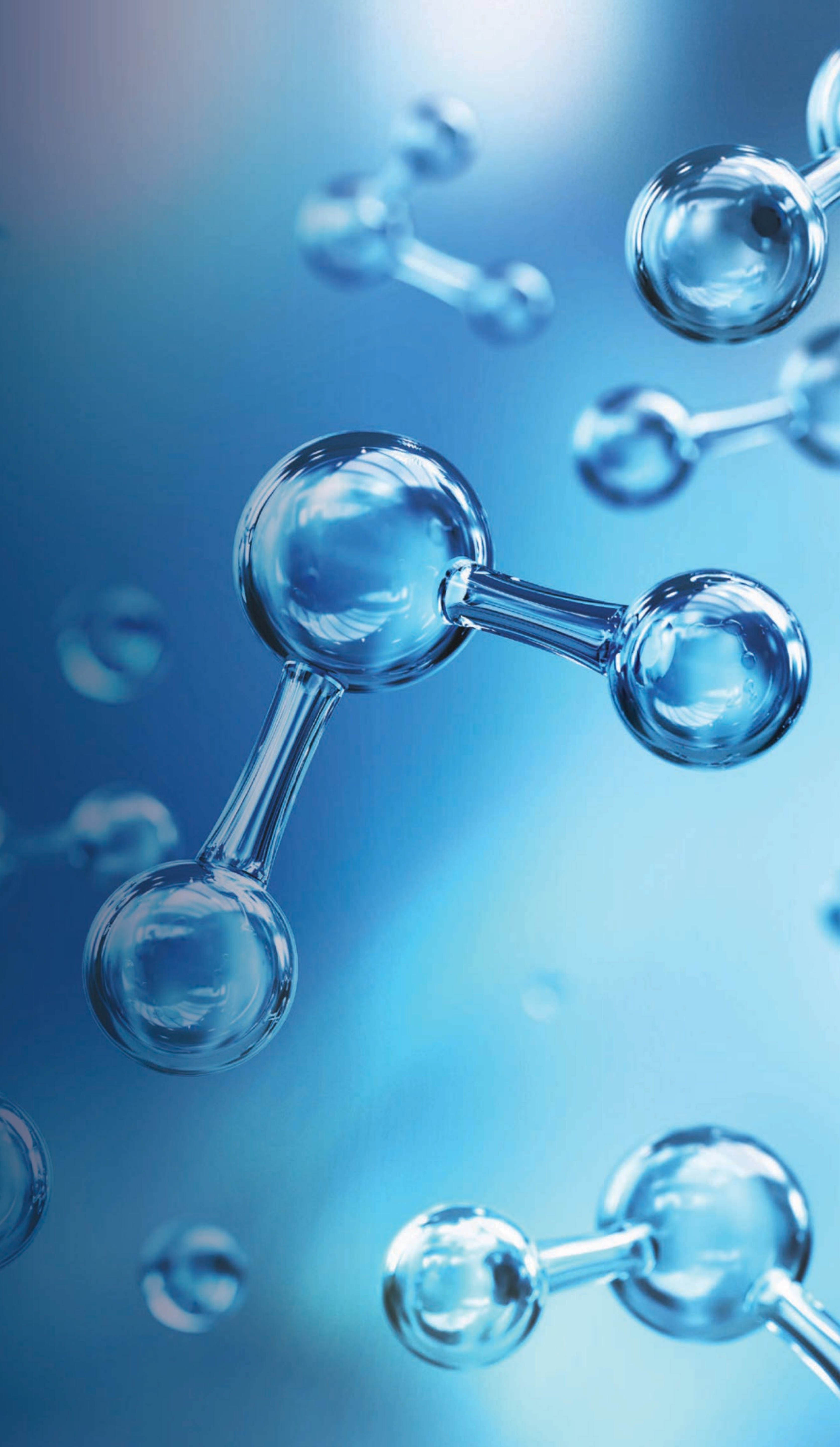
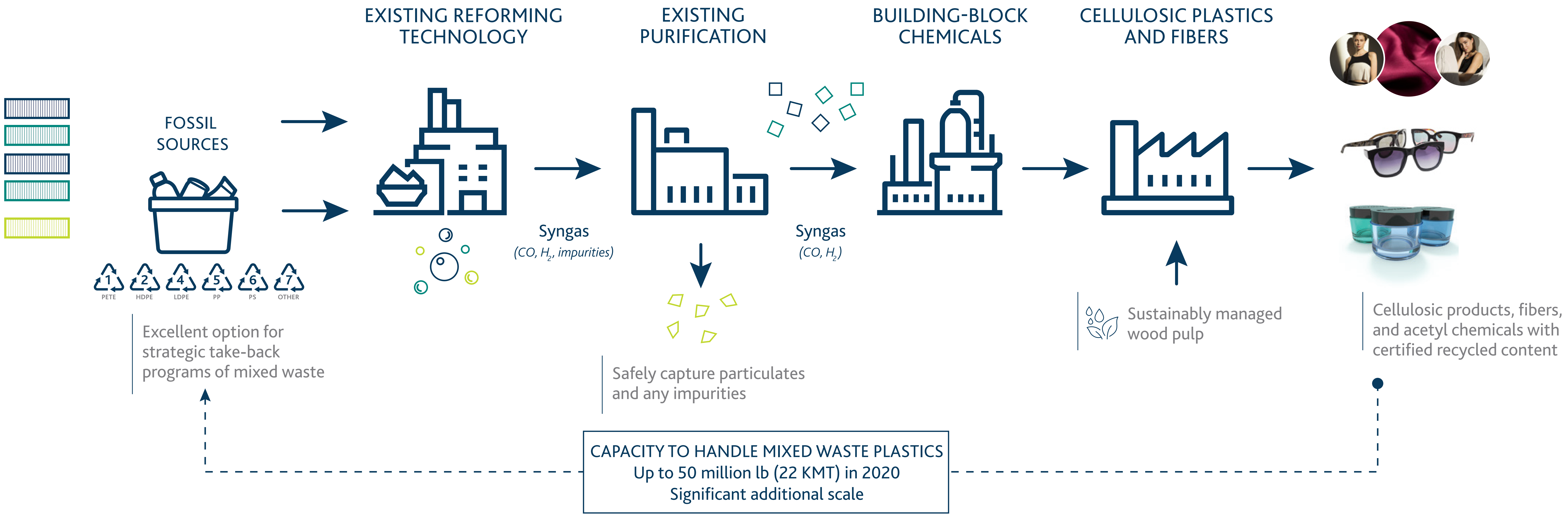


Figure 1. CRT process overview

20%–50% less GHG emissions than fossil-based syngas

REFORMING: A unique approach to converting circular feed stream into basic chemical blocks



GOALS

The goals and intended uses of this study are:

- To compare the carbon footprint of syngas produced by Eastman's commercial carbon renewal technology from recycled waste plastic to the syngas coproduced in the same Eastman facility from coal. Eastman wants to use LCA to quantify and communicate the relative greenhouse gas performance of CRT compared against conventional processing.
- To communicate to external stakeholders how syngas made by CRT from waste plastic results in an improved carbon footprint compared to equivalent syngas made from coal gasification
- To support decision making for development of waste plastic feedstock sources and supply chains
- To serve as a primary data source for the carbon footprint of downstream Eastman products derived from CRT syngas

SCOPE

Functional unit

The functional unit of this study is one kilogram of syngas (a mixture of carbon monoxide and hydrogen gas) at the specific composition, temperature, and pressure that Eastman uses to further convert into intermediates and products. The syngas made by CRT is controlled to be indistinguishable and functionally equivalent to syngas made from coal.

System boundary

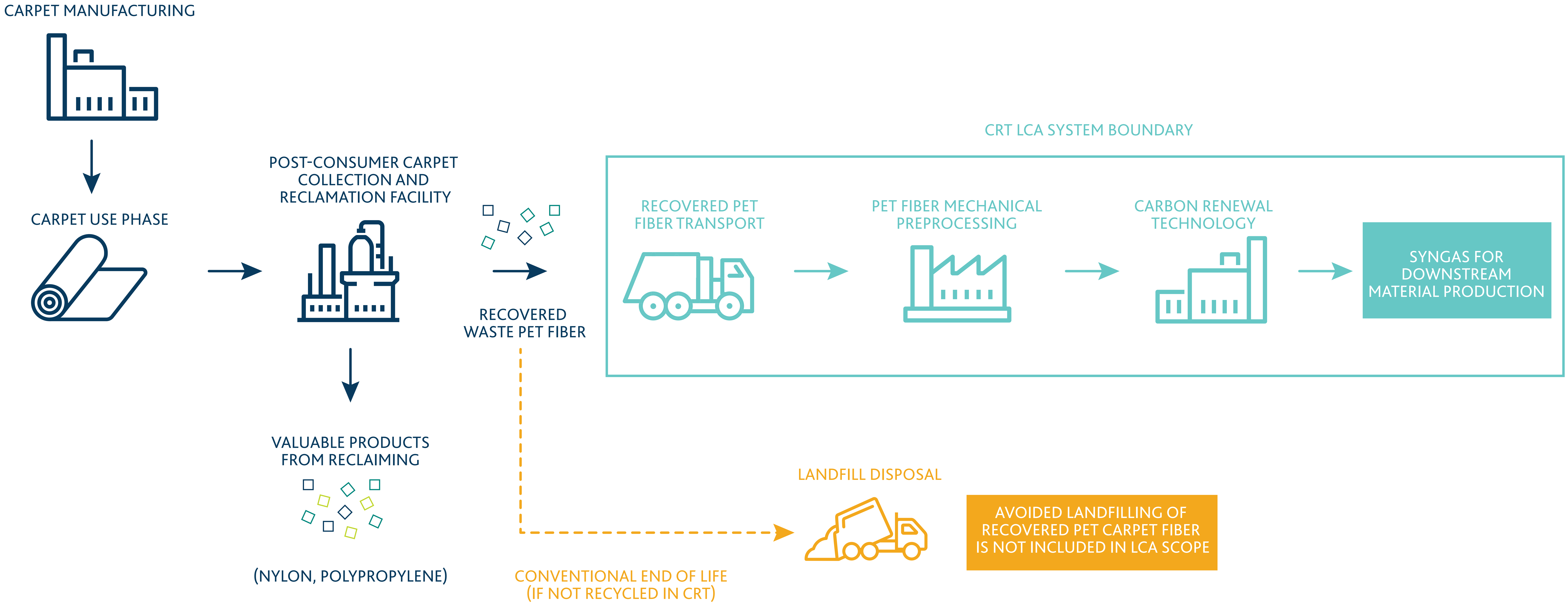
The scope of the study is cradle to syngas (cradle to intermediate), and the boundary extends from point of origin of recovered waste plastic material through production of syngas. The study includes scenarios for three different types and suppliers of waste plastic feedstock, reflecting a range of actual operational sources in 2020. An example of scope boundaries based on recycled post-consumer carpet fiber is shown in Figure 2. All relevant life cycle phases are included. Transportation of recovered waste plastic feedstocks from their point of origin, mechanical preprocessing, and CRT reforming operations are within the scope of the system boundaries. Supply of energy, utilities, and auxiliary materials are within scope. The system boundary for the scenario of conventional coal gasification includes the supply chain for coal feedstock.

Eastman does not sell syngas. It is an intermediate material used internally by Eastman to produce commercial plastics and fibers. Syngas is the most direct point of comparison to highlight the differences between CRT and conventional reforming.

CRT results in recycling of waste plastic materials that would otherwise be disposed of by landfilling. The scope does not include improved emissions due to avoidance of landfilling for the recovered waste plastic.

The reference year for this study is 2020. The reference geography is North America. Eastman's commercial CRT operation is in Kingsport, Tenn.

Figure 2. Example system boundary for post-consumer polyester carpet recycling with CRT



LIFE CYCLE INVENTORY

Data and calculations

GaBi 8.0 software was used to develop the life cycle inventory and impact assessment modeling. Eastman used a combination of data sets within GaBi and internally developed LCA models to create the GaBi models for CRT. The external data sources were ecoinvent 3.0, GaBi professional database, and USLCI.

The data for Eastman operations are from internally developed LCA studies based on Eastman commercial primary data for material manufacturing and utility systems. Inventory data for preprocessing machinery is based on equipment data sheets from the manufacturers. Electricity for mechanical preprocessing is based on Eastern United States inventory models from GaBi. U.S. rail and truck transportation data are from USLCI/GaBi. Energy consumption within Eastman's gates is based on Eastman's primary data for internal power generation systems.

Allocation principles

1. Recycled material cutoff approach

This study uses the cutoff method for recycling. Cutoff is judged to be the most appropriate methodology for an advanced recycling system that recycles a diverse set of mixed waste plastics into a set of specialty plastics and fibers which, in many cases, are completely different types of polymer.

The beginning of life for waste plastic CRT feedstock material is set at a cutoff at the exit of either the material recovery or industrial facility where the waste plastic feedstock materials are generated as waste materials. Based on this cutoff, the recovered waste plastics are LCA burden-free at their point of generation. The system boundaries for CRT do include the LCA burdens of transportation of waste plastic from the point of origin to Eastman and preprocessing operations required to prepare waste plastic materials for processing in CRT.

2. Mass balance chain of custody for coprocessing

Eastman's CRT is operated under ISCC PLUS certification[1] and uses a verified[2] mass balance chain of custody model[3] to attribute recycled content to CRT syngas. The LCA principles of applying mass balance to molecular recycling are analogous to the application for biomass balance.[4]

The life cycle inventories for CRT and coal gasification are based on an allocation, which follows the ISCC PLUS certified mass balance. Unique conversion factors are determined for coal and each individual waste plastic feedstock based on its composition and physical properties. The conversion factors account for yield losses in the system. Mass balance enables the combined output of the process to be apportioned into specific amounts of syngas that correspond to each feedstock material.

Mass balance is a critical enabler of the circular economy for plastics via molecular recycling because it enables utilization of existing world-scale manufacturing assets and complex supply chains without the prohibitive environmental, cost, and operational burdens of a physical segregation chain of custody model.

3. Comparability assumptions

The LCAs for both CRT and the conventional syngas process both use consistent methodology choices such as cutoff criteria and multifunctionality. Cutoff criteria was set at 0.5% by mass, but all significant material and energy flows were included in the inventories. Waste heat recovered as steam from the reforming process was treated through a system expansion approach.

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[1] *ISCC PLUS system documents and copies of Eastman certificates are available at* https://www.iscc-system.org/process/iscc-documents-at-a-glance/iscc-system-documents/
[2] *SCS Global Services is the ISCC PLUS certification body for Eastman*
[3] *Ellen MacArthur Foundation, 2019.* **"Enabling a Circular Economy for Chemicals with the Mass Balance Approach."** https://www.ellenmacarthurfoundation.org/assets/downloads/Mass-Balance-White-Paper-2020.pdf
[4] *Jeswani et al, 2019.* ***"A methodology for integrating the biomass balance approach into life cycle assessment with an application in the chemicals sector."*** Science of the Total Env. Vol 687. *https://doi.org/10.1016/j.scitotenv.2019.06.088*

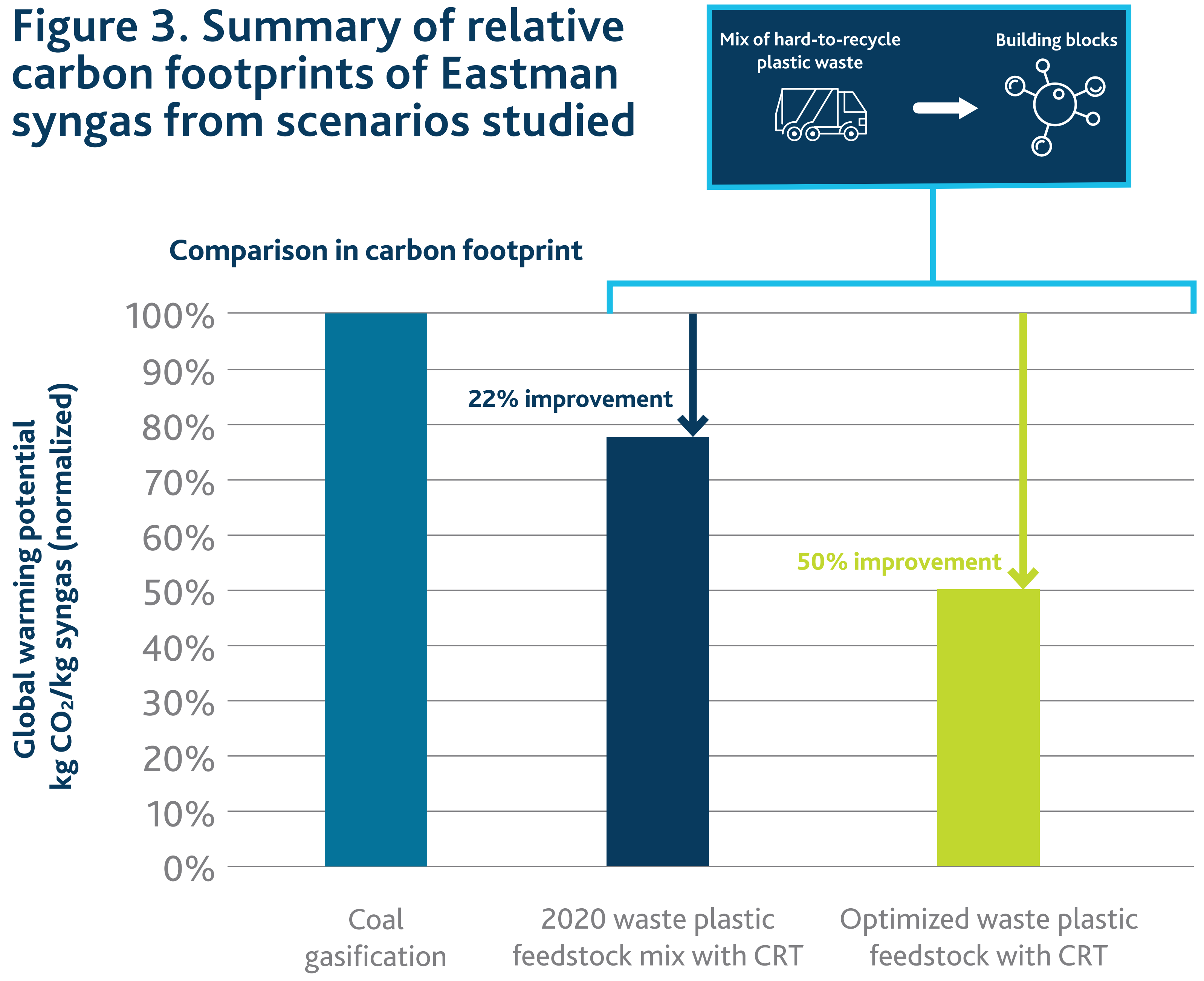
LIFE-CYCLE IMPACT ASSESSMENT

Life-cycle impact assessment (LCIA) results represent environmental impact potentials for the reported impact categories. These are approximations of environmental impacts according to specific LCIA methods. LCIA results are therefore relative expressions and do not predict actual impacts, the exceeding of threshold safety margins, or risks.

The goal of this study is focused on carbon footprint impact, which is a priority for Eastman's internal and external stakeholders. Carbon footprint impact assessment in this study utilizes the Intergovernmental Panel on Climate Change (IPCC) AR5 GWP 100 method that is integrated into GaBi software. The carbon footprint is a midpoint indicator expressed as a global warming potential (GWP) with the units of kilograms of CO_2-equivalent per kilogram of syngas. The potential GWP impacts are assessed over 100 years. A follow-up LCA study is underway to report on other impact categories beyond GWP.

The central LCIA result of this study is summarized in Figure 3. This figure presents the relative GWP for syngas based on three sources. The left column represents conventional syngas based on coal gasification. The middle and right columns represent syngas from CRT. The middle column reflects a commercial-weighted average of CRT feedstocks based on an operating plan for the reference year 2020. The right column reflects the most advantaged CRT waste plastic feedstock material sourced from within a 500-mile radius of the CRT site.

Figure 3. Summary of relative carbon footprints of Eastman syngas from scenarios studied



The full Eastman confidential report includes detailed contribution analyses for all the scenarios and for each specific waste plastic feedstock. The full study also includes sensitivity analyses for waste plastic transportation variables.

The full study also analyzes a scenario including the avoidance of waste plastic incineration within the system boundary. If avoided incineration would have been included in the system boundary, the carbon footprint of CRT syngas would be significantly less than zero. This scenario is an effort to estimate the consequential GHG benefits of recycling waste plastic in CRT as compared to disposing of it by incineration.

CONCLUSION AND INTERPRETATION

The most important conclusion of the study is that Eastman CRT enables a 22%–50% improvement in carbon footprint for syngas based on waste plastic (per scenarios analyzed) compared against Eastman syngas based on coal. The carbon footprint of CRT is lower primarily because waste plastics are a more efficient feedstock than coal for the production of syngas. For the sake of simplicity and conservatism, Eastman is rounding this range to 20%–50% for communication purposes. The primary variables causing this range are the waste plastic composition and the transportation distance/mode from the point of origin to Eastman's site.

By using waste plastic as a raw material instead of conventional fossil materials, Eastman's CRT can deliver benefits for both waste avoidance and life-cycle greenhouse gas emissions. The CRT carbon footprint advantage does not rely on taking credit for avoided waste treatment of the waste plastic feedstocks.

CRITICAL REVIEW

A critical review of the full report was performed by CE Delft, and a final review statement was issued on August 20, 2020. The statement is included as an appendix. The review statement recommends communication of the following three aspects of the study:

1. The study compares syngas from CRT produced from three specific waste plastic streams to syngas from coal (natural gas-based production is not included in this study because Eastman does not produce natural gas-based syngas at this site).
2. The conclusion covers carbon footprint results only (other environmental impact categories are not studied).
3. The main result (22% carbon footprint reduction) is based on a planned 2020 waste plastic feedstock mix.

CLICK HERE to learn more about our carbon renewal technology and other circular solutions.

FINAL REVIEW STATEMENT: LCA of Eastman carbon renewal technology

Study title	LCA Report for the Generation of Synthesis Gas from Eastman Carbon Renewal Technology[1]
LCA practitioner	Eastman (Ben Coleman, Randy Waymire, Neil Brown)
Reviewed by	CE Delft (Martijn Broeren, Geert Bergsma)
Review period	Review rounds: March–August 2020; Review statement: August 20, 2020[1]

CE Delft

Committed to the Environment

BACKGROUND AND REVIEW PROCESS

The goal of the reviewed life cycle assessment (LCA) report is to enable Eastman to make a direct comparison of the carbon footprint of synthesis gas produced by carbon renewal technology (CRT) to synthesis gas produced by Eastman's coal gasification process. The study's authors conclude that syngas produced via CRT has a 22% lower carbon footprint than coal-based syngas. This value is based on the feedstock mix that Eastman expects to use in 2020. A scenario analysis based on an optimized feedstock mix and streamlined transportation concludes that CRT may in the future show up to a 50% improved carbon footprint compared against the conventional process.

The critical review process consisted of a kickoff meeting followed by two review rounds, after which the LCA report was updated by Eastman. The LCA modeling in software was not part of the review. Various suggestions were provided in the review; for instance, to make the LCA modeling more transparent, to analyze and discuss uncertainties and limitations, and to improve the structure of the study. These comments and questions were addressed in subsequent versions, resulting in a more complete, transparent report and higher quality LCA.

In all LCA studies, the accuracy of the results and conclusions are determined by the process data of the compared systems. For a novel technology such as CRT, it can be more difficult to gather process data. Basic cross-checks have been carried out to verify the input data and results, and the reviewers trust that Eastman has used the best available process data in the models. Similarly, the utilities used for CRT at Eastman's Kingsport site are modeled using internal LCA models, which were not verified as part of this critical review.

[1] *Version of August 10, 2020.*

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CRITICAL REVIEW MAIN STATEMENT

The LCA by Eastman is an interesting LCA of a highly relevant technology in the transition toward a circular economy. The report provides a good overview of the conducted assessment and is generally easy to read.

All aspects considered, from an LCA methodological point of view, there is very little reason to doubt the study's overall conclusion that CRT produces syngas with a lower carbon footprint than the conventional process. The methods used to carry out the study are valid, the modeling and scope is appropriate for the study's goal, and the results are in line with those found in earlier studies. Uncertainties and limitations are addressed and mentioned in the conclusions. The LCA conforms to the requirements in the ISO 14040:2006 and ISO 14044:2006 standards on life cycle assessment.

Furthermore, the LCA is generally conservative in estimating the carbon footprint benefits of CRT. The most notable example is in its handling of the avoided conventional end-of-life treatment of waste plastics. Through recycling, the impact of the incineration of waste plastics can be avoided. This is highly relevant from a societal point of view, but it is debatable whether the benefits should be allocated to the recycled product. While Eastman does analyze the impact of considering avoided incineration, it does not use these results to support its overall conclusion. This is a conservative approach compared to other recent (non-Eastman) LCA publications on novel recycling technologies.

When summarizing the results of this study, we believe three aspects related to its goal should always be mentioned:

- The study compares syngas from CRT produced from three specific plastic waste streams to syngas from coal (natural gas-based production has not been studied).
- The conclusion covers carbon footprint results only (other environmental impact categories are not studied).
- The main result (22% carbon footprint reduction) is based on the 2020 waste plastic feedstock mix.

[1] *Version of August 10, 2020.*

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Eastman Corporate Headquarters
P.O. Box 431
Kingsport, TN 37662-5280 U.S.A.

U.S.A. and Canada, 800-EASTMAN (800-327-8626)
Other Locations, +(1) 423-229-2000

www.eastman.com/locations

CIR-CRT-12181 3/21