Assessing Fossil Fuel and Feedstock Use in the U.S. Plastics and Rubber Sector: A Supply Chain Analysis

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ICOSSE 2018

August 13, 2018

NREL/PR-6A20-72187

Introduction / Motivation

- Feedstock energy accounted for 70% of plastics manufacturing energy requirements (MECS 2014)
- Feedstock requirements may limit overall potential of fossil energy reductions

Goals of this analysis

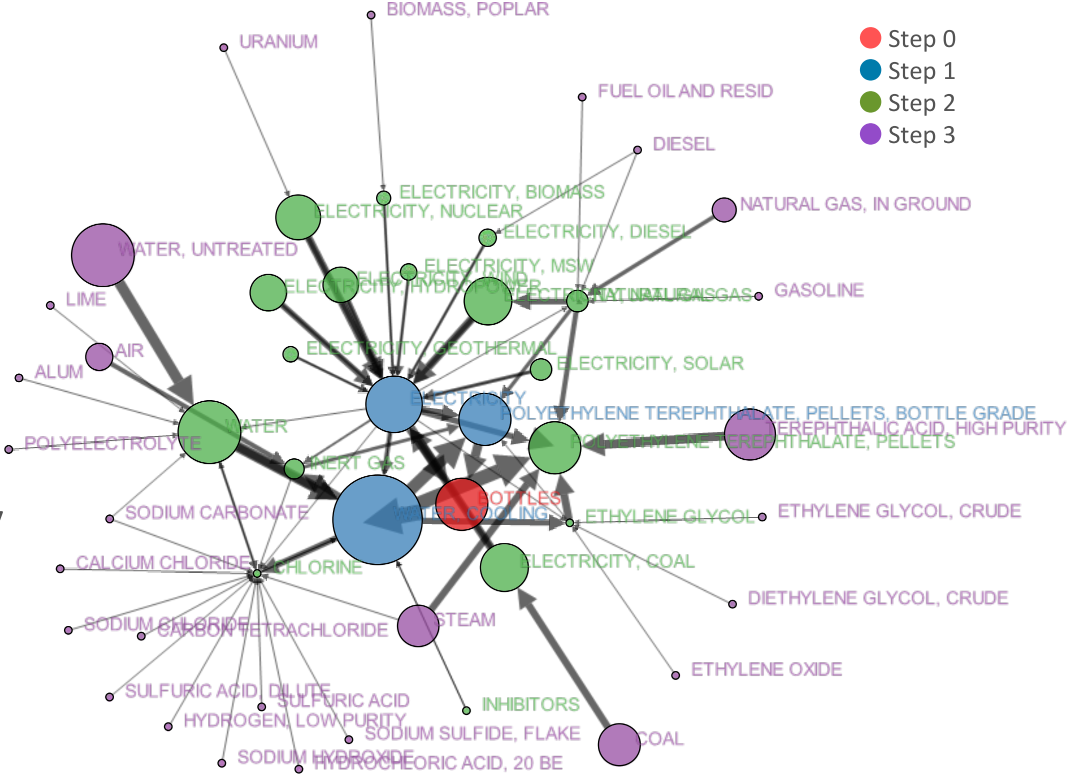
- Compare conventional and bio-based Polyethylene terephthalate (PET) supply chains
- Apply MFI tool to analyze a novel PET upcycling process for composite manufacturing

Photo by Chris Standlee, NREL 7265

The Materials Flows though Industry (MFI) Tool

- Linear network model
- US-based supply chains
- Cradle-to-gate; does not include use-phase or end-of-life
- Coproduct offsets; all estimates are on a “net” basis
- Energy requirements and combustion GHG emissions only
- Web application now publicly available to try out!

Modeled PET Supply Chain Network in MFI– 3 steps

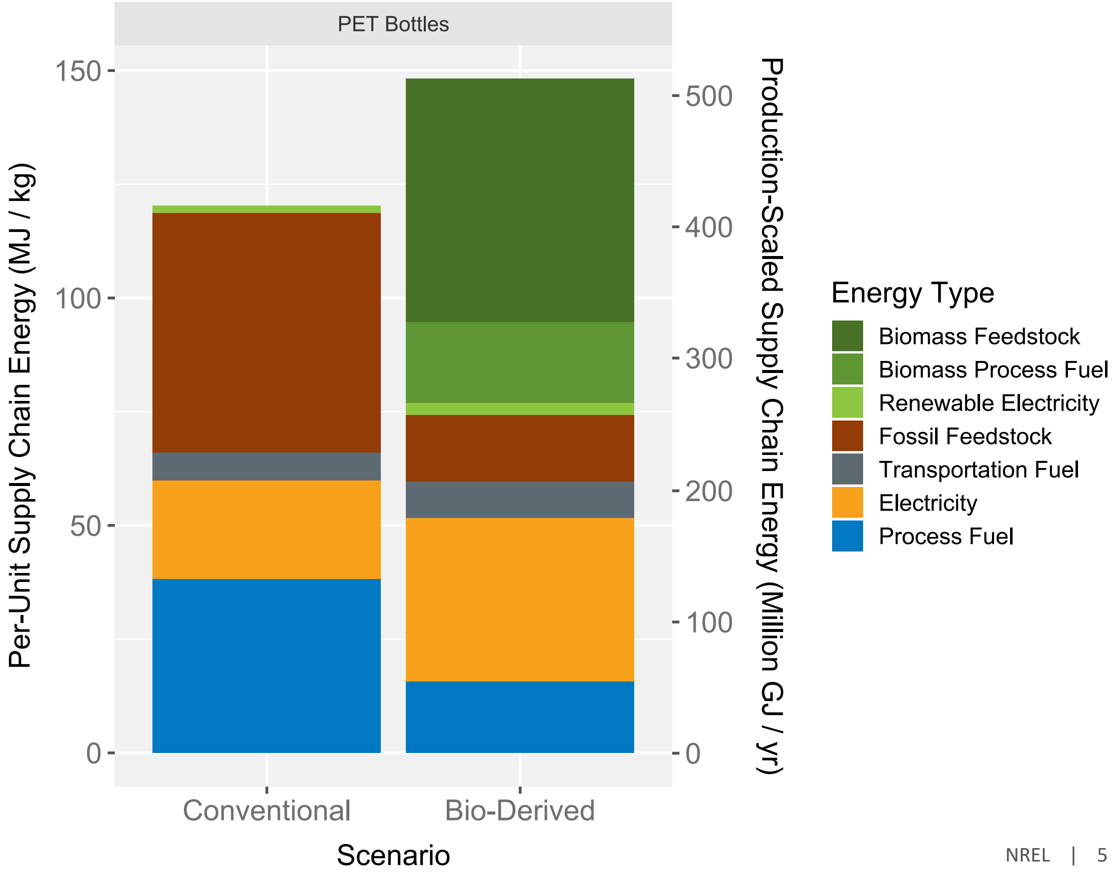


Bio-Based PET Supply Chain

- Supply Chain Total Energy
- Supply Chain Feedstock Energy
- Supply Chain GHG Emissions

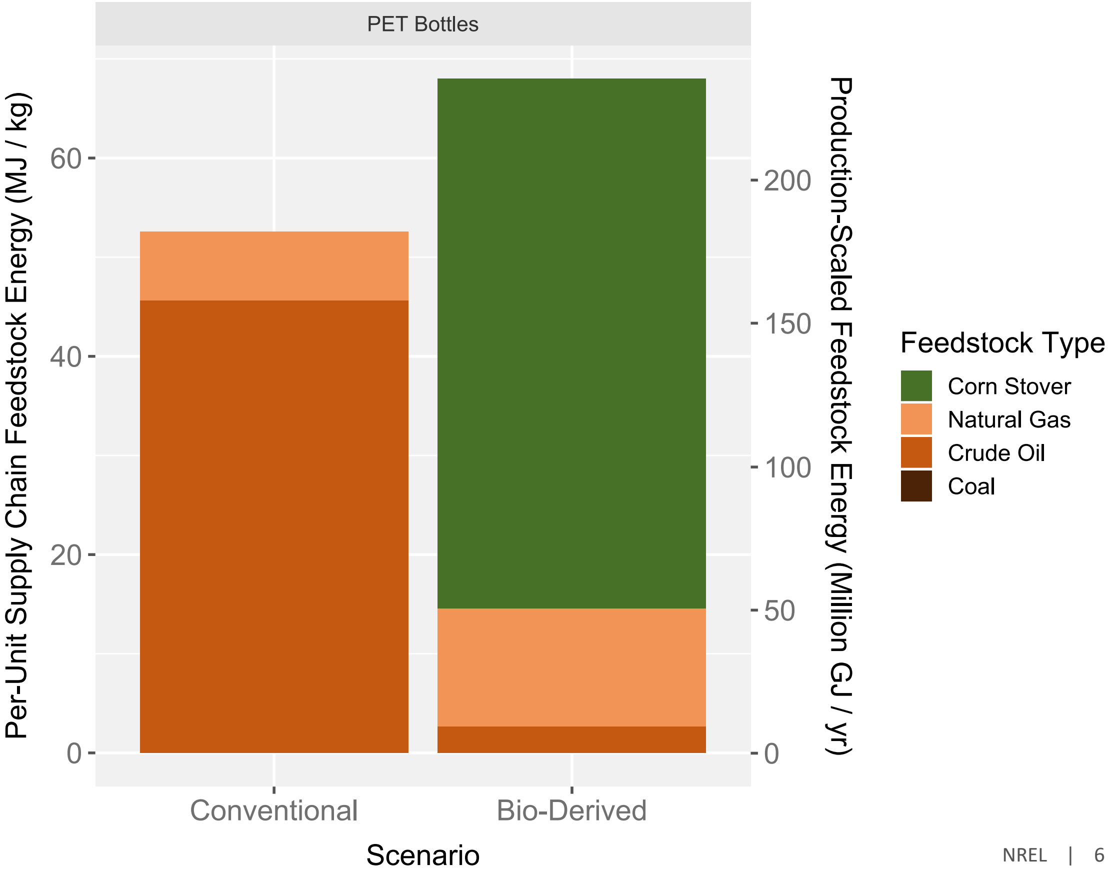
Conventional and Bio-Based Supply Chain Energy Requirements

- Biomass-derived terephthalic acid (TPA) monomer
- Supply chain fossil energy requirement reduced by 37%
- Additional renewable energy inputs (green bars) more than offset fossil energy reductions, leading to increased total energy requirement



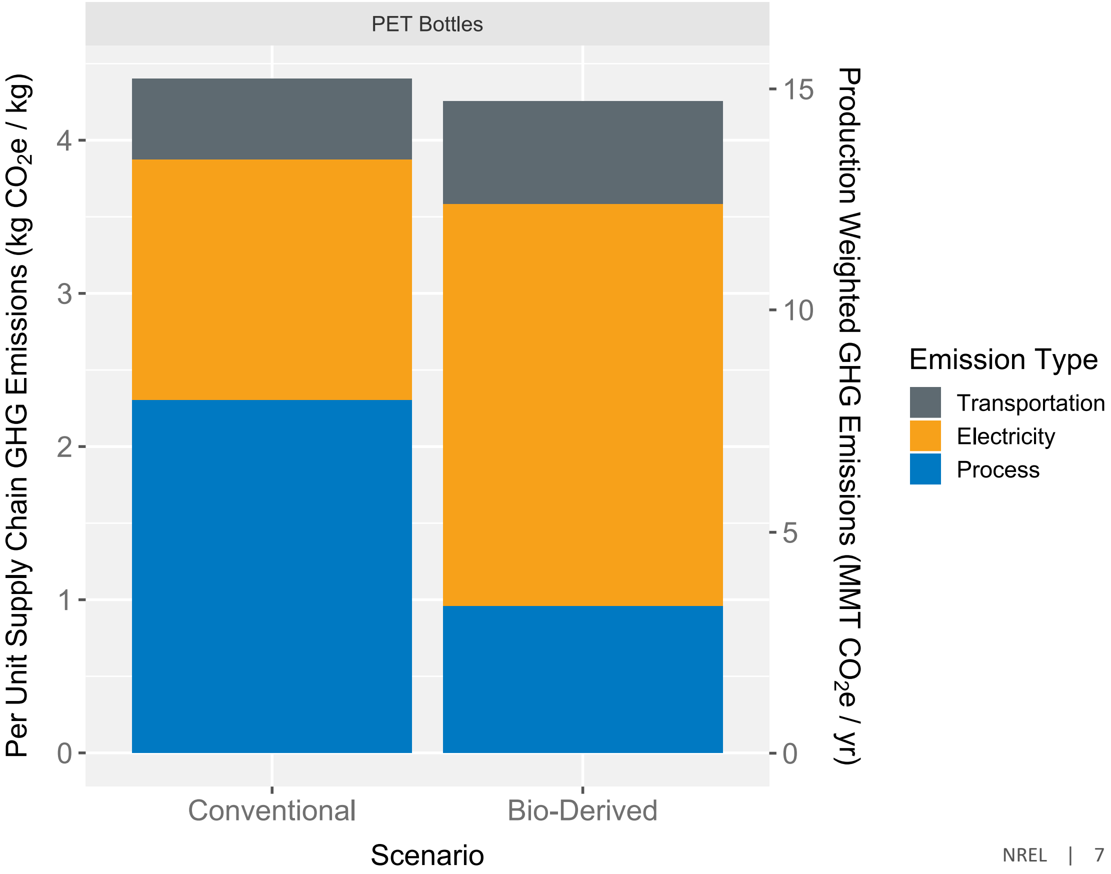
Conventional and Bio-Based Supply Chain Feedstock Energy Requirements

- Total fossil feedstock energy requirement reduced by 72%
- Crude oil feedstock requirement reduced by 94%



Conventional and Bio-Based Supply Chain GHG Emissions

- Negligible total GHG emissions change, but the dominant GHG *source* has changed
- Reductions in process fuel GHG emissions nearly offset by increased electricity requirements



PET Upcycling Case Study

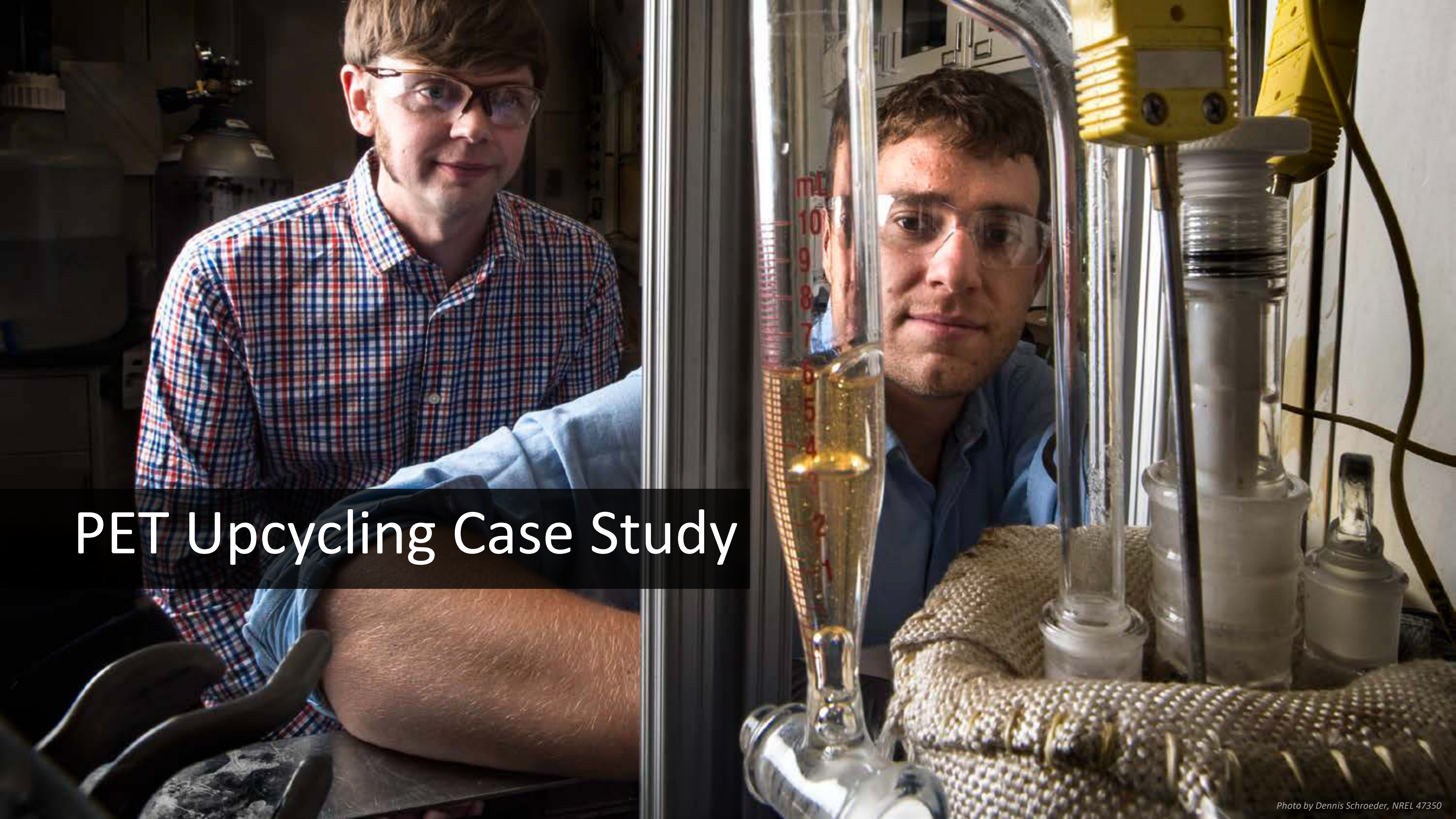


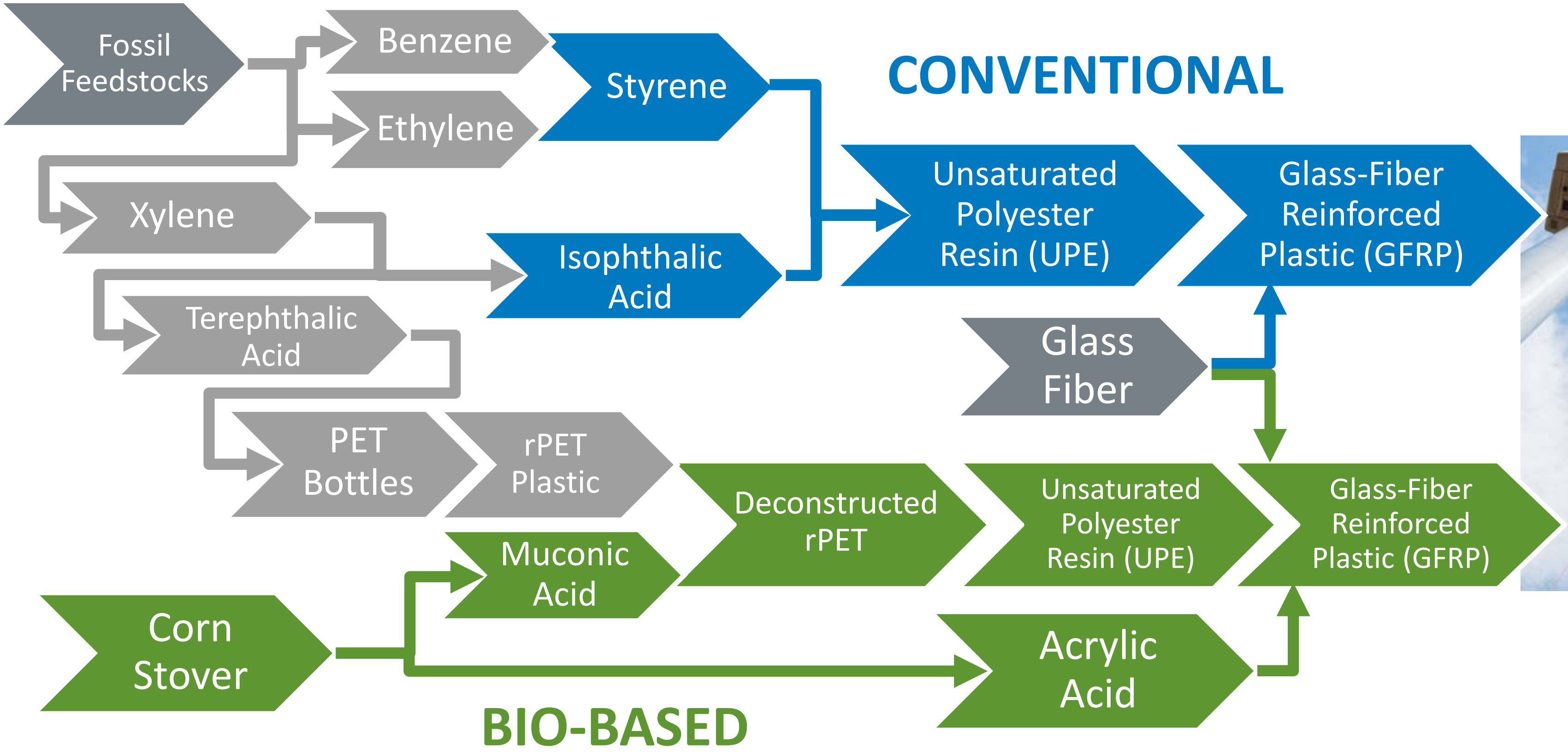
Photo by Dennis Schroeder, NREL 47350

rPET Upcycling Background & Motivation

- Most commercial PET recycling is mechanical
- Mechanical recycling leads to lower-grade plastic with fewer applications (carpet fiber, etc.)
- Chemical recycling of PET bottles back to its monomers is expensive
- What if we could make higher value products with recycled PET?

Photo from pxhere.com

Conventional and Bio-Based GFRP Production



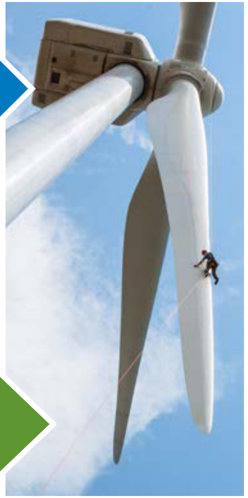
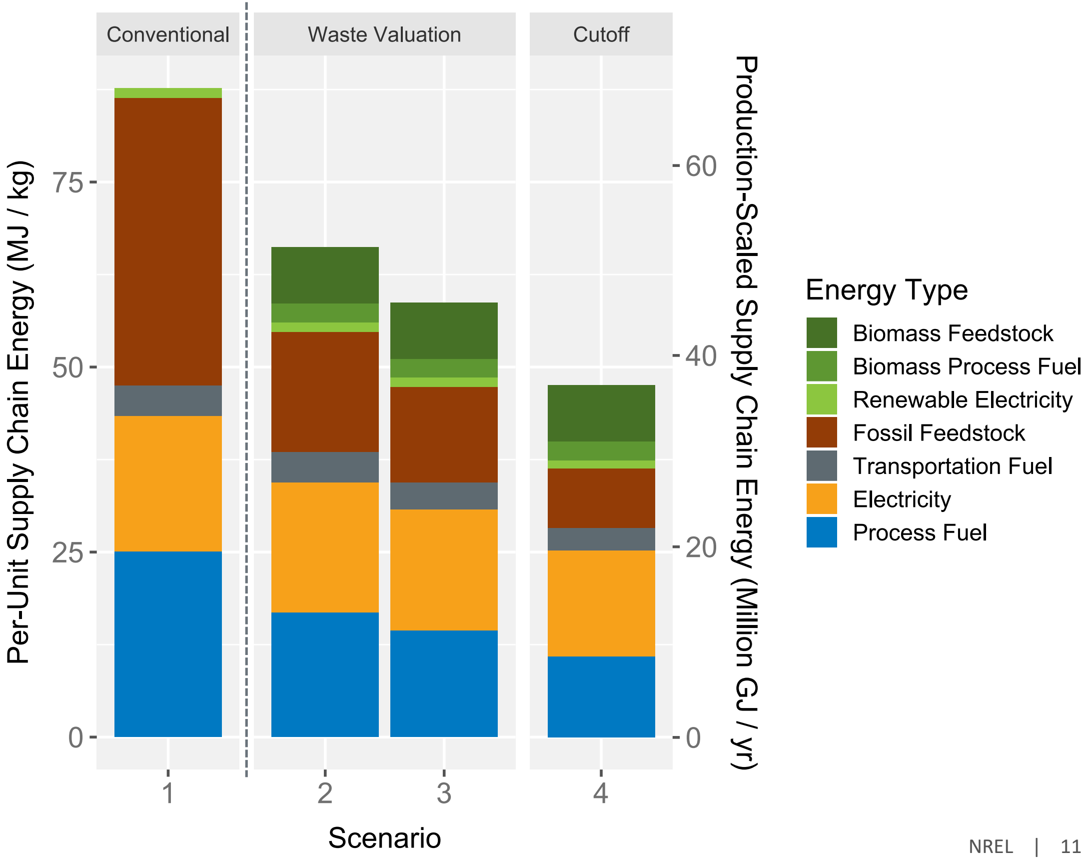


Photo by Dennis Schroeder, NREL 27204

Comparison of Supply Chain Energy Requirements for GFRP from Conventional vs Upcycled rPET

- Depending on the allocation method, supply chain fossil energy reductions range from **37% to 58%**.
- 2016 GFRP production in US estimated at 780,000 metric tons per year based on 2016 US consumption of UPE (IHS) and assumed 40:60 GF:UPE ratio.

Scenario	Name	PET Bottle (First Life) Allocation
1	Conventional GFRP	N/A (No rPET Used)
2	Waste Valuation; Reclaimed Clear rPET 	≈54% (Economic)
3	Waste Valuation; Reclaimed Green rPET 	≈32% (Economic)
4	Reclaimed rPET - Cutoff	0%



Supply Chain Feedstock Energy Requirements for GFRP from Upcycled PET

Overall, supply chain fossil feedstock energy reductions range from **58% to 79%**

Scenario	Name	PET Bottle (First Life) Allocation
1	Conventional GFRP	N/A (No rPET Used)
2	Waste Valuation; Reclaimed Clear rPET 	≈54% (Economic)
3	Waste Valuation; Reclaimed Green rPET 	≈32% (Economic)
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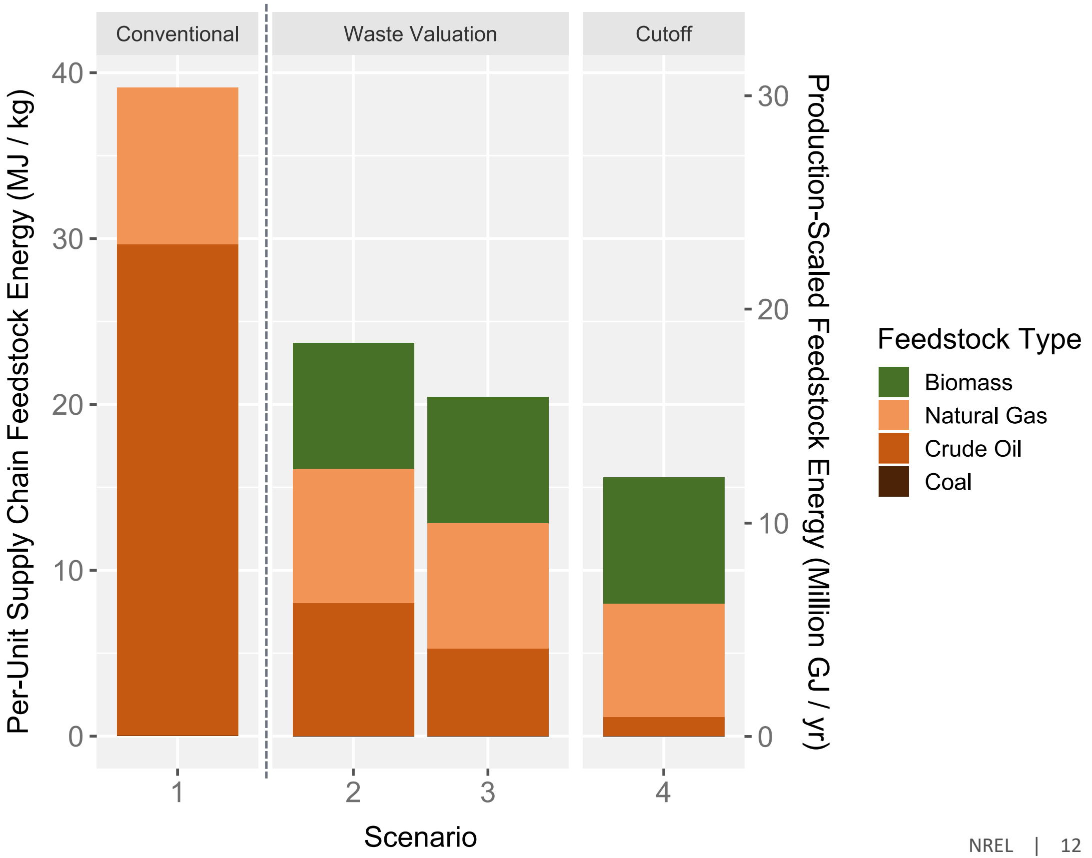
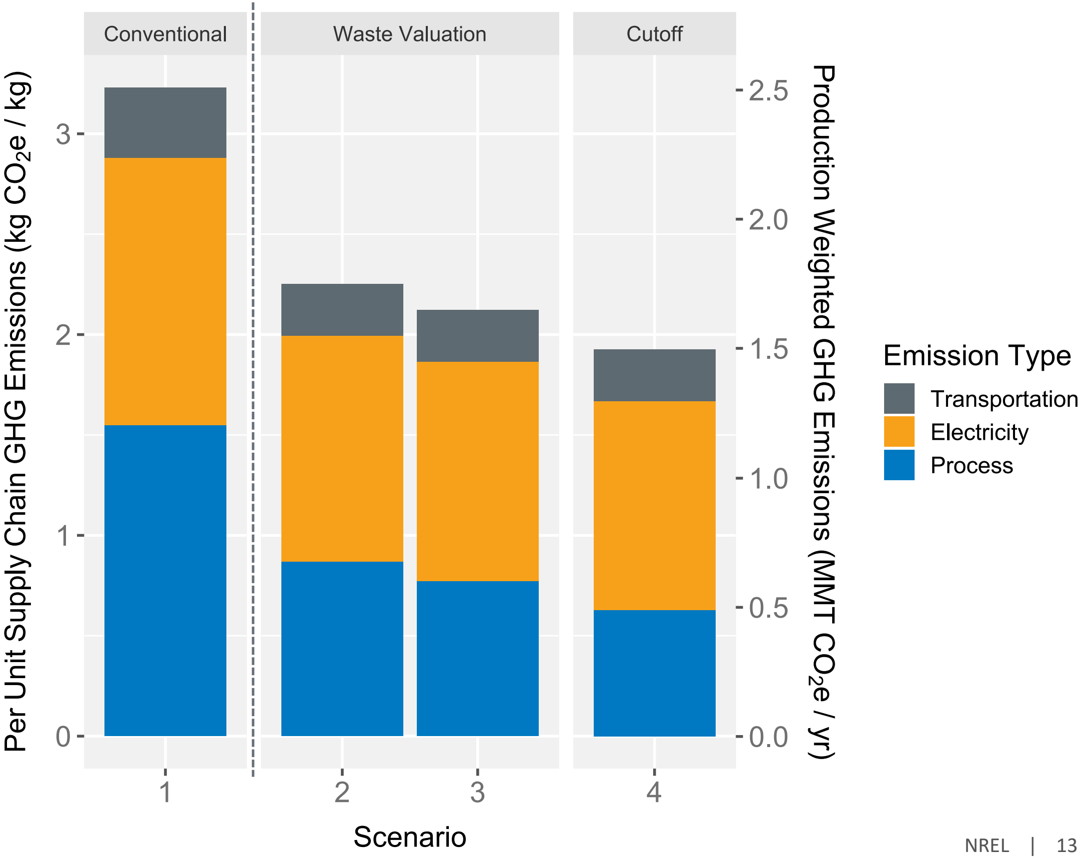


Supply Chain Combustion GHG Emissions for GFRP from Upcycled PET

- Overall, supply chain GHG emissions reductions range from **30% to 40%**
- 0.7 – 1.0 MMT-CO_2e offsets; Equivalent to taking **150,000 - 200,000 cars** off the road

Scenario	Name	PET Bottle (First Life) Allocation
1	Conventional GFRP	N/A (No rPET Used)
2	Waste Valuation; Reclaimed Clear rPET 	≈54% (Economic)
3	Waste Valuation; Reclaimed Green rPET 	≈32% (Economic)
4	Reclaimed rPET - Cutoff	0%



Summary / Conclusion

- Bio-based PET plastic supply chain:
  - ~ 40% lower total fossil energy
  - ~ 70% lower fossil feedstock energy

- Upcycling PET could significantly reduce total GFRP supply chain energy, including fossil feedstock energy, as well as GHG emissions

- Journal article for rPET upcycling process and energy analysis forthcoming– to be submitted to *Joule* later this month

GFRP from Upcycled PET Bottles

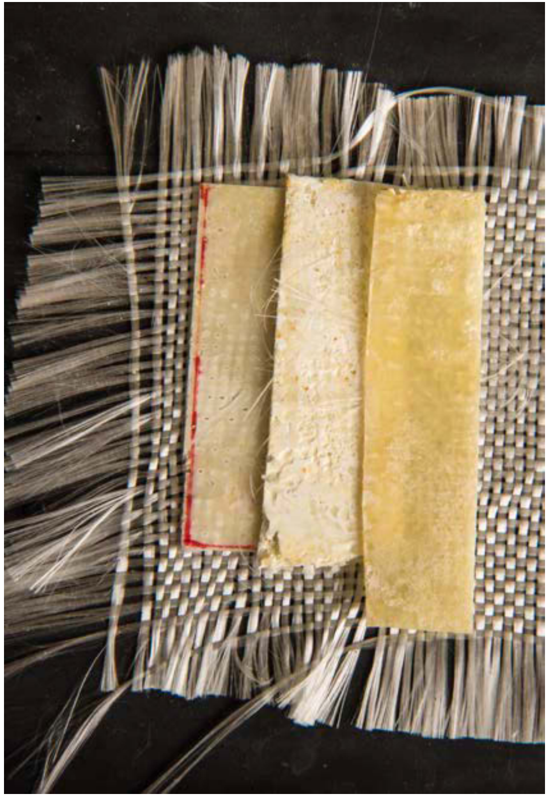


Photo by Dennis Schroeder NREL 47349

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Thank you

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This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Advanced Manufacturing Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

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