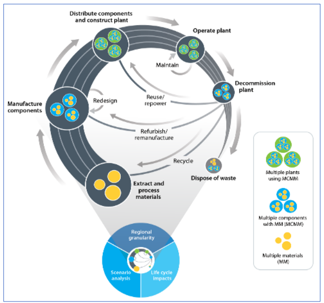
The Circular Economy Lifecycle Assessment and Visualization Framework – CELAVI

Tapajyoti Ghosh, Rebecca Hanes, Alicia Key, Julien Walzberg and Annika Eberle

NREL

Introduction



The Circular Economy Lifecycle Assessment and Visualization (CELAVI) framework hybridizes **discrete event simulation, system dynamics modeling, material flows**, and **life cycle concepts** into a **dynamic multiscale framework** for assessing how impacts vary as supply chains transition from linearity toward circularity.

Captures **supply chains** using detailed, dynamic models of production, use, and **circular pathways** that are linked to **background life cycle processes.**

Research Questions

How much technological learning needs to occur before circularity technologies reach cost parity with linear technologies?

How does increasing circularity change the environmental impacts of renewable energy technologies?

How do end-of-life pathway costs, locations of supply chain facilities, and deployment trajectories modify circularity?

What level of circularity could be reached with investment in new circularity technologies?

Applications

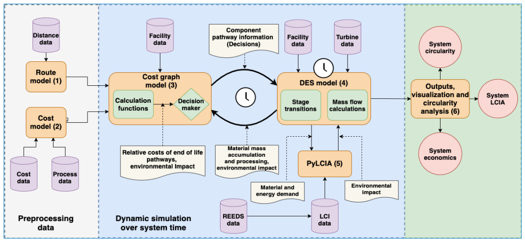
Our intended audience for CELAVI includes governing bodies, corporations, and nongovernmental organizations at multiple levels.

The framework's initial focus is on renewable power systems and materials, but the intent is to develop a flexible and modular approach that can be used in other applications as well.

Lifecycle Assessment + ***Circularity*** + ***Economics***

Framework Structure

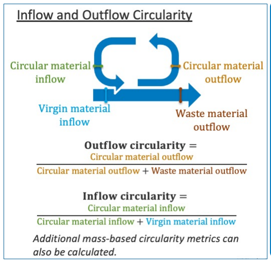
Discrete Event Simulation	Cost Graph	PyLCIA
Simulates and tracks material flows and transportation. Runs Cost Graph and pyLCIA at user-specified intervals.	Calculates end-of-life (EOL) pathway characteristics: cost, distances, and total environmental impacts. Identifies preferred EOL pathways and associated facility locations.	Calculates environmental impacts by material and processing step. Updates electricity grid mix in foreground LCI to capture emissions changes over time.



References

- *Hanes, Rebecca, et al. "The Circular Economy Lifecycle Assessment and Visualization Framework: A Case Study of Wind Blade Circularity in Texas." Frontiers in Sustainability 2 (2021): 45.*
- *Ghosh, Tapajyoti et. al "The Circular Economy Life Cycle Assessment and Visualization Framework: A Multistate Case Study of Wind Blade Circularity in United States. Submitted. Under review*
- *US Wind turbine database : https://eerscmap.usgs.gov/uswtdb/*
- *US Life Cycle Inventory: https://www.lcacommons.gov/lca-collaboration/search/page=1&group=National_Renewable_Energy_Laboratory*
- *TRACI 2.1 : https://www.epa.gov/chemical-research/tool-reduction-and-assessment-chemicals-and-other-environmental-impacts-traci*
- *GITHUB Repository for CELAVI - https://github.com/NREL/celavi*

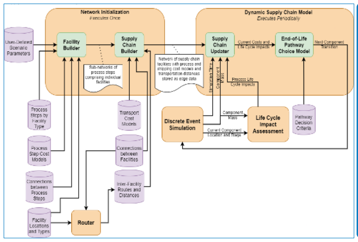
Circularity Metrics



Within the CELAVI framework, circularity metric calculations are therefore kept as post-processing steps applied to the material flow outputs of the discrete event simulation; this allows the metric calculations to be changed to suit different case studies with relative ease.

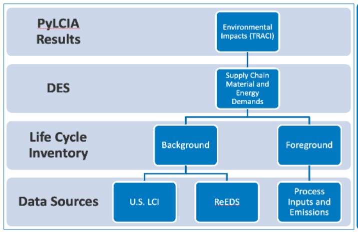
Circularity metrics calculated within CELAVI are inflow and outflow circularity

Framework Modules



Cost Graph is a network representation of the supply chain superstructure, including all supply chain facilities, end-of-life pathways, processing and transportation costs, transportation distances, and any other supply chain characteristics.

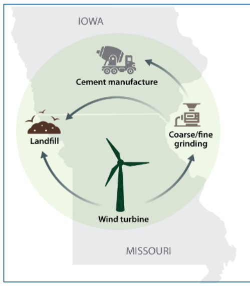
Calculates preferred routes using algorithms.



Python-LCIA (PyLCIA) is a rapid LCA calculation module that removes dependencies on commercially available LCA tools and executes completely in a Python environment.

PyLCIA also includes a dynamic electric grid mix that changes with time and state.

Case Study

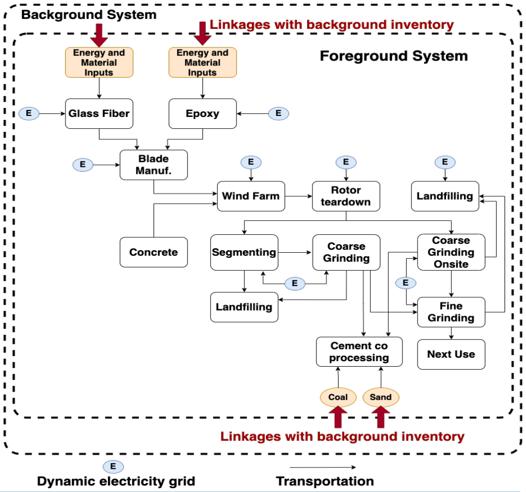


Scope

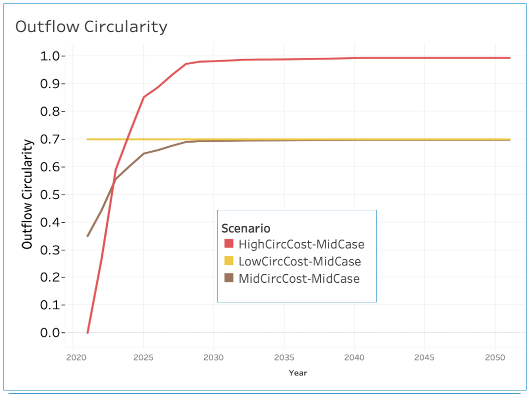
- Turbines installed and retired in the U.S. states of Iowa & Missouri, 2000 – 2050
- Glass fiber and epoxy materials contained in GFRP blades
- EOL pathway options are cement co-processing, mechanical recycling, or landfilling

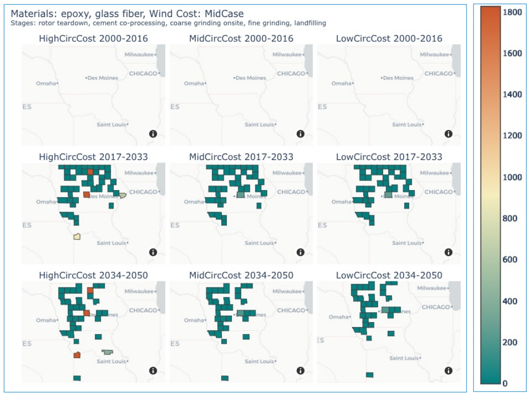
Scenarios

- Low, moderate, and high circularity costs
- Low, moderate and high installed wind capacity between 2020 and 2050 (ReEDS Standard Scenarios)



Results

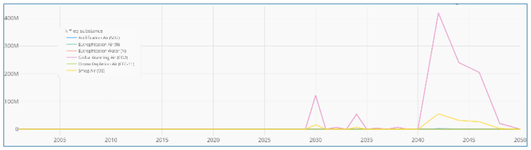




Processing costs may not be a major obstacle to the wind turbine blade supply chain transitioning towards circularity.

Cost of transporting end-of-life material between supply chain facilities had virtually no impact on which pathway was preferred.

Pathways with high circularity might have larger environmental impacts.



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 NREL's Laboratory Directed Research and Development Program. 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.

Industrial Ecology Gordon Research Conference
Newry, Maine
June 12-17,2022
NREL/PO-6A20-82941