Analyzing Life Cycles of Trucks

PACCAR CAPSTONE PROJECT

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INDUSTRIAL & SYSTEMS ENGINEERING

Intro & Problem Statement

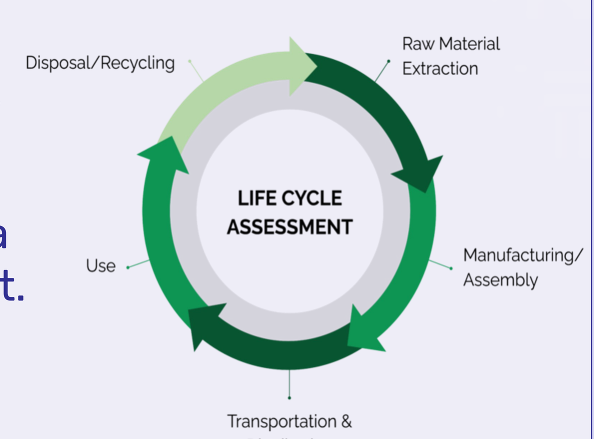
Leading the heavy-duty transportation industry in sustainability initiatives, **PACCAR seeks a more comprehensive understanding of the environmental impacts from their sourcing, manufacturing, and distribution processes via a proof-of-concept Life Cycle Analysis (LCA) tool** to gain insight of opportunities to improve sustainability of their products.

How can we estimate environmental impacts of a heavy-duty truck using a streamlined LCA to comprehensively analyze various data inputs and create a rudimentary but dynamic model?

How can we relay the significance and use-case of LCA to PACCAR and bolster corporate sustainability?

What is LCA?

- The process of assessing a product, process, and/or system from "inception to expiration," including raw material extraction, processes of production, lifetime use, end of life, and disposal.
- Scientifically recognized & standardized methodologies
- Scope can be refined to analyze specific impacts of a life stage or part of a product.



Why Use LCA?

- Optimize sustainability initiatives
- Understand product's impact at various stages of lifecycle
- Ensure adherence to environmental regulations
- Develop performance indicators
- More holistic evaluation of alternatives
- Pinpoint areas for process and material improvements
- Make more environmentally informed business decisions

Scope 1, 2, & 3 Emissions

PACCAR wants to reduce their direct Scope 1 & 2 emissions, while creating products that minimize indirect scope 3 emissions.

Scope 1	Scope 2	Scope 3
Direct	*Indirect*	*Products*
From owned / controlled sources	From generation of purchased energy	From supply chain and customer use of products

Project Roadmap

Step 1: Research and Meet Stakeholders

- Visited Kenworth Plant and PACCAR Technical Center
- Initial project research, brainstorming and planning
- Literature review & competitive analysis

Step 2: Identify Scope and Alternatives

Research and Model Creation: Research LCA software and alternatives to create an easy-to-use model that can compare basic environmental impacts of very basic heavy-duty vehicles

Analyze Alternatives:

1. Carculator Packages
2. GREET
3. Full Component LCA

Step 3: Assumptions & Risks

Project Assumptions:

- Majority of model will be based on estimated data
- LCA will be built upon by PACCAR from our base model
- PACCAR is interested in and striving to minimize their environmental impacts

Project Risks:

- Inaccurate analysis due to poor data sourcing
- Misinformed business decisions based on inaccurate analysis
- Model becoming outdated due to large changes to vehicle manufacturing

Step 4: Design and Build

PACCARculator Interface

The PACCARculator, based off of Carculator-Truck, consists of a **single python file to generate figures that can be easily modified and interpreted.**

- Capable of **impact and sensitivity** analyses
- Easy to use - Python based with GUI component

GREET-Based Materials Analysis

Developed by the Argonne National Laboratory to calculate fuel cycle and vehicle cycle emissions. GREET is customizable, but as a streamlined LCA it is only designed to model manufacturing processes with a limited amount of precision. GREET is easy to operate and is provided as an Excel spreadsheet.

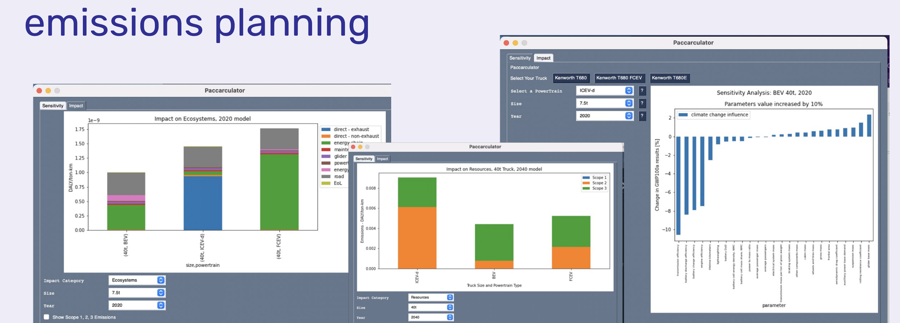
Step 5: Implement & Iterate

Deliverable Iteration: Implementing PySimpleGUI

- Create a user interface allowing users to modify and visualize Carculator-Truck inventories using any Python-compatible IDE.

Improvements made:

- Increase modifiable inputs
- Generate additional data visualizations
- Improve UI experience
- Built out GREET analysis for materials emissions planning



Results and Recommendations

Project Impacts:

LCA can be performed in the spirit of **continuous improvement**. We hope that this project will serve as a jumping off point for PACCAR to implement LCA as a common practice in PACCAR's US subsidiaries.

This project has demonstrated:

- PACCAR has **multiple viable options** for pursuing LCA implementation and other environmental initiatives
- **A streamlined LCA analysis interface is possible to develop and can aid in sustainable decision making**

Project Deliverables:

1. Written Research & Recommendation Report
2. PACCARculator files & modifiable interface
3. GREET Analysis

Team Recommendations:

1. **Build upon the PACCARculator and GREET** - modify to fit PACCAR needs and input PACCAR specific data
2. **Go beyond LCA** to pursue sustainability in design, sourcing, manufacturing, & distribution
3. Utilize LCA to **inform customers and stakeholders** about PACCAR's industry-leading sustainability measure

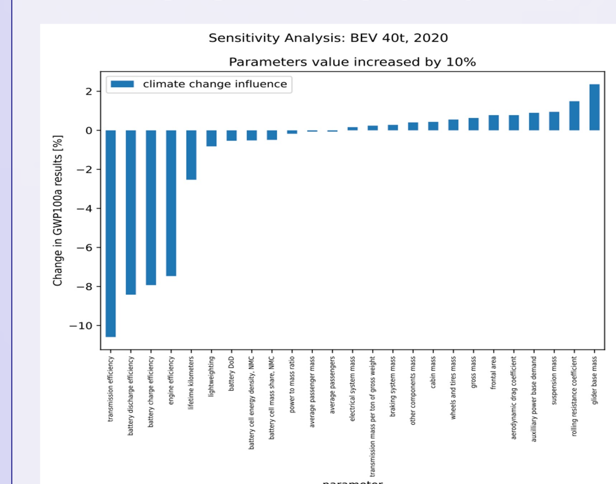
Identified Alternatives

Carculator-truck: Open-source, python-based parameterized LCA model that allows users to generate life cycle inventories for different truck configurations based on selected input parameters.

GREET: Excel-based tool that evaluates life-cycle impacts of vehicles by calculating energy and water consumption, air pollutants, and emissions.

Full Component LCA: LCA approach with goal definition and scoping, inventory analysis, impact assessment, and interpretation. Typically requires 6+ months to complete. While outside the scope of PACCARpe Diem, PACCAR seeks to ultimately incorporate full-scale LCA into their decisions analyses and design processes

PACCARculator: LCA Analysis



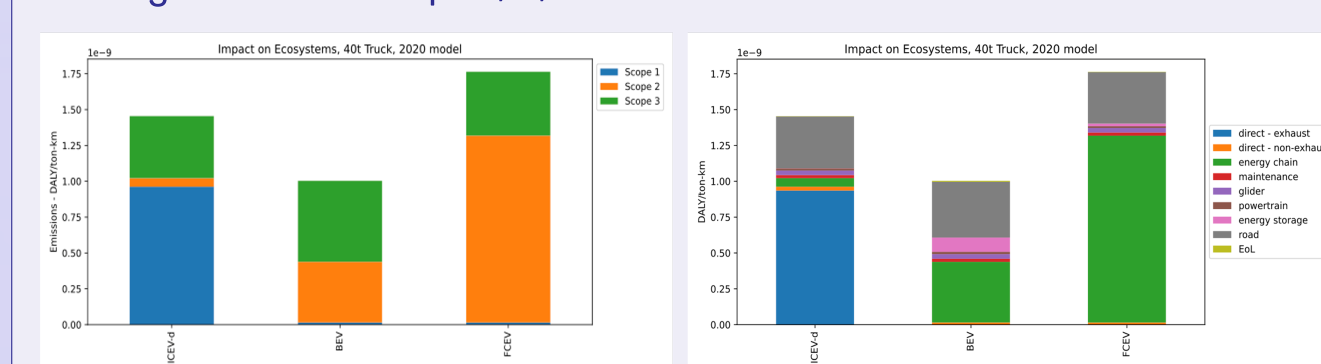
Sensitivity Analysis:

PACCARculator generates a climate change sensitivity analysis based on generalized truck data

Sensitivity analysis shows the parameters with the most effect on climate change if they were to be modified.

Impact Analysis:

Given a specified year and vehicle size, generates an impact analysis based on a selected impact category. Compares three powertrain types: internal combustion engine vehicle (ICEV-d), battery electric vehicle (BEV), fuel cell electric vehicle (FCEV). Impacts can be categorized into scope 1, 2, and 3 emissions if indicated.

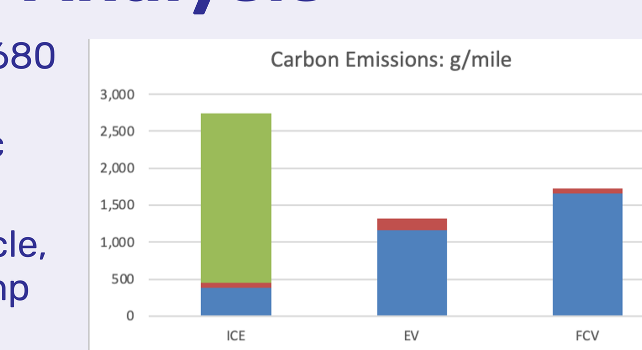


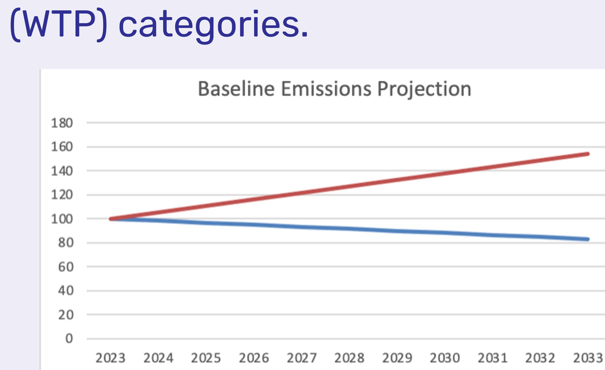
Model Assumptions:

- All visualizations show results based estimated data
- Model will be used as an **initial framework** for streamlined LCA and not yet as a fully accurate, completed solution

GREET: Materials Analysis

- Analysis based on a Kenworth T680 internal combustion vehicle (ICE), hydrogen fuel cell (FCV) & electric battery vehicle (EV).
- Emissions defined by vehicle cycle, vehicle operation, and well to pump (WTP) categories.





- Based on linear interpolation of federal heavy duty vehicle EV targets, PACCAR vehicle cycle emissions are projected to increase as total lifetime emissions are reduced.