Analyzing Life Cycles of Trucks

PACCARpe Diem Team: Ciara Gormley, Travis Mason, Rudolph Toepfer, Ashley Woodworth, Sally Yoon

Project Sponsor, Project Advisor: Andrew Wells, Professor Patricia Cecilia Buchanan

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: Direct
- From owned / controlled sources

Scope 2: Indirect
- From generation of purchased energy

Scope 3: Products
- From supply chain and customer use of products

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 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 changes in vehicle manufacturing

Step 4: Design and Build
PACCARculator Interface
The PACCARculator—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

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

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

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 4-6 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:
- Analysis based on Kenworth T880 internal combustion vehicle (ICEV) - hydrogen fuel cell (FCEV) & 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.

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

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.

University of Washington College of Industrial and Systems Engineering