BREN SCHOOL OF ENVIRONMENTAL SCIENCE & MANAGEMENT
UNIVERSITY OF CALIFORNIA, SANTA BARBARA

patagonia®

Assessing On-Road Freight Emissions for Patagonia and Evaluating Low Carbon Fuel Alternatives

A project at the Bren School of Environmental Science and Management, UC Santa Barbara

Project Members
James Choe
Kosuke Fujiwara
Jeremie Hakian
Jeremie Rafter
Jake Sultan
Derek Wiggam

Project Advisor
Roland Geyer
Brandon Kuczenski

Project Client
Patagonia Inc.

Introduction:

Over the next 25 years, vehicle miles traveled (VMT) by heavy-duty vehicles (HDVs) are projected to increase by over 100 billion. With the transportation sector accounting for nearly one-third of all US energy consumption, VMT by conventional HDVs averaging less than 7 miles per gallon are a growing source of greenhouse gas (GHG) emissions. Accordingly, decoupling GHG emissions from increasing VMT remains a core objective of sustainable transportation practices. Patagonia, an outdoor clothing company, has long been dedicated to promoting environmental stewardship with its own operations and has recently begun to examine its domestic freight distribution network. In this context, the project investigates the life cycle GHG emissions from Patagonia's HDV fuel use, provides actionable recommendations to reduce those emissions, and facilitates the process by which the company identifies alternative fuel options. To meet these objectives, the project also developed the Freight Emissions Assessment Tool (FEAT), a logistics tool that evaluates the full life cycle of both conventional and alternative fuels (existing and near-term) for Class 8 HDVs.

Project Objectives:

1. Conduct a well-to-wheels fuel cycle (fuel cycle) assessment of Patagonia's freight GHG emissions
2. Construct a transparent, user-friendly logistics tool that includes current and near-term transportation technologies, fuel types, and emission profiles
3. Develop actionable recommendations for reducing Patagonia's freight GHG emissions
4. Supply Patagonia with relevant information to intelligently respond to concerns about the potential use of specific fuels in their distribution network

Methods:

Based on data availability, methodological choices, and company interests, the project was scoped to evaluate GHG emissions (carbon dioxide, methane, and nitrous oxide) from domestic Class 8 HDVs (excluding Hawaii) over the 2012 FY. Moreover, the project focused on the fuel-use GHG emissions of diesel, hybrid-electric, propane, biodiesel, fuel cell, and natural gas propulsion systems; embodied emissions related to vehicle production, disposal/recycling, and operation and maintenance were identified but excluded from the FEAT model. In addition, the project incorporated fuel cost data and HDV and infrastructure availability; due to limited production, all-electric and all-biodiesel HDV systems were beyond the project scope. Importantly, the project was conducted in light of the fact that Patagonia's products are shipped primarily through UPS and other freight forwarders; the company does not own its own distribution fleet.

Figure 1: Patagonia's domestic distribution network under study. Cargo shipments arriving at the ports of Long Beach and San Francisco are transported to the Reno Distribution Center; from there, freight is shipped to the rest of the US through 3 primary legs (Retail, Direct-to-Customer, and Wholesale)

A Freight Emissions Assessment Tool: FEAT

Determining the total GWP from the product system involves the following formula in FEAT model:

$$
\begin{array}{c}
\text{Fuel Consumption} \\
\text{per Unit Freight} \\
\left(\dfrac{\text{gallon}}{\text{metric ton} - \text{km}}\right)
\end{array}
\times
\begin{array}{c}
\text{Fuel Energy} \\
\text{Density} \\
\left(\dfrac{\text{BTU}}{\text{gallon}}\right)
\end{array}
\times
\begin{array}{c}
\text{GHG Emissions per} \\
\text{Unit Energy Consumption} \\
\left(\dfrac{\text{kgCO}_2\text{e}}{\text{BTU}}\right)
\end{array}
\times
\begin{array}{c}
\text{Total Freight} \\
(\text{metric ton} - \text{km})
\end{array}
=
\begin{array}{c}
\text{Total GWP} \\
(\text{kgCO}_2\text{e})
\end{array}
$$

Fuel Consumption per Unit Freight

Diesel fuel requirements for freight movement were modeled from the GaBi process for a diesel truck-trailer with a 25.34 metric ton payload capacity.

Fuel Energy Density

US Department of Energy provides technical data of diesel energy content, which is 0.1287 million BTU per a gallon of Diesel.

GHG Emissions for Unit Energy Consumption

The amount of GHG emissions (CO_2e) per BTU for each fuel in GREET are utilized to calculate the amount of CO_2e per unit of freight for each HDV.

Total Freight

Based on the billing information Patagonia provided, we calculated the total freight as follows:

Shipment Category	Metric ton-km
Inbound	1,414,738
Direct to Customer	1,760,456
Wholesale	2,072,594
Retail	445,002
Total	**5,692,790**

We assume that:

1) None of alternative fuels is currently used.

2) Rail is not utilized.

3) Each truck carries 100% of Patagonia products.

4) Each state's freight miles/kilometers are averaged by the distance from the Reno, NV distribution center to the three largest cities in each state (Google Maps) and the relative populations of these cities.

Figure 2:

User Input Tab

User Inputs

- Average package weight (kg)
- Average package volume (m^3)

- Average trailer volume (m^3)
- Average maximum payload of truck (metric tons)

- Total freight shipped (metric ton-km)
- Percentage shipped by each truck option (%)

- Percentage driven on each road type (%)

Results

- GHG emissions (CO_2e)

- Fuel consumption
- Fuel cost ($)

Figure 3: Result Tab

Results:

Emission Factors

Figure 4 illustrates GHG emissions per unit of freight as a function of fuel type. Emission factors are shown in grams of CO_2/metric ton-km.

The red segments show WTT emissions. Some upstream emissions are negative because some fuels, such as biodiesel, sequester carbon during production, and others such as natural gas from landfills are credited for avoided flaring emissions. The blue segments show the TTW emissions. Some fuels do not have use-phase emissions, since all electricity or hydrogen vehicles do not emit any GHGs during operation.

To address Patagonia's interest in tar sands, emission factors for two extraction and production pathways were calculated. Three emission factors for diesel used in conventional trucks are shown in Figure 4. The first diesel value is based on the average consumptive mix in the US, which comes from a number of production sources, both conventional and unconventional. While the other two diesel emission factors are based on two different production pathways, representing the low and high end of emissions associated with tar sands. It is observed that the GHG levels from tar sands are higher than the average consumptive mix, suggesting that Patagonia's interest in avoiding tar sands was justified.

The total GHG emissions associated with moving all domestic Patagonia freight by Class 8 conventional diesel trucks is 534 metric tons CO_2-equivalents. The other bars show the emissions broken down by distribution leg.
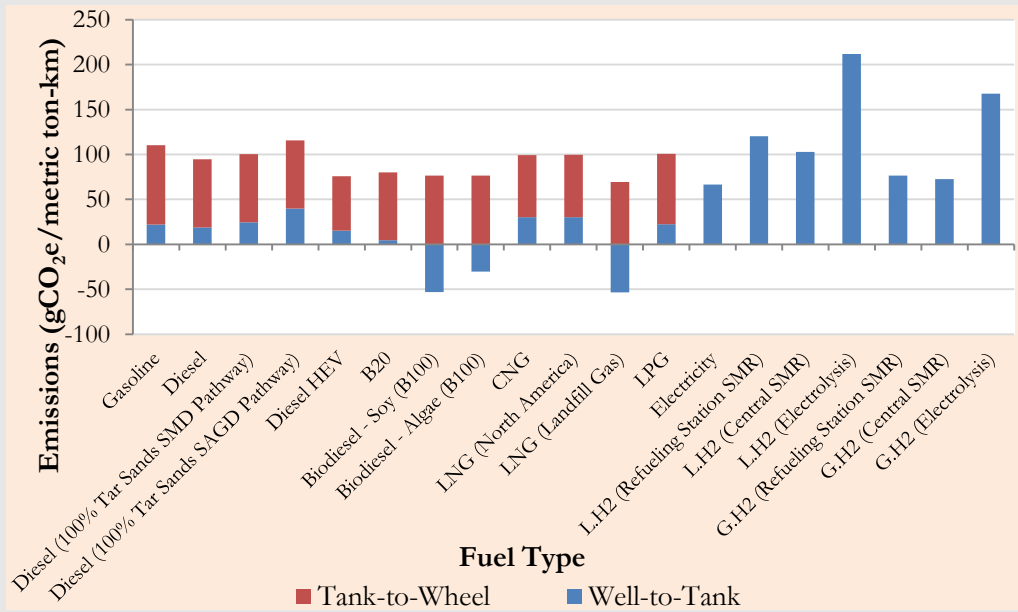

Figure 4: Calculated WTW emission factors showing the relative contributions of upstream (WTT) and use (TTW) emissions.
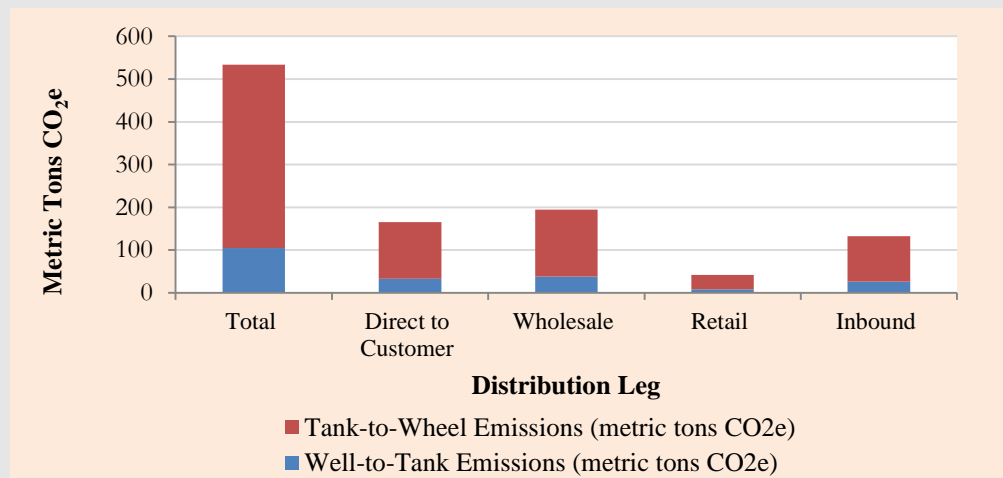

Figure 5: Breakdown of Patagonia freight GHG emissions by distribution leg.

Scenario Testing

In considering implementation scenarios, the fuels that were observed to have lower emission factors than diesel and for which trucks are currently available were examined. The three fuels that fit these criteria are B20, Diesel HEV, and LNG (landfill gas).

Having identified the alternative vehicles to analyze, the project considered scenarios in which diesel trucks were replaced by the different alternative vehicles, from 0% replacement of diesel trucks to 100% replacement. As seen in Figure 6, LNG trucks using natural gas from landfills showed the largest decrease in emissions from replacement, while diesel HEV and B20 fuels show more modest improvements.
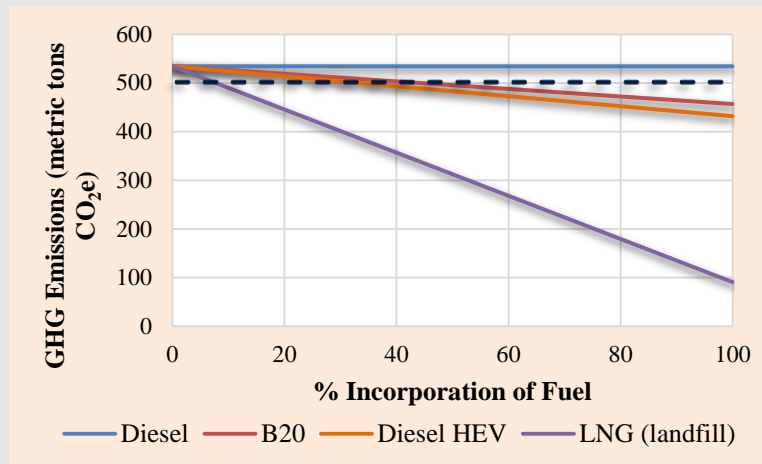

Figure 6: Alternative fuel replacement scenarios.

Sensitivity Analysis

As shown in Figure 7, the reduction and increase of current parameter input values by 20%, and the alteration in package density and trailer volume inputs resulted in the largest variation in WTW emissions. By reducing the package density by 20%, the WTW emissions increase by 19%. Similarly, by increasing the package density by 20%, WTW emissions decrease by 13%. Since the payload value is package density multiplied by the trailer volume, which is one of the direct variables utilized in calculating both TTW emission factors and energy required per metric ton-km, both parameters possess equivalent sensitivity in the model. While a long-haul distribution network solely composed of urban use is entirely unrealistic, it is interesting to note that by altering the drive share to 100% urban use, WTW emissions increase by 35%. On the other hand, if drive share is altered to 100% motorway, WTW emissions only decrease by 3%.

From Figure 7, we observe that the density can have a large impact on GHG emissions, ranging from over 4,000 metric tons of CO_2-equivalents at a low package density, to less than 500 metric tons at high package densities.
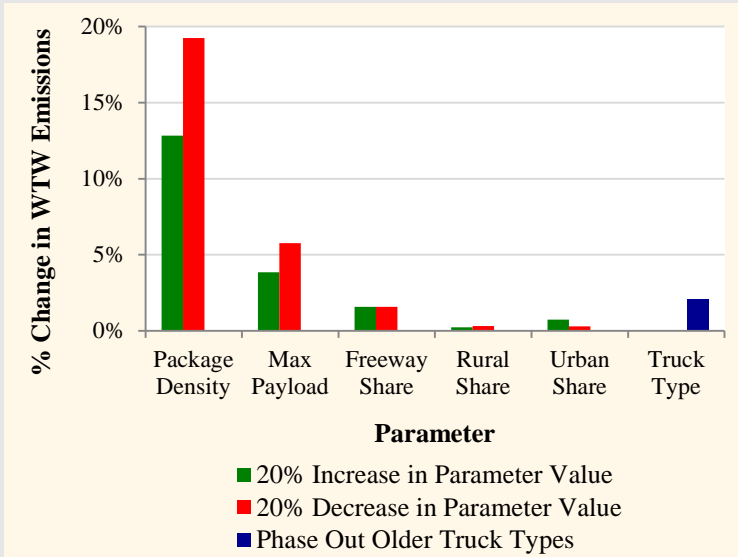

Figure 7: Sensitivity of all major parameters included in the model.
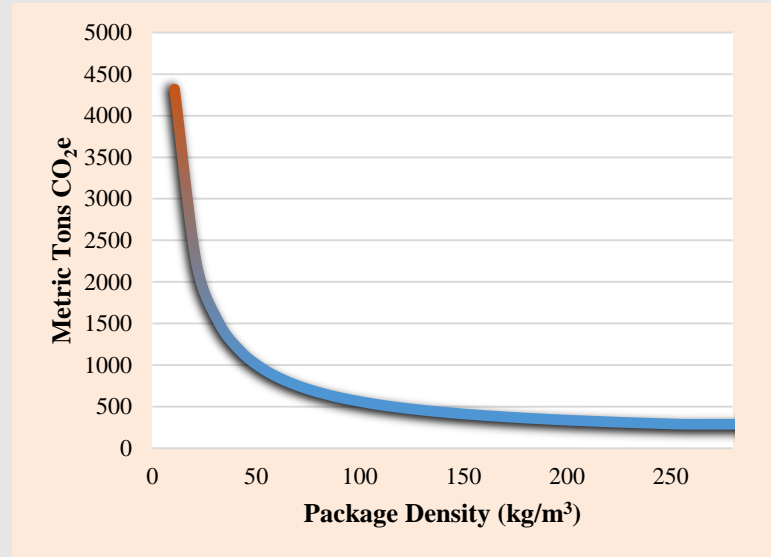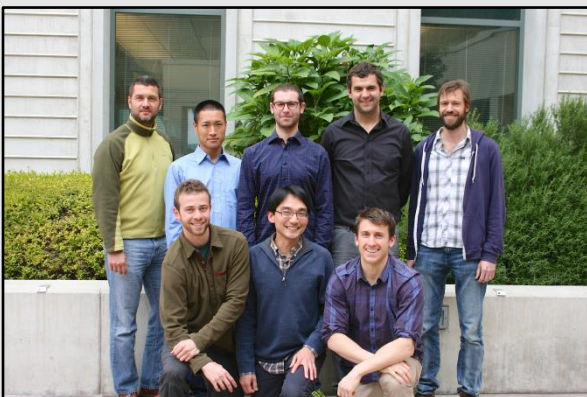

Figure 8: Well-to-Wheel emissions as a function of package density.

Recommendation to Patagonia:

Ultimately, there was the concern of whether or not the integration of alternative fuel technologies was feasible for Patagonia, given that they do not own their own truck fleet and contract with third-party shipping companies. Alternatively, GHG emissions could be altered through other parameters unrelated to fuel type. A sensitivity analysis of FEAT suggested that package density had a large impact on GHG Emissions.

As such, the project's most feasible recommendation is to increase the density of shipped packages as much as possible. Not only does an increased density have a large GHG emissions reduction potential, but also Patagonia has direct control over this parameter.

Acknowledgements