Decarbonizing Long-haul Trucking
Climate change caused due to rising global mean temperatures from greenhouse gas (GHG) emissions is a major problem, plaguing the 21st century. Solving the climate crisis is largely reliant on phasing out fossil fuels and replacing them with renewable energy. Today, medium and heavy duty trucks run exclusively on diesel, and accounts for 7.1% of the total GHG emissions.

Decarbonization of the trucks is a hard problem. Trucks are an indispensable part of the modern supply-chain, any increase in the cost of trucking is felt universally. Decarbonization solutions need to be both economically viable and practical to implement.

This document summarizes the preliminary findings from studying three decarbonization options for long-haul trucking in the US:

- Biofuels
- Battery Electric
- Hydrogen
“Long-haul trucks often do not return to depots at night, need to refuel/recharge at many locations”

“Trucks have high energy demand. One day of driving consumes 80 gallons of diesel”

“Operating Cost dominates Capital Cost by a factor of 5 over the lifetime of the truck”

“Labor & Fuel make up majority of Operating Cost, while Powertrain (engine, transmission, etc.) has small contribution to Capital Cost”

Total Cost of Trucking

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPEX</td>
<td>47%</td>
</tr>
<tr>
<td>CAPEX</td>
<td>18%</td>
</tr>
<tr>
<td>Misc.</td>
<td>23%</td>
</tr>
<tr>
<td>Powertrain</td>
<td>1%</td>
</tr>
</tbody>
</table>

Flexible Routes

11 hours/day

600 miles/day
“Biodiesel is functionally equivalent to diesel, thus compatible with standard trucks”

“Relatively inexpensive”

$0.42 \ USD/\text{mi}

157 \ gCO_2/\text{mi}

“89% reduction from diesel”

“Crops need land and water to grow. Both scarce resources, leading to scalability concerns”

“CO_2 emissions arise from burning fossil fuels to generate electricity”

“Grid is expected to be cleaner in the future”

“We need a $1500 \ kWh$ battery, weighs $\approx 6$ tonnes, costs $\$200k$”

“Batteries are getting cheaper each year”

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“Blue hydrogen is cheap and relatively clean”

$2 \text{ USD/kg} \\
3.6 \text{ gCO}_2/\text{gH}_2 \\
*90\% \text{ Carbon Capture}

“Green hydrogen is expensive but very clean”

$8 \text{ USD/kg} \\
0.6 \text{ gCO}_2/\text{gH}_2

Summary

Today (2020)

Our Projections (2050)

Total Cost of Trucking (incl. Carbon Tax)

“Long-haul trucking remains an open problem with no clear winner”

“Hydrogen has practical advantages for long-hauling such as scalability and fast refueling time. Also, there is a enormous potential to improve delivery and refueling to further reduce H\text{2} cost”

Energy lost - 20 to 30% 
Compressor cost > $1MM USD

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At gas station

$1.70 \text{ USD/mi} \\
1020 \text{ gCO}_2/\text{mi}
Liquid Organic Hydrogen Carriers (LOHCs)

They are organic molecules that can be reversibly hydrogenated (exothermic) and de-hydrogenated (endothermic) to absorb and release hydrogen as needed.

**Pros**
- Liquid fuel - Synergistic with existing fuel infrastructure
- High thermo-stability and inert
- Mature technology can handle fuel demand for long-hauling

**Cons**
- 30% energy penalty due to highly endothermic dehydrogenation
- Hydrogen still needs compression before using it as a fuel

**LOHC Today**

**Our Idea: On-board Hydrogen Generation**

“40% of the fuel’s energy is wasted in the exhaust of an internal combustion engine. We will use this to power dehydrogenation”

“No need for compression as we eliminate any need to store hydrogen as a gas”

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