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Decarbonizing Transport in India

LCA of Lightweighted ICEs and BEVs: An India Perspective

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The Rise of Automotive Industry in India

Before 1990’s

- 7.1% Contribution to India’s GDP in 2017. Increases to 12% by 2026
- Sustained Growth Rate of 7.5% per Year
- Sales Volumes Reaching 10 million units by 2030

Now

Part of The Big Three

SIAM, 2017
Three Major Sustainability Challenges for Automotive Industry in India

- Globally Third Largest Offender in terms of GHG Emissions
- Transport Sector Responsible for 12% Impact

- 14 out of 20 World’s Most Polluted Cities in India (WHO Report 2017)
- Passenger Cars: 11% PM and 7% NO\textsubscript{x} Emissions

- $101 billion USD of Crude Oil Imports in 2020
- Threefold Increase in Oil Demand - 280 Mtoe by 2040 (Trading Economics 2020)
And We Cannot Forget Traffic Congestion Problems

Driving in Urban Areas

5 kmph

Fuel Loss: 1625 Kilo Liters/Year
GHG Emissions: 3899 tons/year
PM$_{10}$: 9.75 tons/year

Sarath, sim-air.org Study, 2009
Electric Cars Touted as a Cleaner Alternative

Electric vehicles in India: Govt gets realistic, plans to develop ecosystem first

First came the ambitious target of having all new cars electric by 2030. Then, the about-turn of not needing any policy on electric vehicles. And now, toning down the hyperbole.

All electric cars by 2030? Nitin Gadkari inaugurates EV charging points at NITI Aayog

In a bid to go green, the government is targeting the year 2030 by which it plans to go all-electric in terms on new car sales across India. In a step towards its mission, Union Minister Nitin Gadkari inaugurated Electronic Vehicle (EV) charging points today.
For India, Is Electro Mobility a Sustainable Solution?

- Coal Intensive Electric Grid: Increase GHG Emissions

- Reduced Foreign Oil Dependency
- Improved Urban Air Quality
LCA of Lightweighted ICEs and BEVs

Env. Performance of a Passenger Car Driven for a Lifetime Distance of 150,000 km in 15 Years
## Key Modeling Parameters

<table>
<thead>
<tr>
<th>Material</th>
<th>Regular ICE</th>
<th>Lightweight ICE</th>
<th>Compact BEV</th>
<th>Sub Compact BEV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wt. kgs</td>
<td>Wt.%</td>
<td>Wt. kgs</td>
<td>Wt.%</td>
</tr>
<tr>
<td>Steel</td>
<td>770</td>
<td>66%</td>
<td>57</td>
<td>7%</td>
</tr>
<tr>
<td>HSS</td>
<td>80</td>
<td>7%</td>
<td>244</td>
<td>30%</td>
</tr>
<tr>
<td>Plastic</td>
<td>75</td>
<td>6%</td>
<td>162</td>
<td>20%</td>
</tr>
<tr>
<td>Aluminum</td>
<td>55</td>
<td>5%</td>
<td>187</td>
<td>23%</td>
</tr>
<tr>
<td>Battery</td>
<td>0</td>
<td>0%</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Others</td>
<td>180</td>
<td>16%</td>
<td>162</td>
<td>20%</td>
</tr>
<tr>
<td>Total</td>
<td>1160</td>
<td>100%</td>
<td>812</td>
<td>100%</td>
</tr>
</tbody>
</table>

Others include: Fluids, Glass, Copper, Elastomers and not included in the model

### Fuel Economy for ICEs

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Petrol Cars</td>
<td>16 km/lit</td>
</tr>
<tr>
<td></td>
<td>(based on avg of 12 variants)</td>
</tr>
<tr>
<td>Diesel Cars</td>
<td>22 km/lit</td>
</tr>
<tr>
<td></td>
<td>(based on avg of 16 variants)</td>
</tr>
</tbody>
</table>

### EV Charging Mix

<table>
<thead>
<tr>
<th>Current (2018)</th>
<th>71% Fossil (60% Coal) and 29% Renewables</th>
</tr>
</thead>
<tbody>
<tr>
<td>2030</td>
<td>56% Fossil (44% Coal) and 44% Renewables</td>
</tr>
</tbody>
</table>

IEA Report 2015
**Key Modeling Parameters: Fleet Level Impact Estimation for 2030**

\[
FEI_{C2030} = N_{V2030} \times \left[ \frac{VKT_{2030}}{\text{Car}} \left( \frac{EID_{C-2030}}{\text{km}} + \frac{EIEA_{C-2030}}{\text{km}} \right) \right]
\]

- **\( FEI_{C2030} \)** = Fleet Level Env. Impact for Year 2030 for impact category “C” (GWP in tons CO\(_2\) eq; Fossil Depletion in Million Barrels of Oil; and Air Pollution in tons PM\(_{10}\) eq.)
- **\( N_{V2030} \)** = No. Vehicles on Road (in 2030) = 69 million units (7.4% growth rate & 10 years retirement age)
- **\( \frac{VKT_{2030}}{\text{Car}} \)** = Vehicle kilometers travelled per car in 2030 (Avg. 10,000 km/year)
- **\( \frac{EID_{C-2030}}{\text{km}} \)** = Env. Impact of Driving a Car per km. (GWP or Oil Consumption or PM\(_{10}\))
- **\( \frac{EIEA_{C-2030}}{\text{km}} \)** = Env. Impact of Attributed to Ageing (Only for GWP @ 10 g km\(^{-1}\) for every year aged)
<table>
<thead>
<tr>
<th>Scenario Type</th>
<th>Petrol (P)</th>
<th>Diesel (D)</th>
<th>EV</th>
<th>Scenario Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Usual</td>
<td>41366257</td>
<td>27577504</td>
<td>0</td>
<td>60% P + 40% D</td>
</tr>
<tr>
<td>Conservative EV</td>
<td>41366257</td>
<td>13788752</td>
<td>13788752</td>
<td>60% P+20% D+ 20% EV</td>
</tr>
<tr>
<td>Moderate EV</td>
<td>34471880</td>
<td>10341564</td>
<td>24130316</td>
<td>50% P+15% D+35% EV</td>
</tr>
<tr>
<td>Agressive EV</td>
<td>34471880</td>
<td>0</td>
<td>34471880</td>
<td>50% P+50% EV</td>
</tr>
</tbody>
</table>

Scenarios are Proposed Based on Gradual Phaseout of Diesel Cars Plus Gradual Introduction of BEVs
LCA Results of Regular Versus Lightweighted Petrol Car

**Lightweight ICEs (Major Benefits)**
- 17% reduction in GWP, Ozone Depletion and Fossil Depletion Impacts
- 54% reduction of Metal Depletion Impact

**Lightweight ICEs (Tradeoffs)**
- 5-10% Higher Eutrophication and Human Toxicity Impacts
LCA Results of Petrol Driven Versus Electric Operated Car in India

Except for Ozone Dep, Petrol Car Performs Better than BEVs in Other Impact Categories

- GWP and Fossil Dep. Lower than Petrol Car with 2030 Grid Mix
- Fossil Dep of BEVs Lowered with 2030 Grid Mix Poor Overall Env. Performance
- Other Impacts Lower than Regular BEVs but Still Lower than Petrol Car
2030 Fleet Level Assessment Results

Fleet GHG Emissions (MMT CO₂ eq.)

Regular BEV Penetration

ICE | 20% BEV | 35% BEV | 50% BEV
---|---|---|---
119 | 125 | 129 | 134

Compact BEV Penetration

ICE | 20% BEV | 35% BEV | 50% BEV
---|---|---|---
119 | 116 | 113 | 111

Compact BEV Option: GHG Friendly for India
2030 Fleet Level Assessment Results

Fleet Oil Consumption (Million Barrels)

<table>
<thead>
<tr>
<th></th>
<th>ICE</th>
<th>20% BEV</th>
<th>35% BEV</th>
<th>50% BEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption (Million Barrels)</td>
<td>358</td>
<td>296</td>
<td>242</td>
<td>196</td>
</tr>
</tbody>
</table>

Fleet Particulate Matter (kilo tons PM$_{10}$ eq.)
(Only Tank to Wheel Considered)

<table>
<thead>
<tr>
<th></th>
<th>ICE</th>
<th>20% BEV</th>
<th>35% BEV</th>
<th>50% BEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate Matter (kilo tons PM$_{10}$ eq.)</td>
<td>102</td>
<td>73</td>
<td>58</td>
<td>36</td>
</tr>
</tbody>
</table>
Conclusions

✓ Lightweighting ICEs is a Short Term and Compact BEVs a Long Term Sustainable Solution

✓ BEVs Reduce India’s Oil Dependency and Air Pollution in Urban Areas.
Some Future Insights: Talk to Industry In Terms of Total Costs

AHSS BIW (235 kg)

MS BIW (280 kg)

CFRP BIW (140 kg)

Lifetime Operation of 200,000 km

- Mfg. Costs (Private Cost)
- Fuel Cost to Consumer

Environmental Impacts (LCA)

Unit Externality (€/Impact)

Total Externality Cost of BIW (€)

SROI
Some Future LCA Insights for India: Talk to Industry In Terms of Total Costs

SROI = \[
\frac{\text{Reduction in Fuel Consumption & Env. Externality Costs from Baseline}}{\text{Body in White (BIW) Manufacturing Cost}}
\]

<table>
<thead>
<tr>
<th>MS BIW Replaced with</th>
<th>Fuel Used for Operation</th>
<th>Mfg. Cost to OEM (€)</th>
<th>Social Costs (€)</th>
<th>SROI (€/€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None (Baseline)</td>
<td>Gasoline</td>
<td>882</td>
<td>3663</td>
<td>0</td>
</tr>
<tr>
<td>AHSS BIW</td>
<td>Gasoline</td>
<td>941</td>
<td>3167</td>
<td>0.52</td>
</tr>
<tr>
<td>AHSS BIW</td>
<td>E-85-Wood</td>
<td>941</td>
<td>1828</td>
<td>1.94</td>
</tr>
<tr>
<td>AHSS BIW</td>
<td>E-85-Corn</td>
<td>941</td>
<td>2426</td>
<td>1.31</td>
</tr>
<tr>
<td>AHSS BIW</td>
<td>Electricity-RER</td>
<td>941</td>
<td>908</td>
<td>2.92</td>
</tr>
<tr>
<td>CFRP BIW</td>
<td>Gasoline</td>
<td>1464</td>
<td>1863</td>
<td>1.22</td>
</tr>
<tr>
<td>CFRP BIW</td>
<td>E-85-Wood</td>
<td>1464</td>
<td>1147</td>
<td>1.71</td>
</tr>
<tr>
<td>CFRP BIW</td>
<td>E-85-Corn</td>
<td>1464</td>
<td>1454</td>
<td>1.50</td>
</tr>
<tr>
<td>CFRP BIW</td>
<td>Electricity-RER</td>
<td>1464</td>
<td>797</td>
<td>1.95</td>
</tr>
</tbody>
</table>

- High SROI for AHSS BIW with Wood Biofuel and Electric Cars
- High SROI for CFRP BIW with Gasoline and Corn Biofuel Driven Cars

Some Future LCA Insights for India: Account for Regionalization

Particulate Matter Impact Assessment

✓ Current Methods (e.g. ReCiPe)
  ▪ No Differentiation Between Emissions of Mobile and Stationery Sources (PM < 10 \(\mu\)m = 0.228; PM < 2.5 = 1)

✓ Fractional Intake Approach
  ✓ Differentiates Emissions from Mobile and Stationery Sources
  ✓ Differentiates Stationery Source Emissions Based on Stack Height
  ✓ Scope for Inclusion of Regionalized Factors.

Humbert et al, ES&T. 2011, 45, 4808-4816
Some Future LCA Insights: Sustainability Goals Also Should Target Social Welfare

<table>
<thead>
<tr>
<th>Category</th>
<th>Group</th>
<th>Income Range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>Bus Rider</td>
<td>$900-1000 /Yr</td>
<td>$900-1000 /Yr, 17% on Transport</td>
</tr>
<tr>
<td>Lower Middle</td>
<td>Cab Driver</td>
<td>$5000-11000</td>
<td>$5000-11000, Buys Own Fuel</td>
</tr>
<tr>
<td>Upper Middle</td>
<td>Car Owner</td>
<td>$22000-36000</td>
<td>$22000-36000, Rebound Effects</td>
</tr>
</tbody>
</table>

**Biomethane Utilization as Transport Fuel**

<table>
<thead>
<tr>
<th>Category</th>
<th>Sustainable Rate of Returns (SRR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>Bus Transport Provider</td>
</tr>
<tr>
<td>Middle</td>
<td>Cab Driver</td>
</tr>
<tr>
<td>Upper</td>
<td>Car Owner</td>
</tr>
</tbody>
</table>

Private Returns Ratio (PRR) = \( \frac{\text{Fuel Savings}}{\text{Annual Income}_{\text{Person}}} \)

Sustainable Returns Ratio (SRR) = \( \frac{\text{Fuel Savings} + \text{Savings on Env. Ext. Costs}}{\text{GDP}_{\text{PPP}}} \)

Questions?

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Upadhyayula et al., Journal of Cleaner Production 2019, Vol. 209, 1604-1613