STRATCON

Environmental Developers & Consultants

# Environmental Analysis of Waste to Fuel Projects

## Well to Wheel…..

# How to look at Well to Wheel Impacts

Break down assessment into three segments,

1. Well (source of fuel) production and purification,
2. Transport of fuel to vehicle, and
3. Tank to wheel analysis

Measuring Environmental Impacts

a) Air Pollution (NOx, $PM_{BC/10/2.5}$, CO2, CO, HC, NMHC).
b) Health Impacts
c) Climate impacts and Community Perception
d) Operator Corporate CSR & access to capital (Discussion).

Note: PM – Particulate Matter broken into all Black Carbon, under 10µm and under 2.5µm
HC – All Hydrocarbons, NHMC – Non Methane Hydrocarbons

# Well to Storage

| Impact | Diesel | CNG | CBG |
|---|---|---|---|
| Extraction Process | Drilling | Drilling | Digestion Parasitic to factory or digestion at landfill |
| Process Size | Large | Large | Small |
| Intermediate Product | Crude Oil (various fractions and contaminants) | Bulk Gas (various fractions and contaminants) | Biogas (45-65% CH4 with H2S/H2o Contamination) |
| Secondary Processing | Shipped as crude to refinery to be cracked and refined | Refinery to/from pipeline to NG or chilled to LNG for transport overseas | Purification to NG quality and compression |
| Final Product | Diesel (various quality) | Natural Gas (NG) or Compressed Natural gas (CNG) | Compressed Bio methane Gas (CBG) |
| Energy Density of Final product | 38.5 MJ/l | 9 MJ/l (LNG 22 MJ/l) | 9 MJ/ (No Ethane) |

# Storage to tank

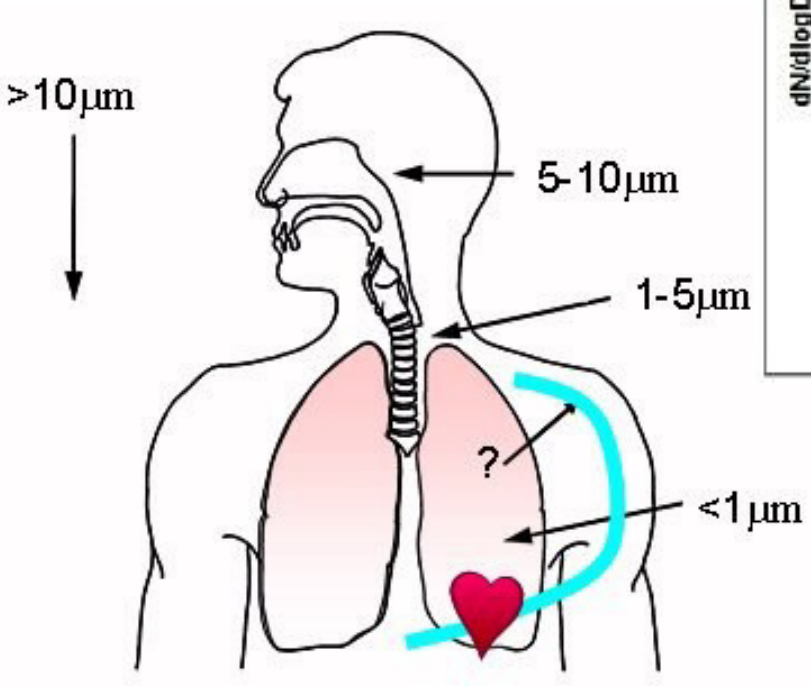
| Impact | Diesel | CNG | CBG |
|---|---|---|---|
| Distribution to Depot | Ship, Tanker | Ship, Pipeline and Tanker | Tanker |
| Typical distance from refining to depot | 1000-9000Km | 1000 - 9000 km | <100km |
| Transport Energy Used | High | High | Very Low |
| Distribution to Buyer | Tanker | Tanker | Tanker |
| Storage Issues | Sulphur and tank time | Lead/Mercury Contamination | Moisture Content if not purified properly |

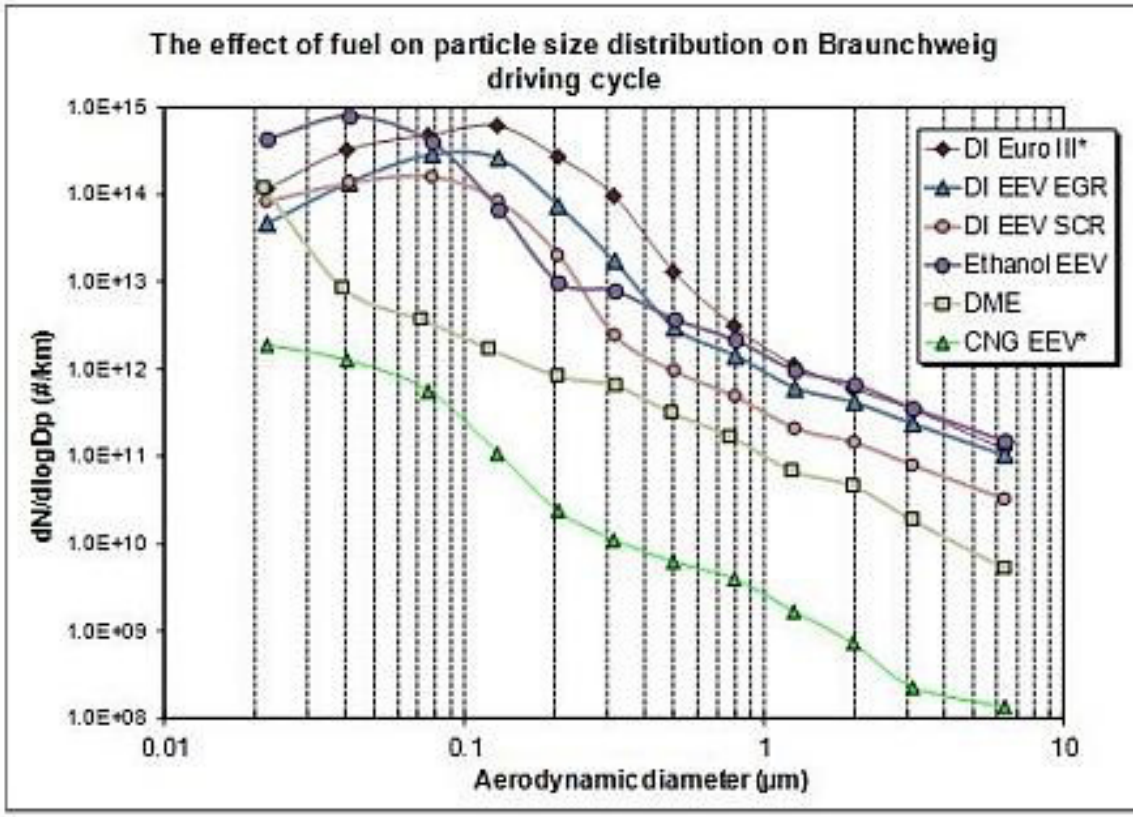
# Tank to Wheel

| Impact | Diesel | CNG | CBG |
|---|---|---|---|
| NOx (g/km) | 5 -7 | 1 - 2 | 0.05 -1 |
| SOx (g/km) | Depends on Mix, CBG higher than CNG but lower than poor quality high sulphur diesel in emerging economies. | | |
| $PM_{10}$ (g/km) | 0.18 | 0.06 | 0.06 |
| NMHC (g/km) | 0.14 | 0.02 | 0.024 |
| CO (g/km) | 0.3 | 0.5 | 0.6 |
| $CO_2$ (g/km) | 1000 | 800 | 800 |
| Ames Mutagenicity test (rev/mg/10) TA99-S9, BSC)<br><br>Source VTT Nyland 2004 with additions. | Averaged 200 | Averaged 95 | Not tested but expected lower due to no ethane in mix and no lead or mercury from bio accumulation in petroleum Products |

# Particulate matter (PM)

**Particulate matter**, especially PM2.5 are a major health issue. CNG is 1% of diesel emissions of PM2.5




Graph above from *Nylund and Koponen 2012* shows cumulative distribution of particulate matter versus the concentration in exponetial (orders of magnitude) scale. *Note conflict with numbers on slide 5 - discuss*

# Other Health considerations

- **Mutagenicity** is the measure of exposure to certain carcinogens.
- All Hydrocarbons contain carcinogens including PAH - Poly Aromatic Hydrocarbons (ie Benzene et al).
- Formaldehyde used in catalysts and a range of other chemicals created in the combustion process are present in exhaust gases.
- Unburnt hydrocarbons especially Non Methane Hydrocarbons with high carbon numbers are present depending on the efficiency of the engines and the stability of the production process (biogas can produce these).
- Fuel Quality, test cycles, vehicle type, filter and catalysts all play a part in giving variable outcomes in research.

# Climate Change Impacts

**The climate impact of each fuel is measured in Tonnes of CO2 equivalents per kilometer**. This is calculated by adding the sum of the following:

A. Amount of CO2 exhausted per kilometer ,
B. Amount of Methane (CH4) exhaust per kilometer time the green house gas impact factor of 34,
C. Amount of PM10 multiplied by 0.75 (to convert to Black Carbon Factor) and then multiplied again by the greenhouse gas impact factor of 900.

| Type | Diesel | CNG | CBG |
|---|---|---|---|
| **CO2 g/km** | 1000 | 800 | 800 |
| CH4 | 0.05 | 8 | 8 |
| **CH4** as CO2e g/km | 1.7 | 272 | 272 |
| PM10 | 0.18 | 0.06 | 0.05 |
| **PM10** as CO2e g/km | 162 | 54 | 45 |
| **total GHG g/km** | **1163.7** | **1126** | **1117** |

Assuming a carbon price of €2/T CO2e, the cost would be €0.093/km (assuming 20 year horizon in IPCC 2013).

# Assessing Other Impacts

- Sweden with the EU developed the ASEC model to measure the cost impact of vehicle emissions.
- A Dutch group subsequently reviewed the impacts and proposed **€0.004/km for Nox, € 0.002/km for $PM_{10}$ and € 0.075/km for $CO_2e$ giving a total of 0.092/km**.
- These Figures have been used in modelling for CNG/ Bio-methane Buses regionally.
- The actual health costs will vary from country to country as will the impact of green initiatives on share price.
- The figures for Holland are unlikely to be applicable to India or Pakistan.
- Further research is required on the impact of these health and social costs in each country on specific routes and under controlled conditions.