Role of Alternate fuels in Sustainability goals of Cummins

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Public

Outline

- ❖ *Decarbonization journey*
- ❖ *Destination Zero*
- ❖ *Cummins Power Journey*
- ❖ *Low Carbon Fuels Deep Dive*
    - ❖ *Understanding the Fuel*
    - ❖ *Impact on Engine*
    - ❖ *Challenges for After Treatment*
- ❖ *Cummins partnership with alternate fuels*

Decarbonizing the total chain of emissions is essential

WELL-TO-WHEELS EMISSIONS

Removing coal, oil, natural gas or raw materials from the earth

Transportation and distribution →

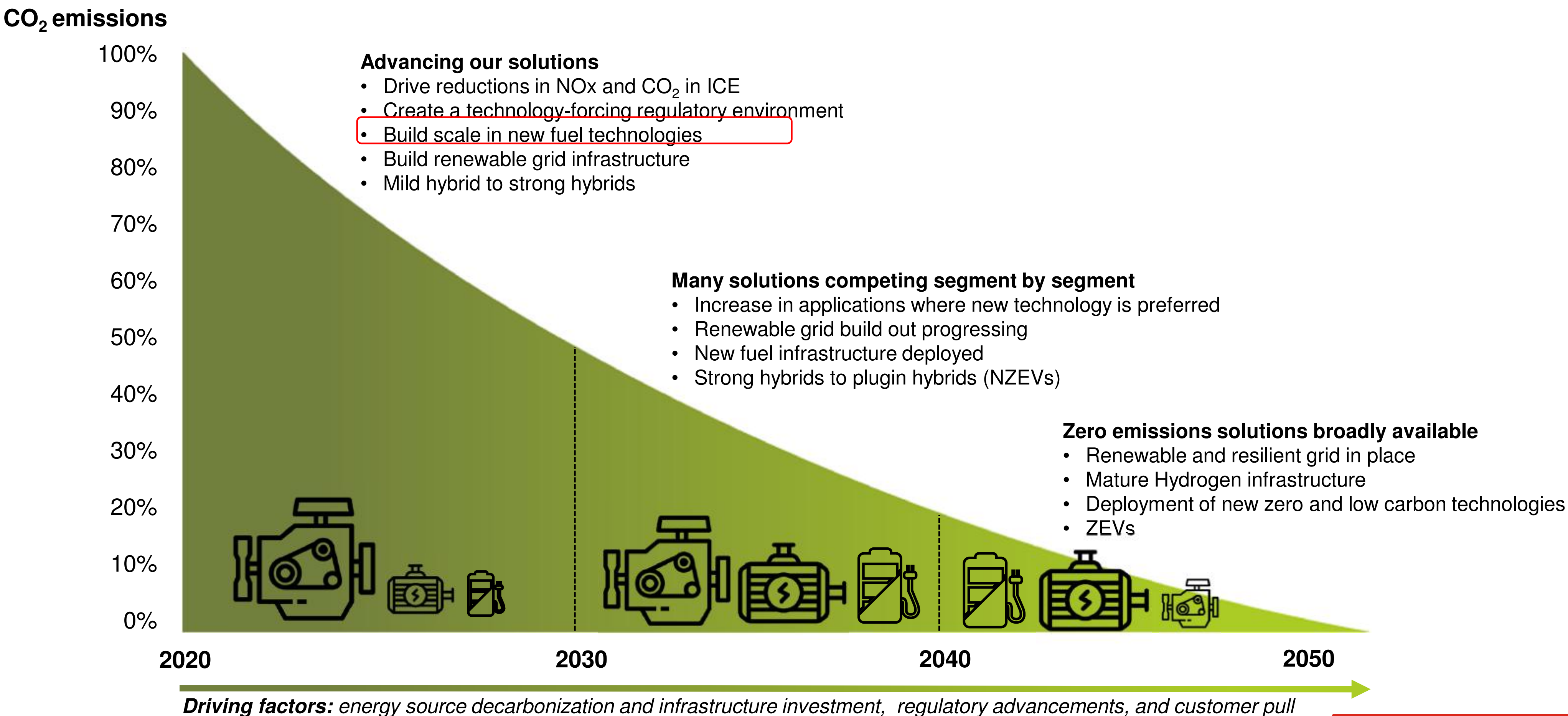
Refining or processing into a usable power source

Transportation and distribution →

CNG

In-use emissions

Reaching Destination Zero



Cummins Power Journey

Fuel Agnostic Engines

Transformative Power

- Diesel & Biodiesel Blends
- Natural Gas
- Hydrogen
- Fuel Cell Technology
- Electrification & Battery Technology
- Electrolyzers

Low Carbon Fuels →

- Natural Gas
- Biodiesel Blends
- Hydrogen
- Methanol
- Ethanol

Carbon-Neutral Fuels →

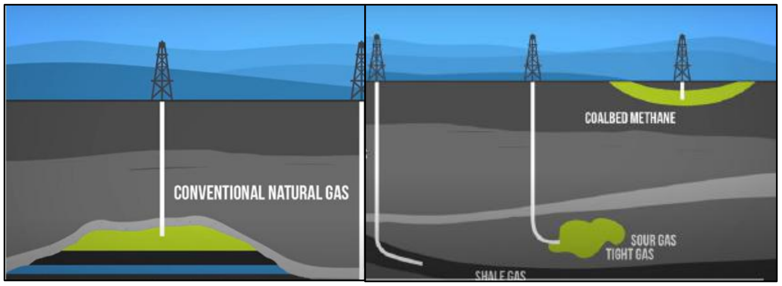
- Renewable Natural Gas
- Methanol from CO_2

Zero-Carbon Fuels →

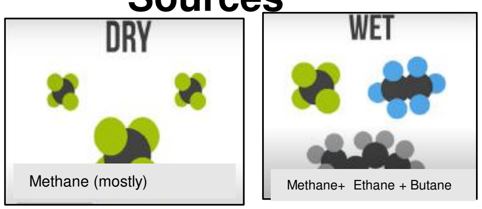
- Hydrogen* (electrolysis)
- Ammonia

Alternative, low, and zero-carbon fuels | Cummins Inc.

Natural Gas



Sources



Types of Natural Gas

Natural Gas — Sources — Student Energy

Diesel vs Natural gas

1. Physical properties

Light gas and odorless

2, Chemical Properties

Natural gas has high energy density on a mass basis

Natural gas consists of 85 to 96% Methane

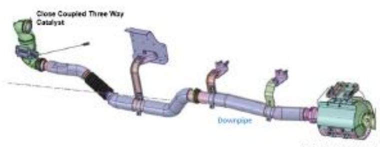
3. Lesser emissions of pollutants like carbon dioxide (CO2), hydrocarbons(UHC), carbon monoxide (CO), sulfur oxides (SOx) and particulate

- Stoichiometric vs. lean burn NG engines
  - Tradeoff between good fuel economy and low emission

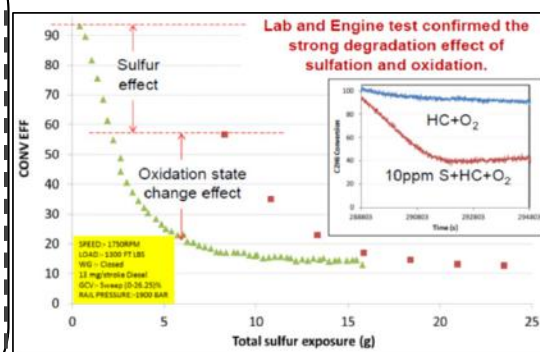
Parameters	Stoichiometric	Lean
Emissions/ Fuel economy	Lower emissions	Better fuel economy
Temperature	Higher T	Lower T
Aftertreatment	TWC	OC+SCR

In Comparison with a diesel Engine:

1. NOx Emissions are higher
2. Additional emittants include Methane and CO



Simpler architecture compared to Diesel ATS



Primarily observed in NG applications

Cause: Fuel quality

Challenges for ATS:

1. Slightly higher H2O compared to diesel
2. Severe Aging- pgm sintering
3. Chemical contamination- S, P, Zn, Ca

Hydrogen

Sources (10 different sources)

Blue: Natural Gas

Grey: Steam methane Reforming with out capture of CO2

Pink: Electrolysis from Nuclear Energy

Green: Electrolysis from Renewable Energy

Diesel vs Hydrogen

1. Physical properties

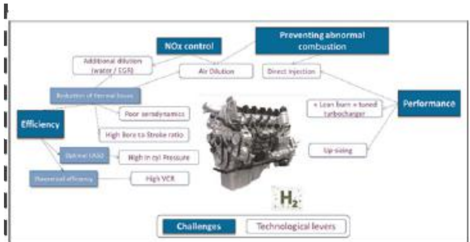
Light, colourless, odourless and highly flammable gas

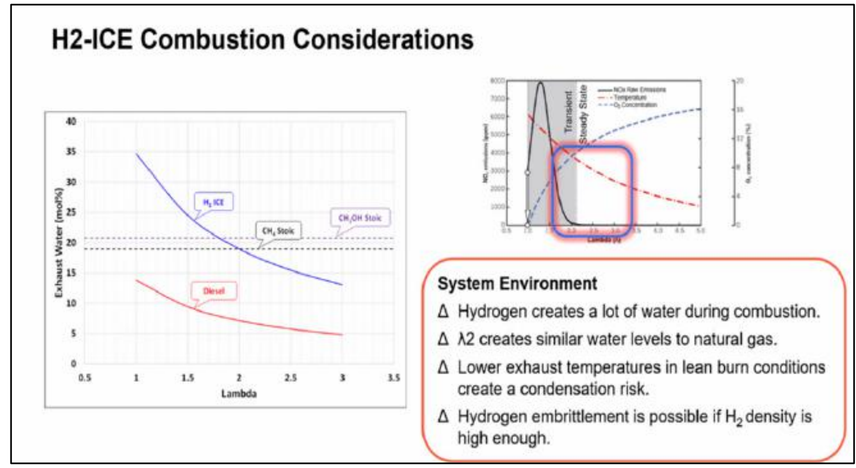
2. Chemical Properties

High octane number of hydrogen

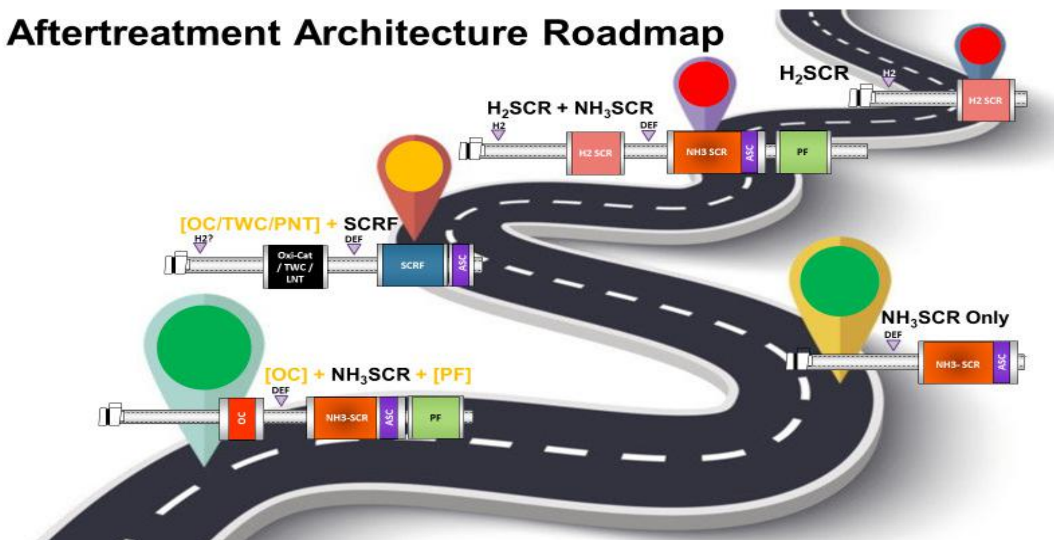
High autoignition temperature

3. Depending on the source it is non-polluting (CO, HC, particulate matter) and lower NOx is produced in a cycle





- System expected to have lower NOx and lower temperatures
- Water levels are higher than natural & diesel



Challenges for ATS:

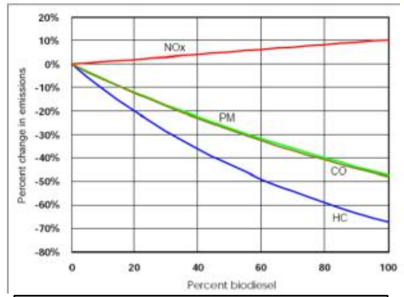
1. Impact of H_2O (~25%)
2. Impact of H_2 in the emissions on catalyst
3. High NOx peaks during transient cycles
4. NOx sensor sensitivity due to H_2O
5. Hydrogen embrittlement is possible at high H_2 density

Biodiesel

Feedstocks

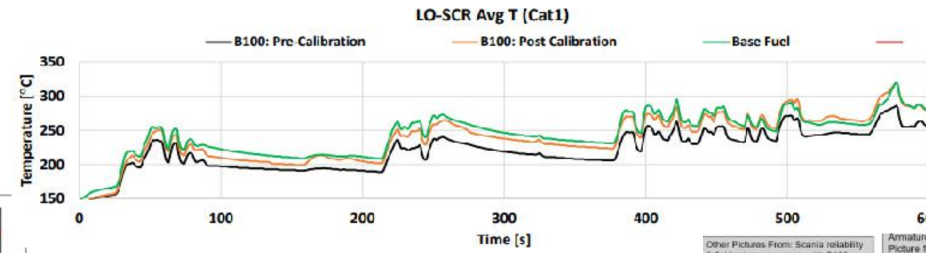
Diesel vs. Biodiesel

1. Physical properties-
   Density, Viscosity & Flash Point are higher for biodiesel
2. Chemical Properties
   Lower Heating value
   Lower oxygen content has an impact on the combustion and regeneration
3. Ash & metallic content have impact on the service life and catalyst deactivation



Increased engine out NOx

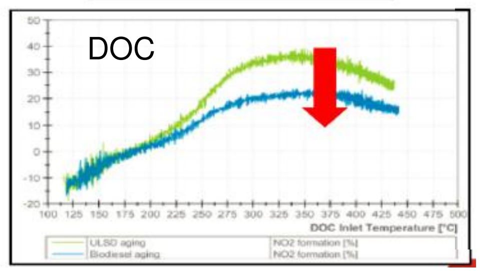
United States Environmental Protection Agency. "A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions", Draft Technical Report, EPA420-P-02-001, (2002).



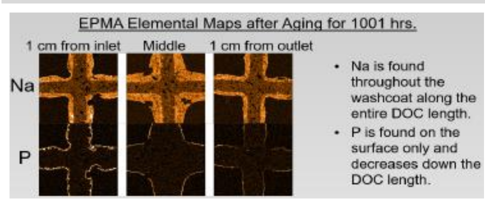
Increased tailpipe NOx due to reduction in energy content of B100 resulting in slower A/T warmup

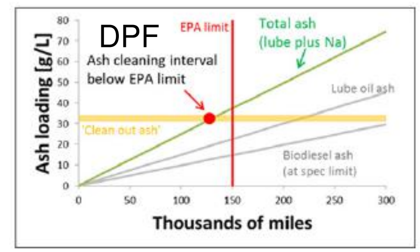
Injector deposits primarily from poor condition fuel

NO2 formation decrease



A/T poisoning from Na, P, and K in biodiesel





Biodiesel impacts the NOx CE of SCR

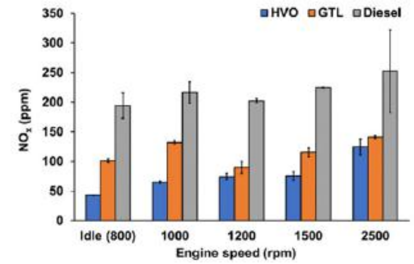
- Presence of elements like Na, P & K have an impact on A/T
- Requirements for ATS may be revisited for supporting customer needs

Hydrotreated Vegetable Oil (HVO)

Feedstock

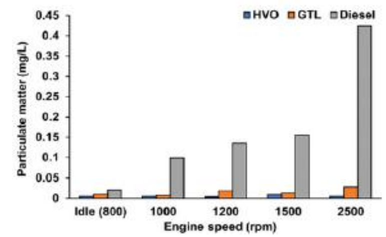
Hydrotreated oil

HVO:Hydrogenated vegetable oil and high value opportunity | NexantECA



https://server1.pla.co.uk/assets/pla-env-alternative-diesel-fuelsv4.p

- ✓ Reduce tailpipe emissions of particulate matter and smoke up to 50%
- ✓ The fuel can be used as drop in fuel , without any change to the engine



Diesel Vs. HVO

1. Physical properties

HVO has similar physical properties as diesel

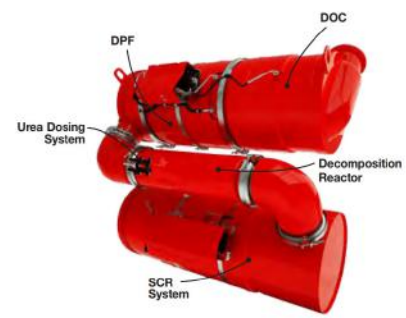
HVO also has approximately 7% less fuel density, limited aromatic and sulfur content, and a higher cetane value versus diesel fuel

2. Chemical Properties

HVO has higher oxidation stability compared to biodiesel

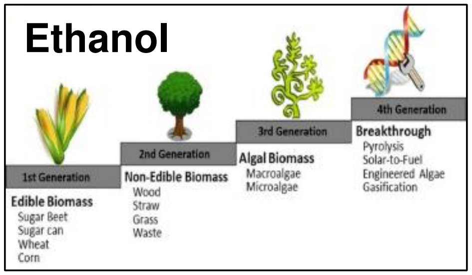
3. HVO are shown to reduce net greenhouse gas (GHG) emission by up to 90% compared to conventional diesel, dependent on the exact feedstock and fuel pathway

- ✓ Due to limited sulfur content in the fuel, there is lower need of temperatures for desulphation and regeneration
- ✓ Regen Temperature requirements are lower due to size and structure of soot
- ✓ Better thermal durability of ATS

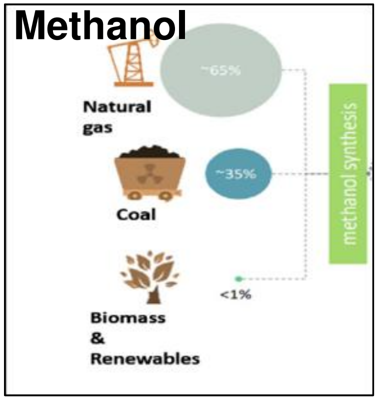


Alcohols(Ethanol/Methanol)

Feedstocks

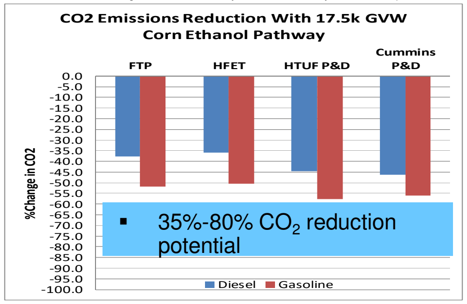


Courtesy: 1G, 2G, 3G Bioethanol: What Are Different Bioethanol Generation Technologies? | ALL ABOUT PIPING



2.8L Ethos- SI (E85)

Cummins: E85-fueled engine cuts medium-duty CO2 emissions by 50% to 80% | FleetOwner



Diesel Blends with Ethanol/ Methanol

- ✓ Higher BSFC with increase in blend concentration
- ✓ Material compatibility is critical for engine durability for both fuels
- ✓ Fuel Pumping System Protection

Diesel Vs. Alcohols (Ethanol/Methanol)

1. Physical properties

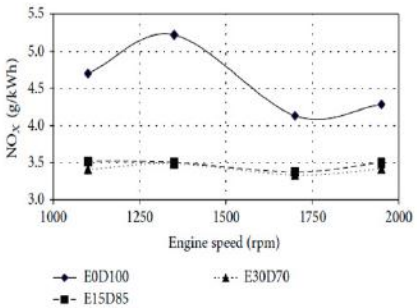
Viscosity, density and high heat value are lower compared to diesel fuel

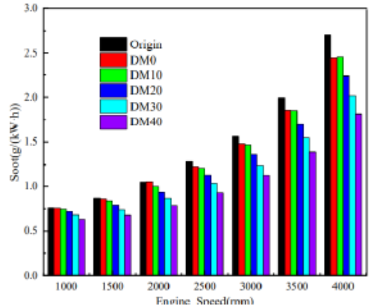
Solubility in diesel is impacted by temperature & water content

2. Chemical Properties

Oxygen content increases and aromatics fractions decreases with increase in alcohol blend

3. Nox and Smoke numbers (particulate matter) decrease with increase in alcohol in blend percentages.





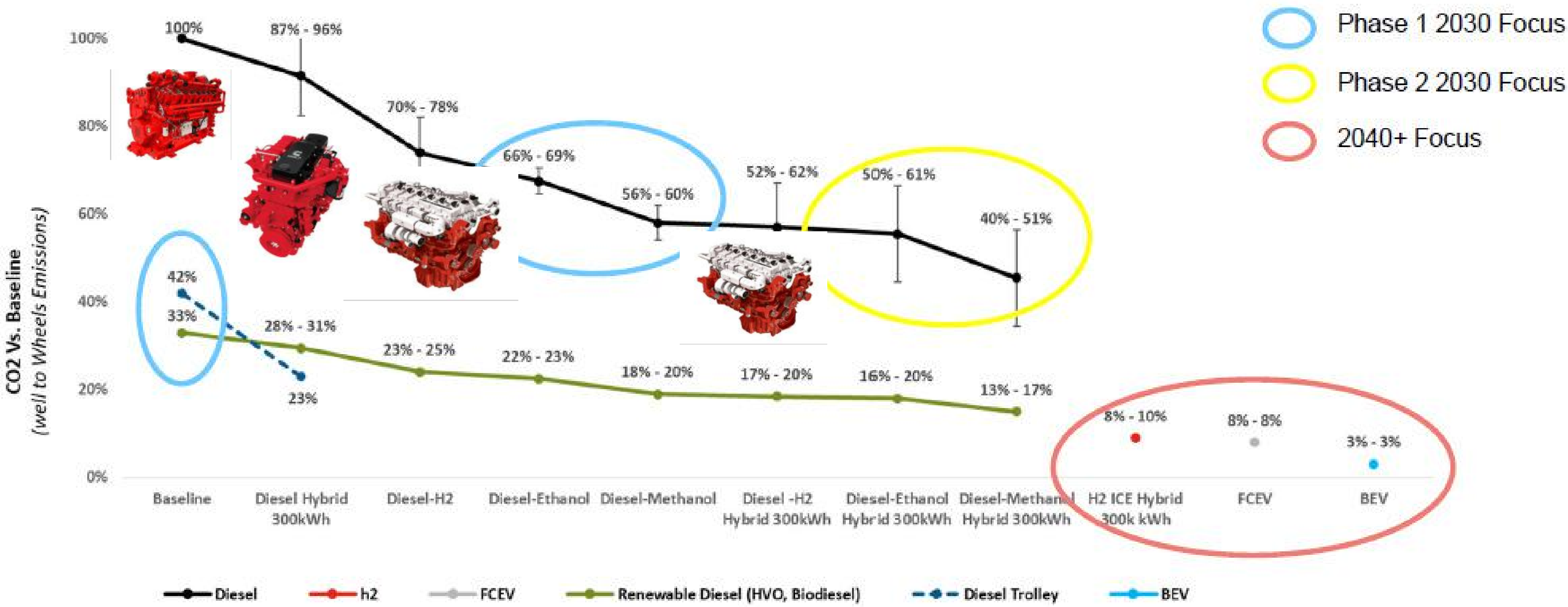
With increase in blend concentration, there is an improvement in emissions

Challenges for ATS

- ✓ After-treatment Poisoning due to fuel source
- ✓ Secondary emittants can be reduced using the catalyst like diesel oxidation catalyst

Summary

✓ Alternate Fuels play a critical role in emission control; reduction on fossil fuel dependency; and energy independence
✓ Cummins has strong presence and development in each type of alternate fuel and is willing to partner for a suitable application of alternate fuel



Q&A

The first natural gas vehicle using pressurized gas container was observed in Italy 1936

Fig. 5. Natural gas inter-urban with 40 seats on FIAT chassis 635 RL of 1936.

Refer: Technical overview of compressed natural gas (CNG) as a transportation fuel

First Internal combustion engine that used a hydrogen/oxygen combination, was developed in 1806 by Francois Isaac de Rivaz

First Ethanol based engine was developed in Brazil in 1978 by Fiat

Refer: History of Biodiesel – Farm Energy (extension.org)

Rudolf Diesel's used Peanut oil in 1890

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