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Combusion and Emission Characteristics of ABE/IBE Diesel Blends

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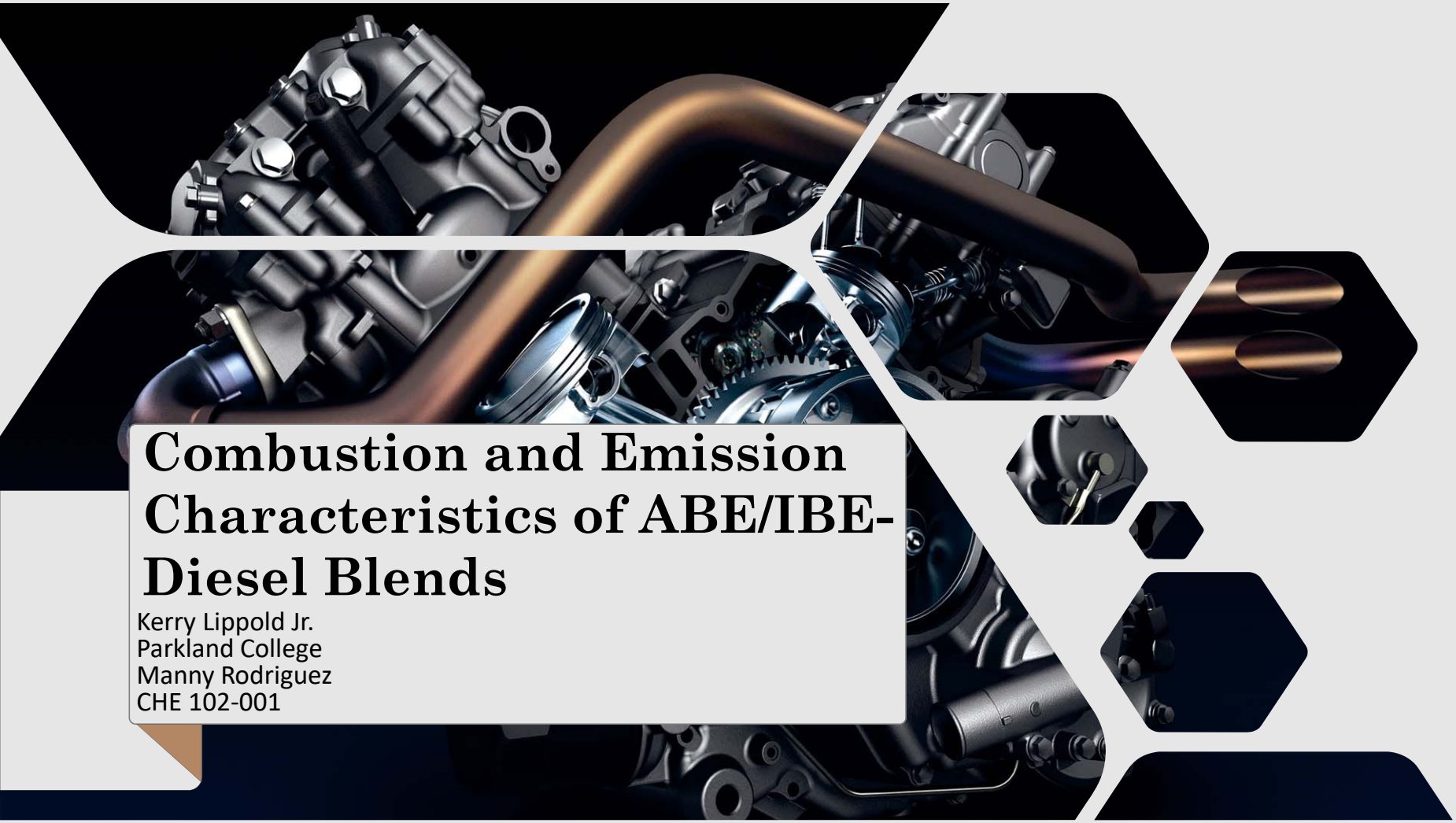

Combustion and Emission Characteristics of ABE/IBE-Diesel Blends

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Image Source: https://www.google.com/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwi4-Jzcid3eAhVRJKwKHXR5CIsQjRx6BAgBEAU&url=https%3A%2F%2Fstmed.net%2Fvehicles%2Fengine-wallpapers&psig=AOvVaw0o6ICWi7QqEdNEkZnY7j78&ust=1542600673863014

Experimental Purpose

Finding Alternative Fuels[2]

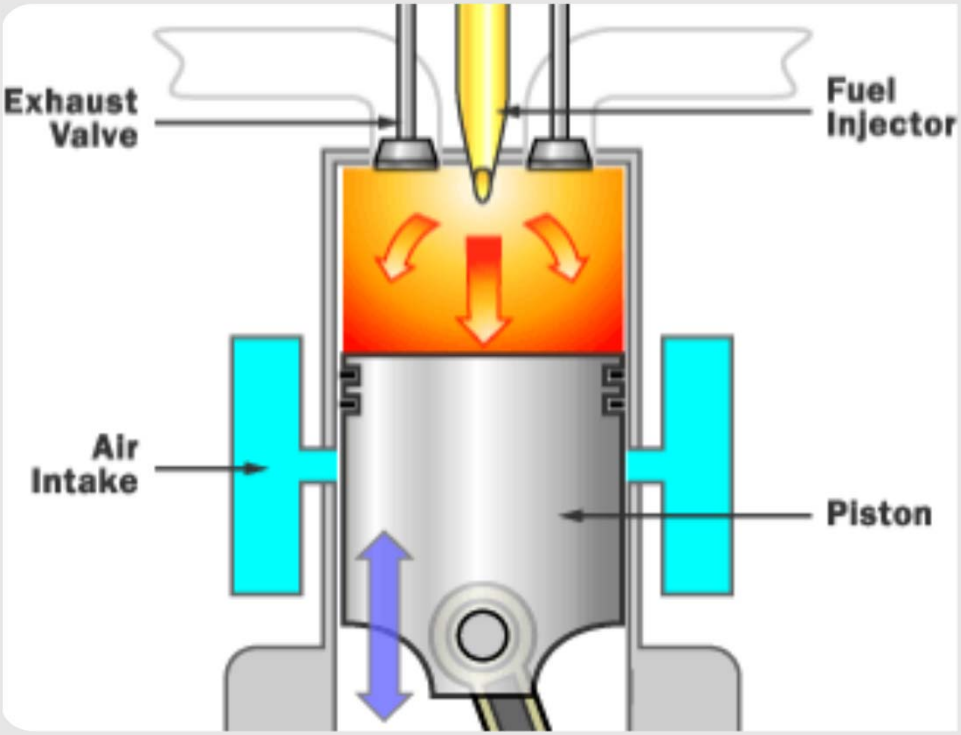
- The Petroleum Crisis
  - Oil Drilling
    - Non-Renewable
    - Limited Fuel Source
    - Dangerous/Wasteful
    - Reserves Running Dry
  - Petroleum Demand
    - Large Portion of the Economy
    - Relatively Cheap Good
      - Mass Production
      - Established Means of Extraction
  - Petroleum Burning Emissions
    - NO_x
    - CO_2 and Other Green House Gases
- Proposed Experimental Solution
  - Cleaner Bio-fuels

https://climate.nasa.gov/solutions/adaptation-mitigation/

Background

Combustion & Emissions[1]

- Compression-Ignition Engine
  1. Intake
  2. Compression
  3. Power
  4. Exhaust
- Ideal Engine Combustion
  - $C_xH_yO_z + O_2 \rightarrow H_2O + CO_2$
- Actual Engine Combustion Reactants
  - $C_xH_yO_z$ + Fuel Detergents
  - Air[2]
    - ~71% $N_2(g)$
    - ~21% $O_2(g)$
    - ~1% Other Inert Gases

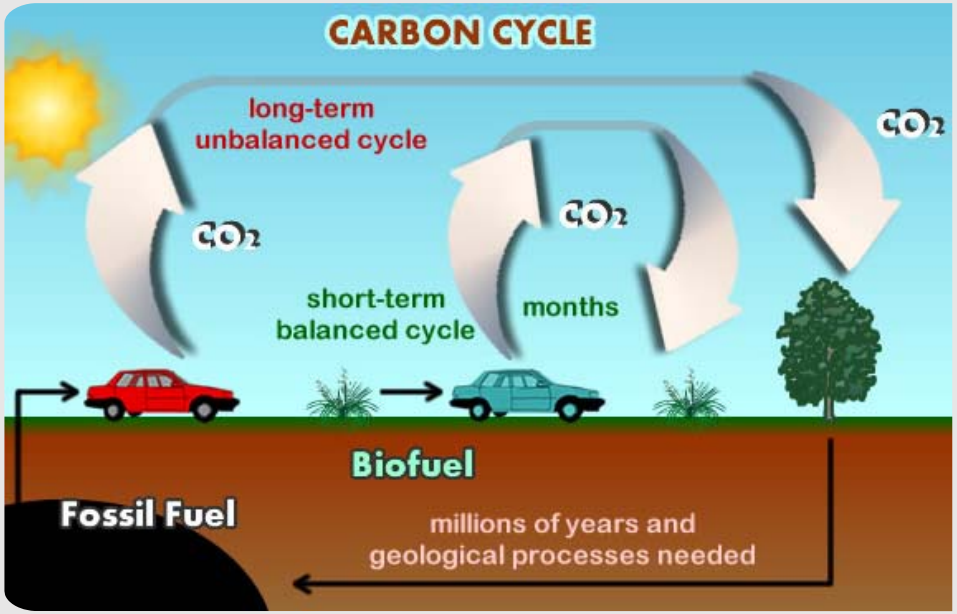


https://auto.howstuffworks.com/diesel-two-stroke1.htm

Experimental Fuels

Advantages vs. Disadvantages[3]

- Advantages
  - Balanced Carbon Cycle
    - Carbon is removed from the atmosphere to produce the fuel
    - Carbon is used up and converted relatively quickly
  - Relatively Renewable
    - Plant Growth
    - Fermentation
- Disadvantages
  - Expensive[4]
    - Fermentation and Production Process
    - Underdeveloped methods for extraction
  - Harmful Emissions
    - Typically used in diesel mixtures
    - Can produce more or less harmful emissions depending on the fuel

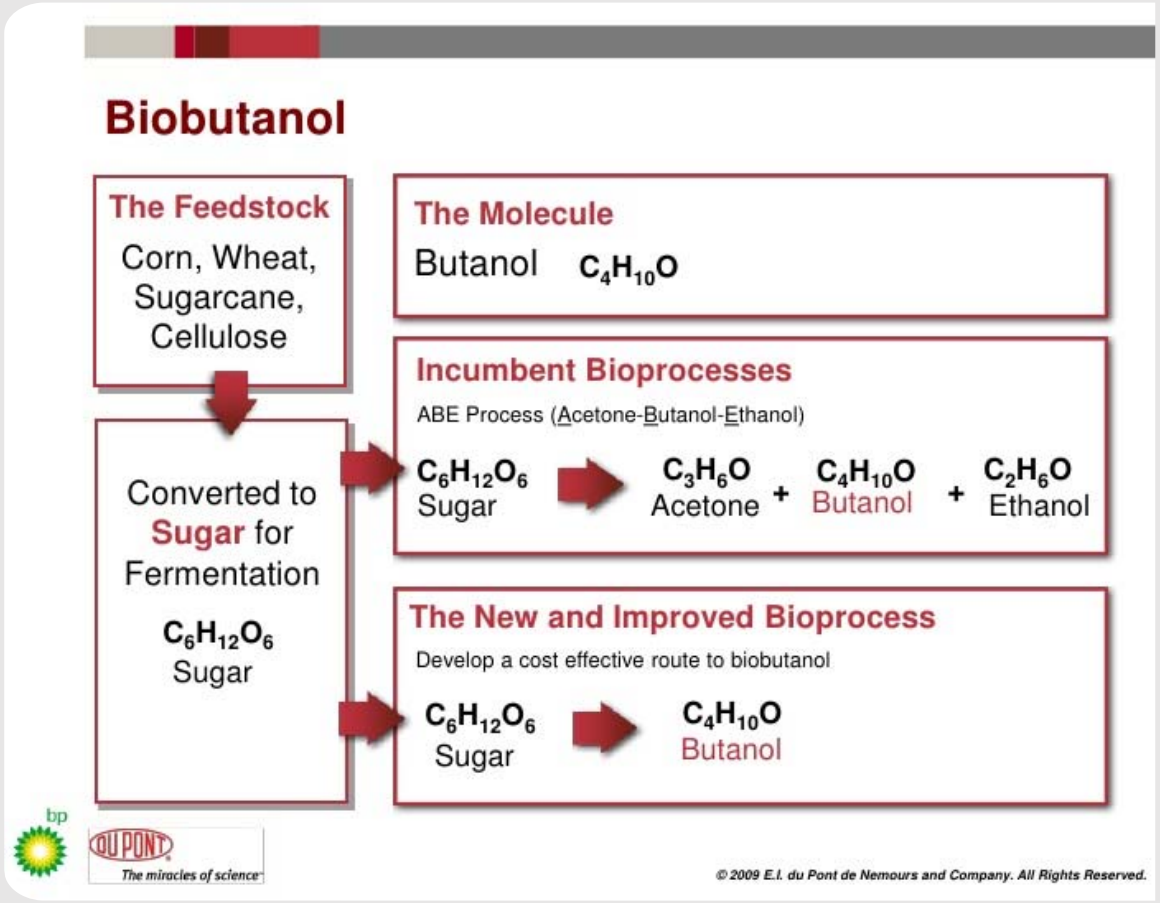


http://www.myfloridahomeenergy.com/help/library/transportation/alternative-fuels-for-vehicles/#sthash.R0Q9xyaP.dpbs

Experimental Fuels

Chemical Properties[2]

- Acetone-Butanol-Ethanol (ABE)
  - Acetone: C_3H_6O
    - Latent Heat (kJ/kg): 518
    - Auto-Ignition Temperature (°C): 465
  - n-Butanol: C_4H_9OH
    - Latent Heat (kJ/kg): 582
    - Auto-Ignition Temperature (°C): 434
  - Ethanol: C_2H_5OH
    - Latent Heat (kJ/kg): 904
    - Auto-Ignition Temperature (°C): 420
- Isopropanol-Butanol-Ethanol (IBE)
  - Isopropanol: C_3H_7OH
    - Latent Heat (kJ/kg): 758
    - Auto-Ignition Temperature (°C): 399
- Diesel
  - Ranges from: $C_{10}H_{22}$ to $C_{22}H_{46}$
    - Latent Heat (kJ/kg): 260
    - Auto-Ignition Temperature (°C): 250

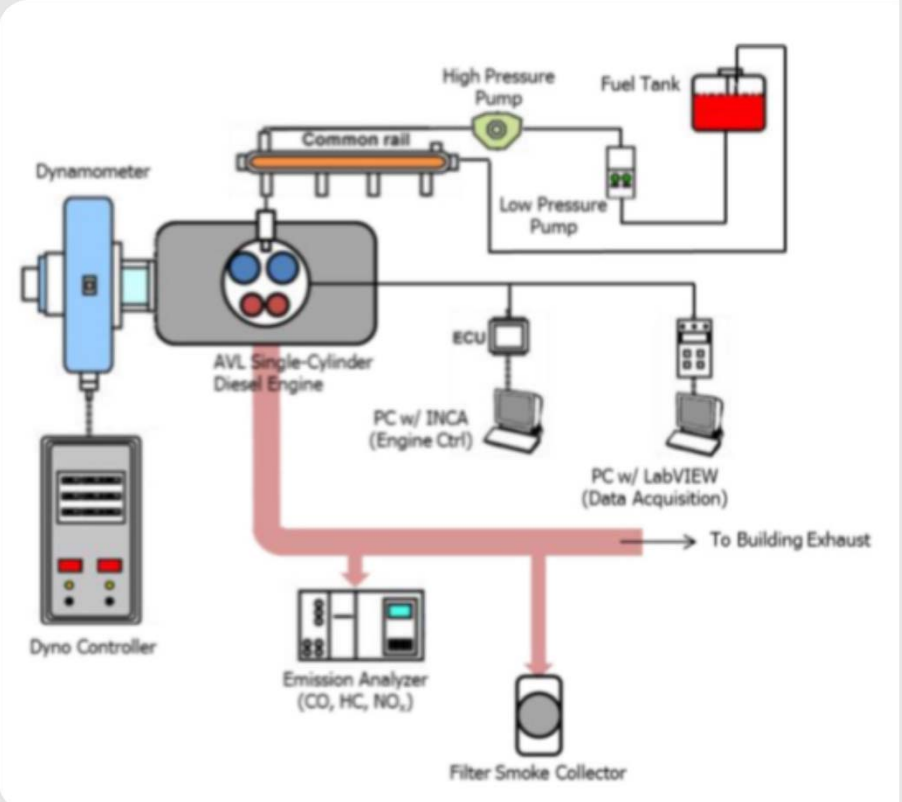


https://www.slideshare.net/WilliamDProvine/provine-few-presentation-2009

Experimental Method

Set-Up[2]

- Single Cylinder, Direct Injection
- Dynamometer
  - Controls Engine Speed and Load
- Horiba Analyzers
  - Measure: Air-Fuel Ratios, NO_x, Hydrocarbon, & CO Emissions
- Standard Filter Paper
  - Measure: Soot Emissions
- Shaft Encoder
  - Measure: Crank Shaft Angle



doi:10.4271/2017-01-2321

Experimental Method

Test Conditions & Procedure[2]

- EEL: Equivalent Engine Load
- MIT: Main Injection Timing
- TDC: Top Dead Center
- ABE20/IBE20:
  - 20% ABE/IBE by Volume
  - 80% Diesel
- Recorded Data
  - Brake Thermal Efficiency
  - Emissions

Items	EEL Cases	MIT Cases
Fuels	Diesel, ABE20, IBE20	
Engine speed (rpm)	1500	
Overall equivalence ratio	0.43	
Equivalent engine load (mg/cycle)	15, 20, 25	20
Pilot injection timing (°CA BTDC)	15 (3mg)	
Main injection timing (°CA BTDC)	4	0, 4, 8
Injection pressure (MPa)	60	

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Experimental Results

Brake Thermal Efficiency (BTE)[2,5]

- Engine Performance
  - ABE20 & IBE20
    - Show decreased BTE for all trials when compared to pure diesel
  - MIT (CA)
    - 0: Slows combustion speed and prolongs combustion
    - 4: Combustion center is close to TDC
    - 8: Creates negative work with an increase of fuel
  - EEL
    - Increased load yielded increased thermal load
    - Combustion phase of diesel is closer to TDC
  - Most Suitable Alternative: IBE20

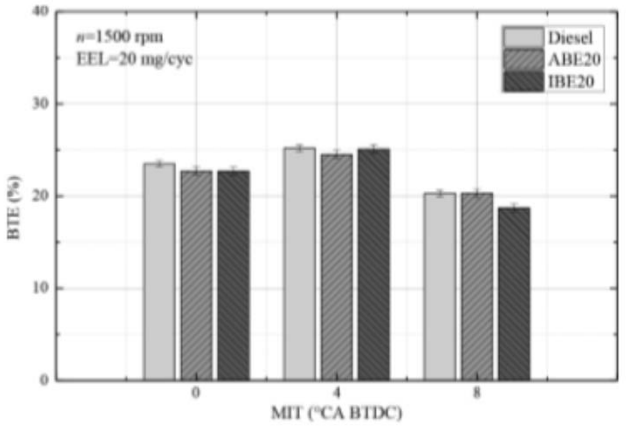

Figure 6. BTE under different MITs.

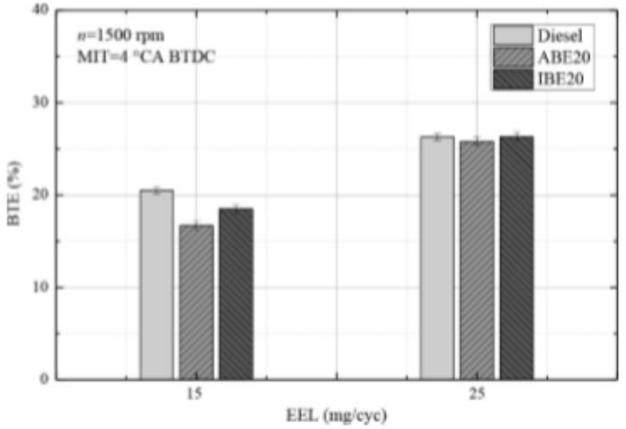

Figure 7. BTE under different EELs.

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Experimental Results

Emissions[2]

- MIT
  - CO & HC Emission
    - Higher for both ABE20 & IBE 20
      - Suspected Reason: Incomplete Combustion
    - Most Suitable Alternative: IBE20
  - NO_x & Soot Emission
    - NO_x: Formation Temperature
      - Higher Emissions at Larger CA
      - Lower Emission than Diesel at CA: 0 & 4
      - Higher Emission than Diesel at CA: 8
    - Soot
      - Both Fuels Reduce Emission
- EEL
  - CO & HC Emission
    - Similar Results to MIT
  - NO_x & Soot Emission
    - Lower for both ABE20 & IBE20
      - Suspected Reason: High Oxygen Content

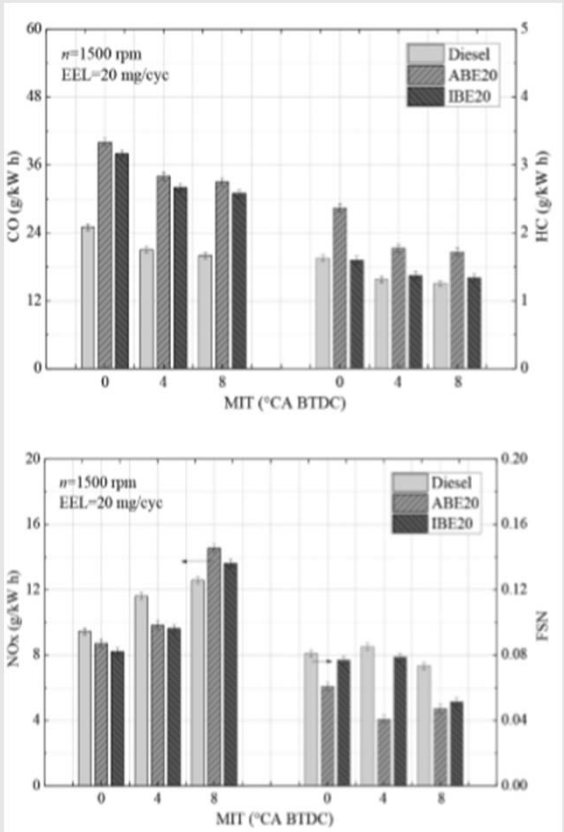

Figure 8. Emissions under different MITs.

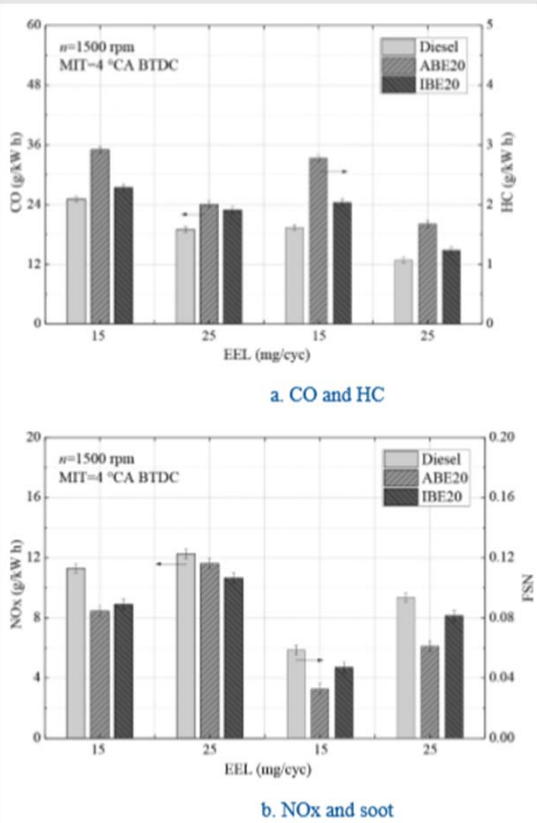

Figure 9. Emissions under different EELs.

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Conclusion

- Experiments concluded ABE and IBE as potential alternatives to diesel.
- The production costs are too significant as they stand in terms of competing in the fuel market.
- ABE and IBE are much more sensitive to injection timing and slightly decrease brake thermal efficiency.
- There was a decrease in harmful emissions for both bio-fuels.
- They suggested conducting more research on the ignition timings and isolating ABE and IBE individual components to optimize the best of both fuel blends.

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[5] Torque and BHP Explained. How A Car Works. https://www.howacarworks.com/technology/torque-and-bhp-explained.