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Comparative Study for Biodiesel Properties and Standards for Gas Turbine

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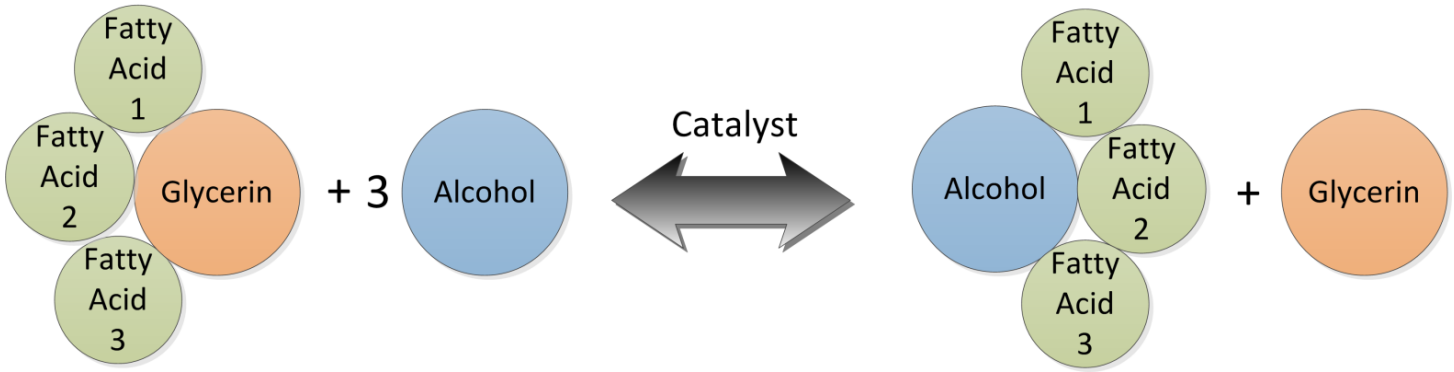
Overview

What is Biodiesel ?	• Definition • Production
Biodiesel Properties	• Free Fatty Acid • Fuel Properties
Fuel Standards and Regulation	• ASTM Standards • Consensus issues
Emissions	• Major tendencies • Limited data
Conclusion	• Future Improvements ?

What is Biodiesel ?

- Fuel composed of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats
- Biodiesel is made through a chemical process called **trans-esterification**, whereby the glycerin is separated from the fat or vegetable oil
- **Fatty Acid Alkyl Esters = FAAE = Biodiesel**



Biodiesel Production Basic

- **FAME = Fatty Acid Methyl Ester** if methanol is used as an alcohol during the process
  - FAME is widely produced due to the low price of methanol
- **FAEE = Fatty Acid Ethyl Ester** if ethanol is used as an alcohol during the process
- Biodiesel blends are denoted as, "BXX" with "XX" representing the percentage of biodiesel contained in the blend
  - B20 is 20% biodiesel and 80% petroleum diesel
- **Fatty Acids (FA)** structure and composition should determine the final properties of the biodiesel (?)

Biodiesel Properties Outline

Free Fatty Acid (FFA) percentage and influence

FFAs Vs. Feedstock

Main fuel properties impacted by the Fatty Acid profile

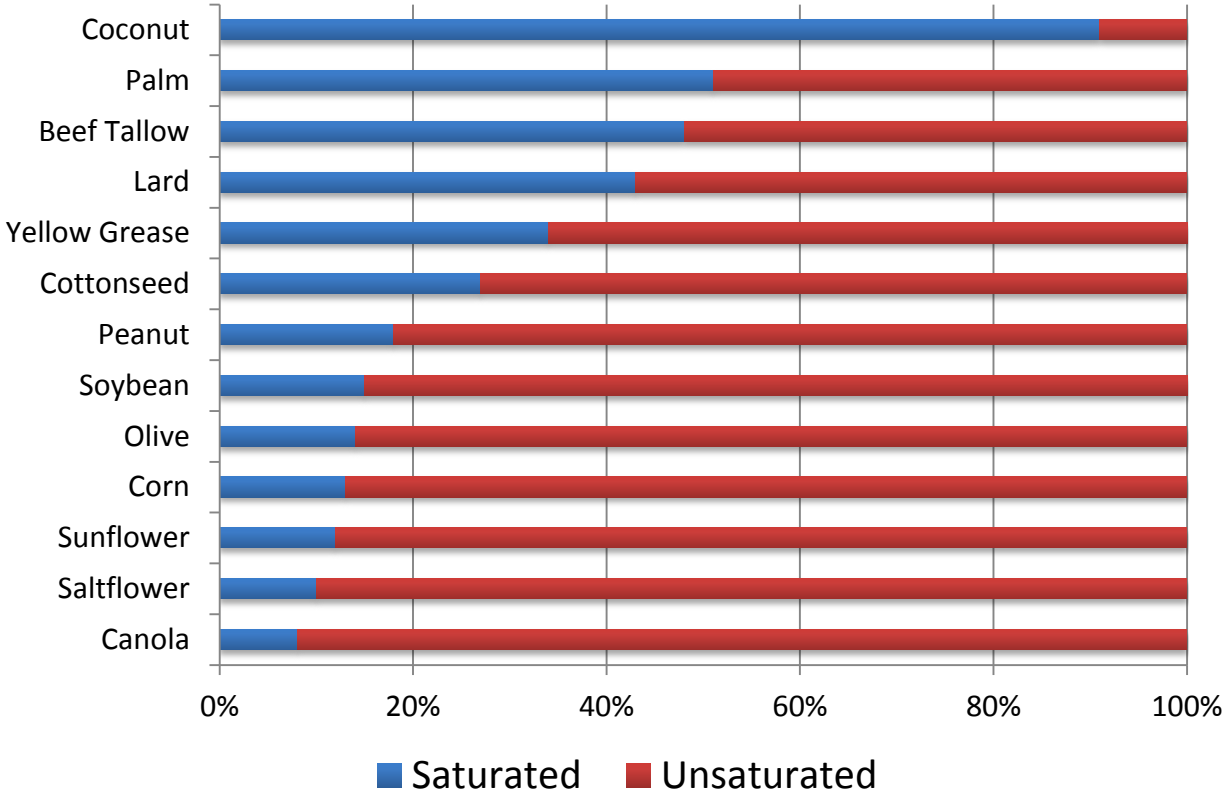
- Viscosity
- Surface Tension
- Cetane number
- Heat of combustion
- Cold flow properties
- Oxidative stability
- Lubricity

Free Fatty Acid (FFA) influence

- **Type and structure** of the fatty acid esters present in biodiesel both play an important role
- Structural features that influence biodiesel properties are:
  - **Fatty acid chain length**
  - **Degree of un-saturation**
  - **Branching of chains (chemical bonds)**

Feedstock Vs. FFA

- Shown below an approximative trend of the composition of FFA with respect to their feedstock



A general indicative trend shows that:

+ cetane number
+ cloud point
+ stability

increase with **saturated** FFA

Viscosity & Surface Tension

Higher viscosity & surface tension
than petroleum based diesel

- Increase with degree of saturation
- Increase with chain length
- Double bond configuration decrease viscosity

Negative impact on atomization and spray

- Sauter Mean Diameter (droplet size)
- Evaporation rate
- Combustion efficiency
- Pollution

Cetane Number

Higher cetane number
than petroleum based diesel

- Decrease with decreasing chain length
- Decrease with increasing double bond configuration

Positive impact on ignition

- Reduce ignition time delay
- Reduction NOx emissions*
  (depending on the degree of un-saturated acid)

Too high cetane number leads to incomplete combustion and smoke emissions

Biodiesel Properties

Heat of Combustion

- Increases with the chain length
- Fatty esters contribute up to 90% of heat of combustion in diesel fuel no.2

Oxidative Stability

- Changes in biodiesel properties with longer storage duration
- Autoxidation is due to the presence of double bonds
- Rate of autoxidation dependent on the number and the position of double bonds

Biodiesel Properties (Cont.)

Cold flow properties

- Higher CP and PP than conventional diesels
- High saturated fatty % will display higher CPs and PPs
- Negative impact it can clog the fuel filters and damage the fuel pump
- Blending biodiesel in a higher portion decrease the CP and PP

Lubricity

- No significant effect (due to fatty acid composition)
- Unsaturated acids exhibits a better lubricity than saturated
- Restore fuel lubricity by mixing biodiesel to the low sulfur petroleum-derived diesel

Standards and Regulation Outline

ASTM

- Biodiesel
- Aviation Gas Turbine
- Stationary Gas Turbine

Adequacy and precision of some test methods

Consensus issues

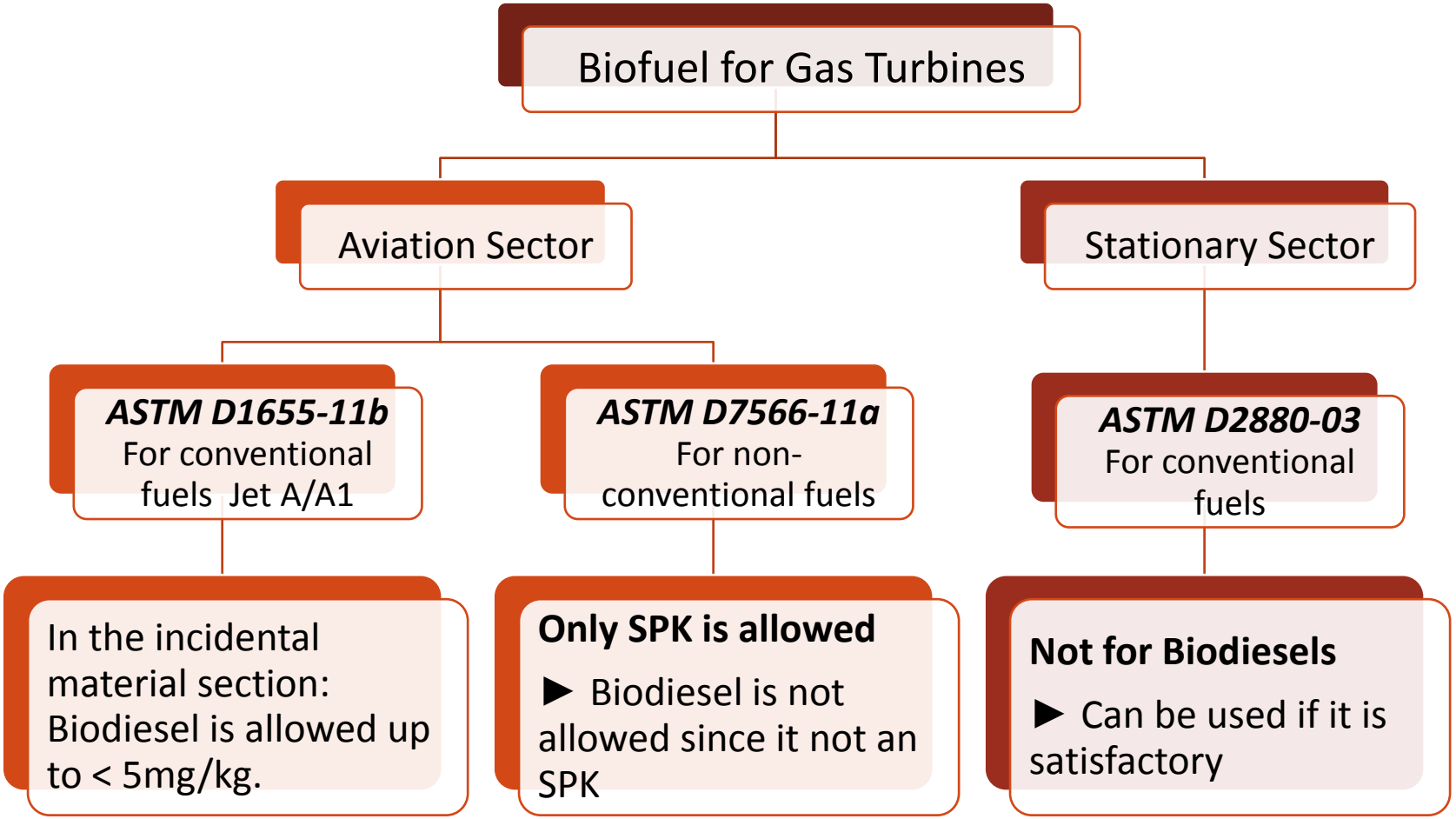
Standards and Regulation

Biodiesel must meet certain specifications in order to be certified as fuel.

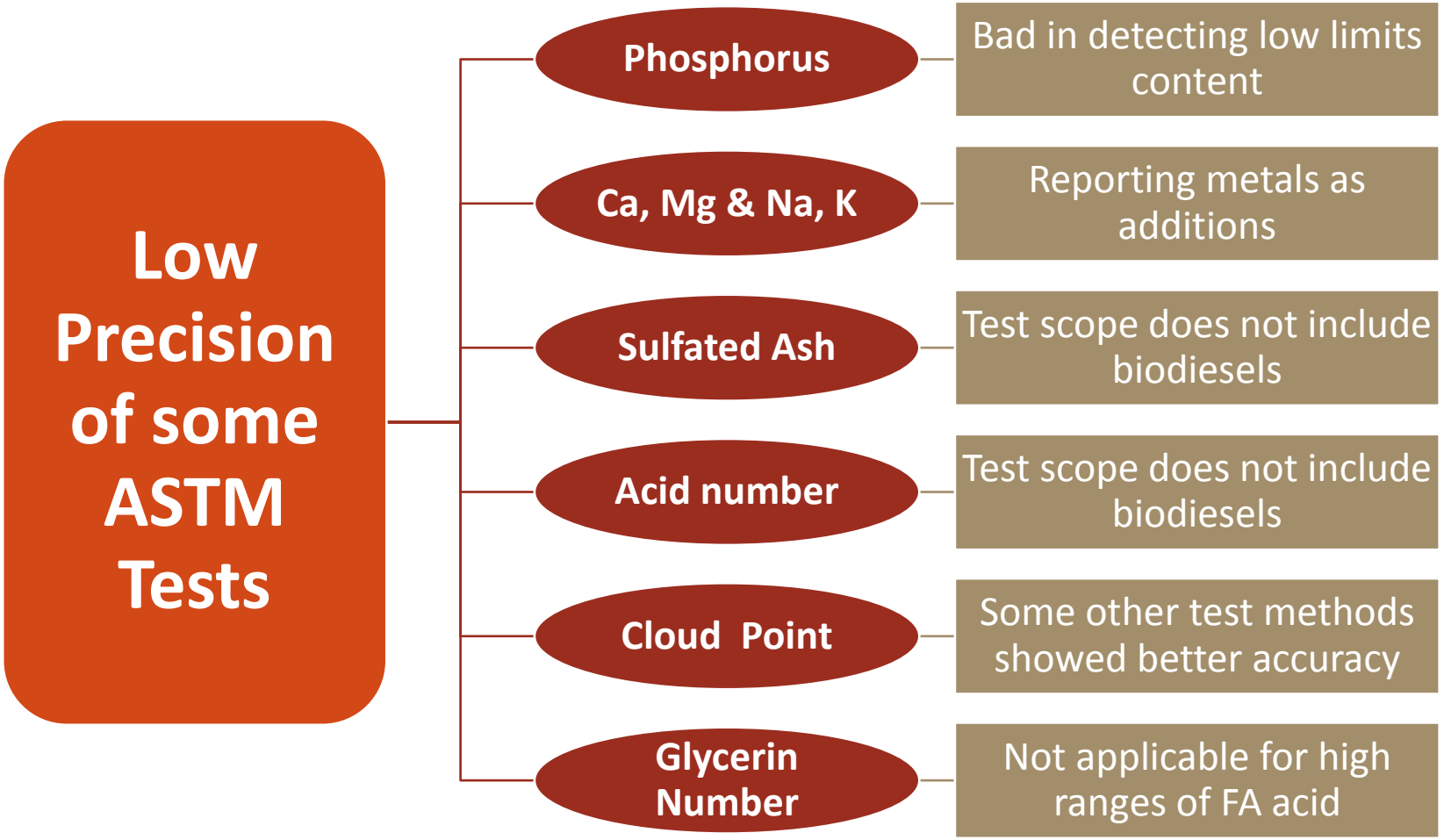
Almost all specification found for biodiesels:

ASTM D6751-11b	• Specifications for pure biodiesels (B100)
ASTM D396-10	• Specifications for conventional fuel oils used for home heating and industrial boilers application (B1 to B5)
ASTM D975-11b	• Specifications for diesel fuel oils used for on-and off- road diesel applications (B1 to B5)
ASTM D7467-10	• Specifications for diesel fuel oils and biodiesel blends (B6 to B20)

Standards of Biodiesels for Gas Turbines applications



Adequacy and Precision of Standards



Reliable Calibration ?

Calibration of **NON-ASTM** test methods

- EN 14538 : For the determination of Ca , Mg & K , Na
- EN 15751 : For the determination of the oxidation stability
- EN 14110 : For the determination of the methanol content

✓ Test Performance Index (TPI)

>1.2	Satisfactory
0.8-1.2	Improvement should be considered
>0.8	Inconsistent to the ASTM precision statement

❖ Some Biodiesel tests found inconsistent <0.8

Emissions Outline

Few Examples

- Experimental Studies

Major tendencies

- CO
- NOx
- UHC
- Smoke emission

Limited amount of reliable data ?

Impact on the NOx emissions in Gas Turbines

NO improvement

- *Exp.1*: RR-T56-A-15 test rig combustor
  - Not preheated
  - High SMD and Low evaporation rate

NOx Reduction

- *Exp.2*: Air blast atomizer with a heated co-flow air
- *Exp.3*: Pressure atomizer + preheated fuel
  - Reduction in viscosity
  - Low SMD (droplet size)
  - Higher evaporation rate

Impact of properties on the Soot formation

General trend shows reduction of Soot, CO, and UHC emissions

- Presence of O_2 molecules in the fuel composition
  → Encourage the combustion, hence low emission
- Absence of aromatic rings

  - *Exp.1*: RR-T63-A-700 (Helicopter engine)
  - *Exp.2*: Air blast atomizer with a heated co-flow air
  - *Exp.3*: Pressure atomizer and the blend was preheated

Lack of reliable data ?

- Information regarding the use of biodiesel in gas turbines is limited
- The lack of reliable data about the emissions of CO, NOx, UHCs, and soot provokes divergent thinking

Difference in combustion mode, equivalence ratio, pressure & temperature ratios

C.I. Engines	Gas Turbine
High blends → High NOx	High Blends → NOx ???

Biodiesel Advantages

- Reduction of Greenhouse gas emission
- Non-toxicity
- Biodegradability
- Safer to handle
- Can be produced virtually from any type of oil or fat

Future improvements

- Cold weather operation
- Specific calibration standards for biodiesel
- Specification for higher blending levels
- Producing enough feedstock oil to replace a large portion of petroleum (biology, chemistry, physics, economics)
- Legislative efforts can make technological advancement more economical while the industry develops (public policy)

Thanks for your attention.

- Any questions?