Technology Issues and Trends: Biodiesel

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Biodiesel Growing Around The World

- Europe is furthest along
  - Approaching 2% of diesel fuel
  - Trend is to low blend levels, B2-B5
  - Principle component RME
  - Spec is EN 14214
- US Biodiesel use very small, growing rapidly
  - 2004: 25 million gallons
  - 2005: 75 million gallons
  - Planned capacity expansions: >800 million gallons by end of ‘07
  - Diesel fuel in US: 64 billion gallons
  - Principle component SME (plus UCO, Palm, Tallow)
  - Spec is ASTM D6751 plus proposed changes to D975
- Other regions with growing biodiesel interest but very little usage
  - Latin America: Brazil
  - Asia: Korea, Thailand, India
  - Canada

Biodiesel as a Fuel / Additive

- Plus:
  - Take advantage of biodiesel excise tax credit
  - Renewable fuel
  - Biodiesel marketing angle
  - Improved lubricity
  - High cetane
- Minus:
  - Substantially higher (>100X) treat rate required than lubricity improver. B2 typically provides adequate lubricity
  - Negative impact on cold flow/CFPP
  - Low ambient temperature issues – storage, blending
  - Most rack blending equipment being installed at terminals for lubricity chemistry cannot be used to blend B2
- Biodiesel specifications still developing
  - Stability / quality / source / specifications

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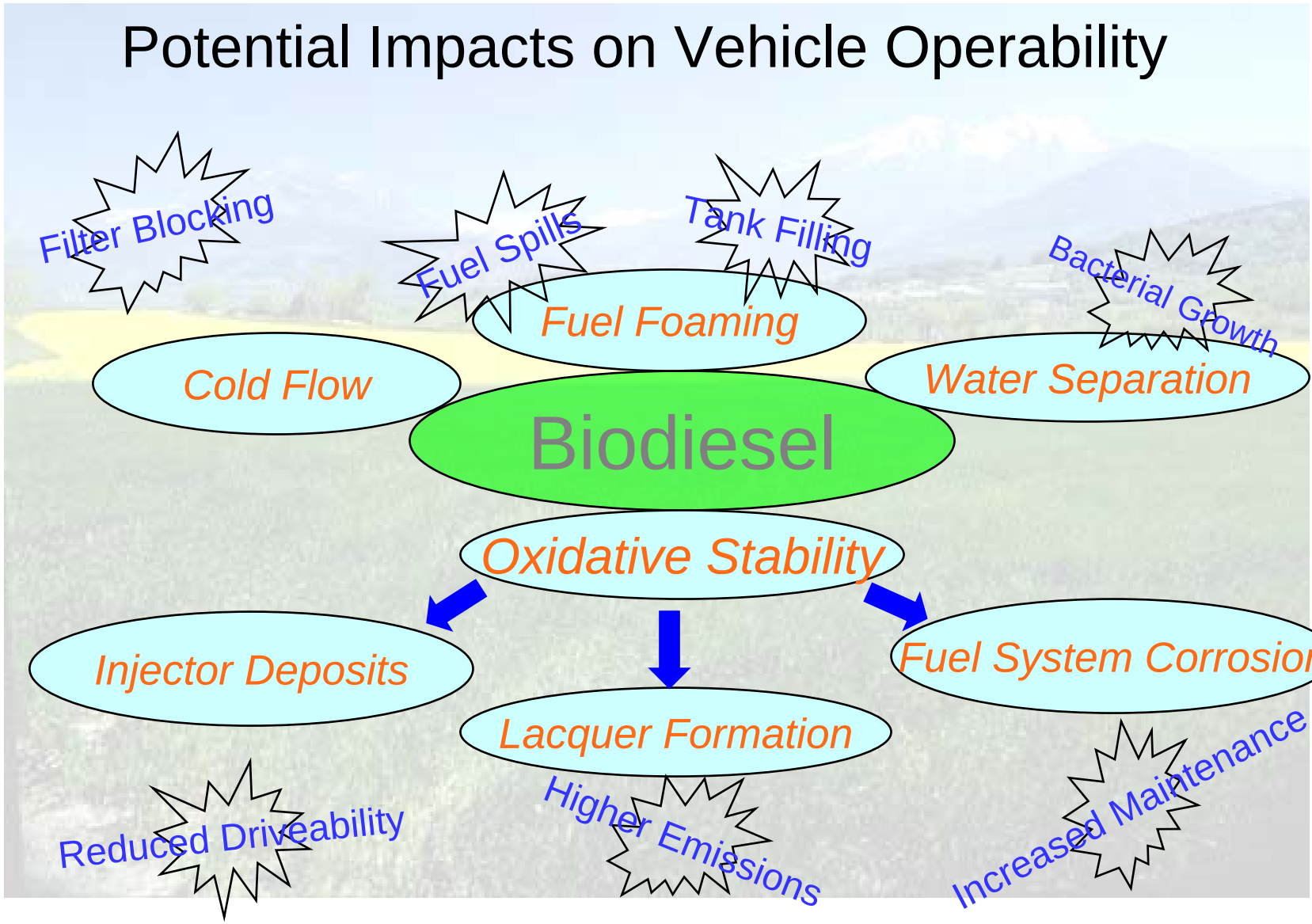
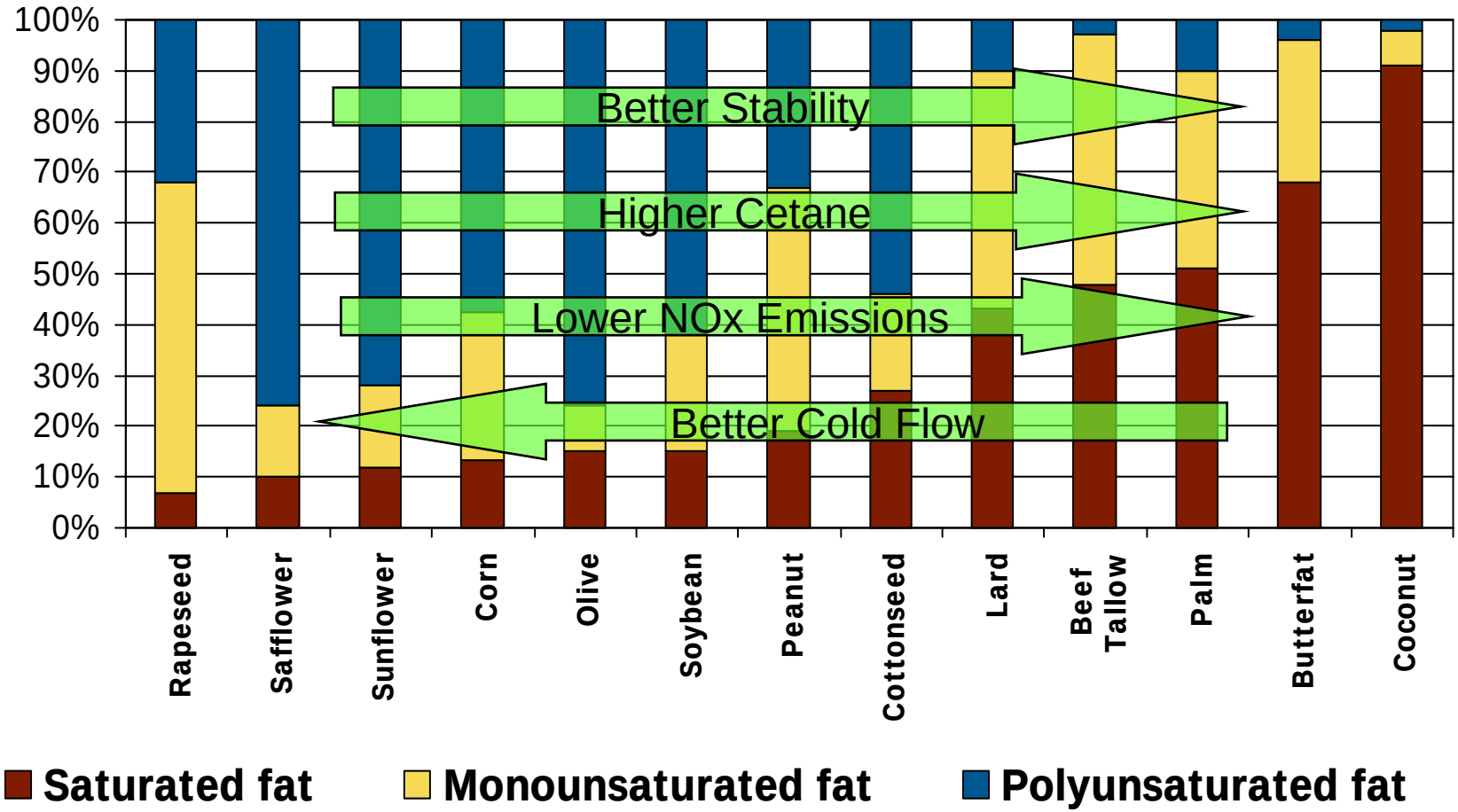
Potential Impacts on Vehicle Operability



What Causes ‘Low Stability’ Biodiesel?

- Biodiesel feedstock
  - Level of fatty acid unsaturation.
  - `virgin’ vs. recycled
- Lack of natural antioxidants (tocopherols) which strongly inhibit degradation.
  - Animal fat derived do not contain any natural antioxidants.
- Biodiesel production method
  - Distillation may produce lower stability fuel.
- Poor handling and distribution
  - Excessive exposure to air.

Composition of Fats and Oils



Information from National Renewable Energy Laboratory

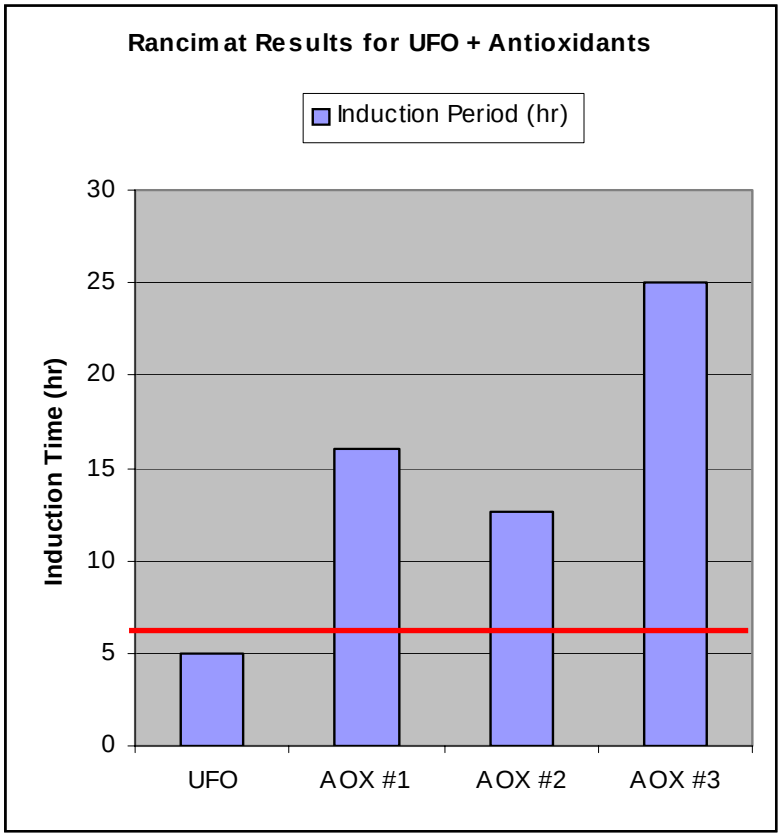
EU 2003 Biodiesel Study - Stability

- High and low stability B100 RME compared
  - Bench testing in HDD and LD CR and
  - Vehicle Trials (low stability FAME only)
    - Some evidence of increased injector fouling, deposits, power loss, corrosion and wear for low stability RME.
  - B5 Vehicle trial (340 ppm S fuel + UFOME)
    - Thermally aged UFOME component
    - No changes in FIE condition observed.
    - No impact on lubricant oil
    - Large reduction in oxidation stability (EN590)

Impact of Biodiesel Oxidation

- Oxidation impacts fuel injection equipment through formation of:
  - polymeric materials giving rise to sludge and varnish.
  - Low molecular weight corrosive acids.
- Solubility of polymerized fatty derivatives decreases in mineral fuel blends.
  - Potential for increased sedimentation compared to B100.
- Damage to fuel injection equipment resulting from polymer formation:
  - Fuel filter clogging
  - Lacquer and varnish formation throughout FIE
    - Pumps and injector nozzles
    - Tank level gauges.
    - Sticking of moving parts

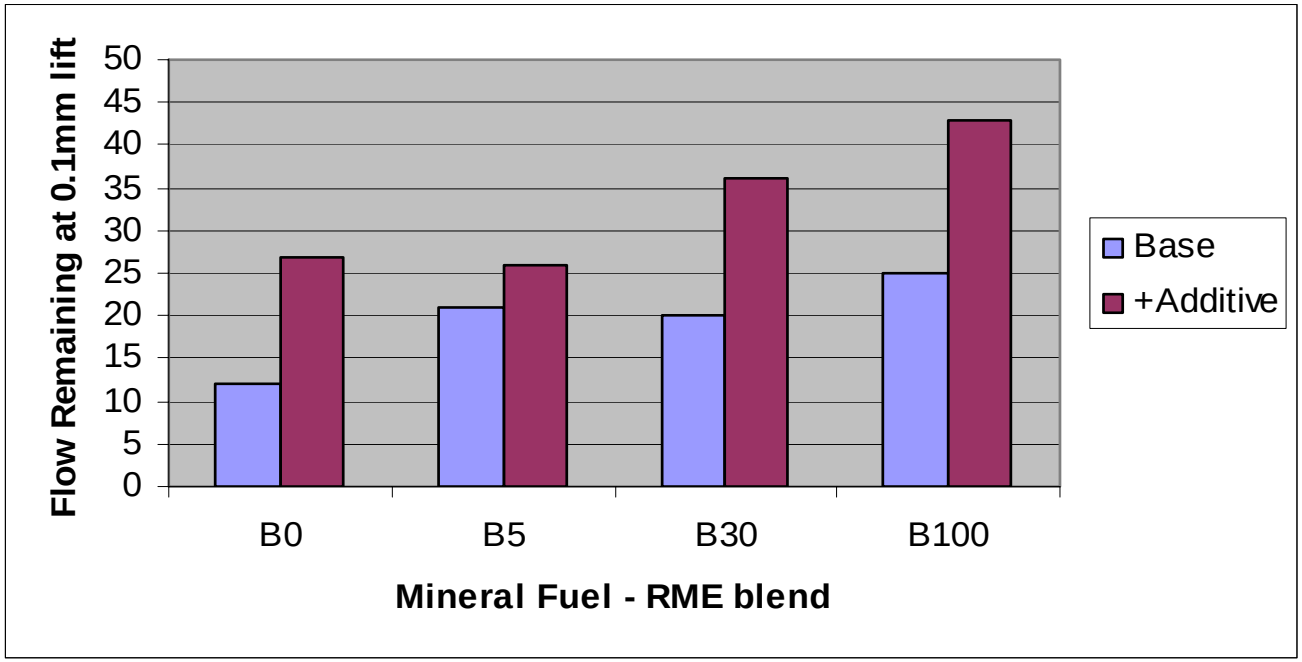
Role of Additives - Antioxidants



- Oxidation stability of biodiesel is currently the principal concern for vehicle operability.
  - Europe: EN 14214 specifies Rancimat test 6 hr minimum induction time limit must be met through distribution system
  - US: ASTM D6751 proposal rejected 2 hr Rancimat induction time or D2274
  - Much industry work ongoing
- OEMs report damage to fuel injection equipment through use of low stability bio-diesel fuels.
- Relatively small proportion of low stability FAME is probably responsible.

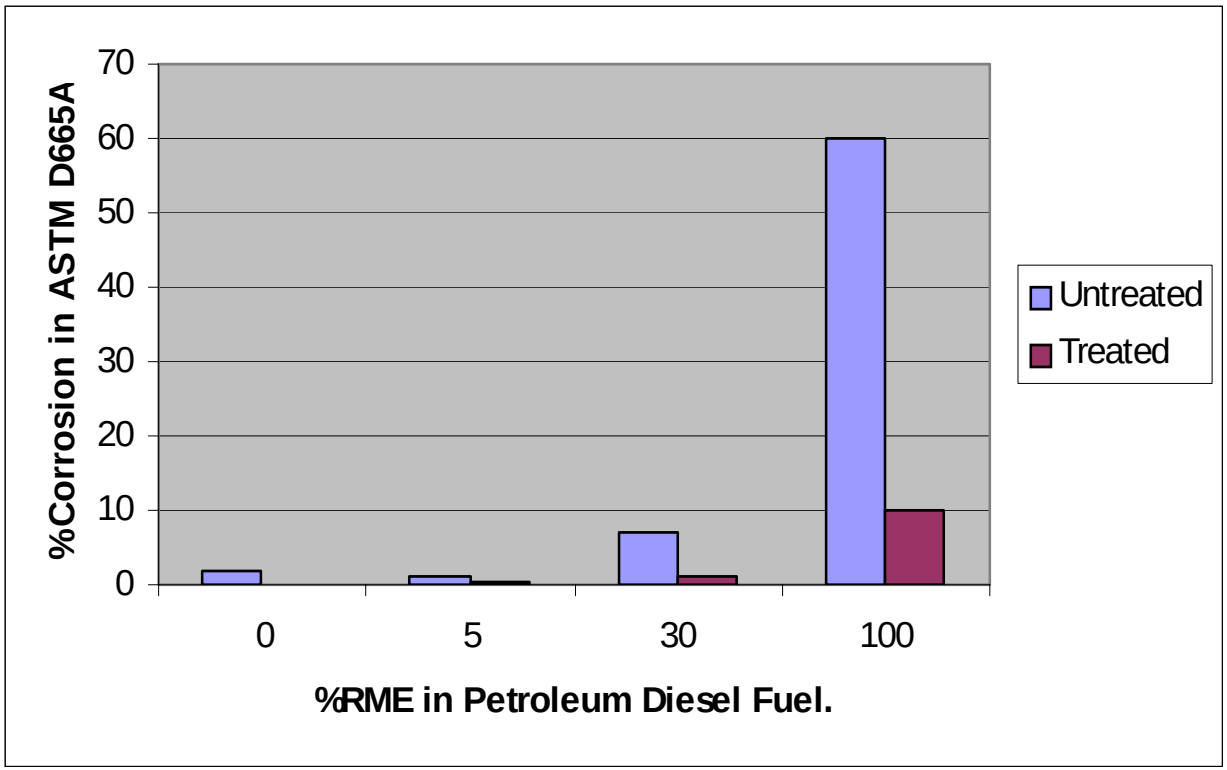
- Can protect against stability problems:
  - Increases Rancimat induction time.
  - Reduces rate of degradation with storage.
  - Helps protect against degradation through distribution network.
  - Treat rates can be relatively high – dependent on FAME source

Role of Additives – Dispersants



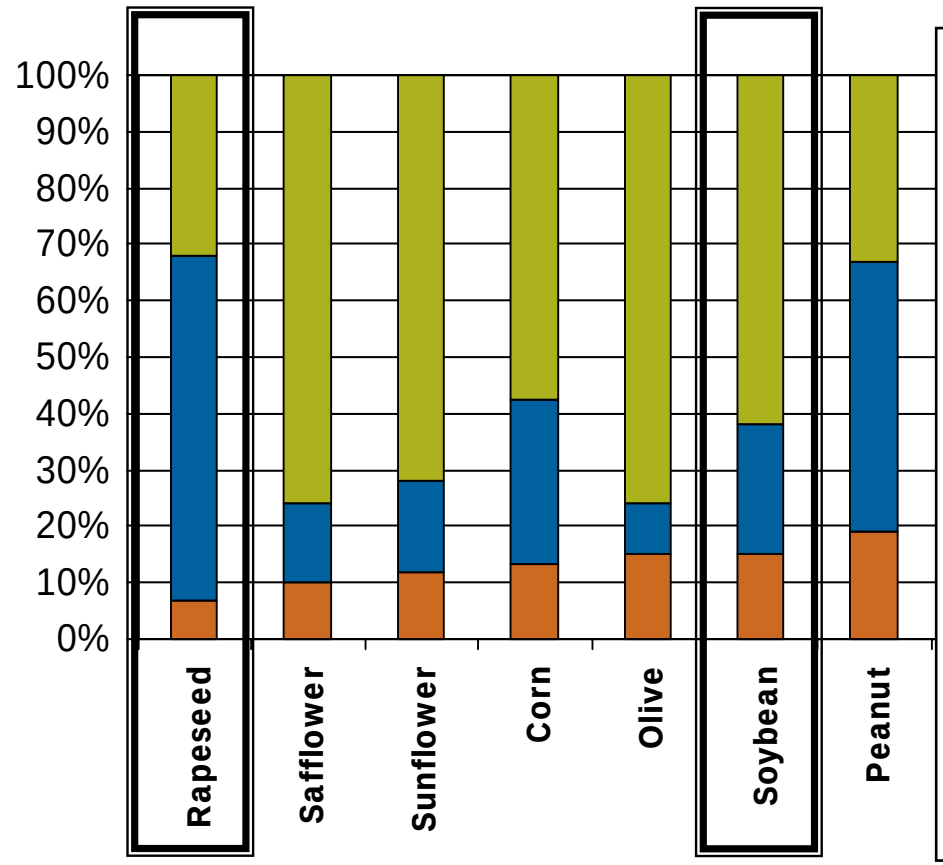
- Dispersant additive reduces nozzle fouling of mineral fuel – RME blends in standard 10 hr XUD-9 test.
- Maintain injector cleanliness and provide insurance against low stability fuels.

Role of Additives - Biodiesel Corrosion Behaviour ASTM D665A



- Significant increase in corrosion with increasing FAME content.
- Petroleum fuel corrosion inhibitor additive is effective.
- Room for optimization of additive treat to eliminate corrosion

Composition of Fats and Oils



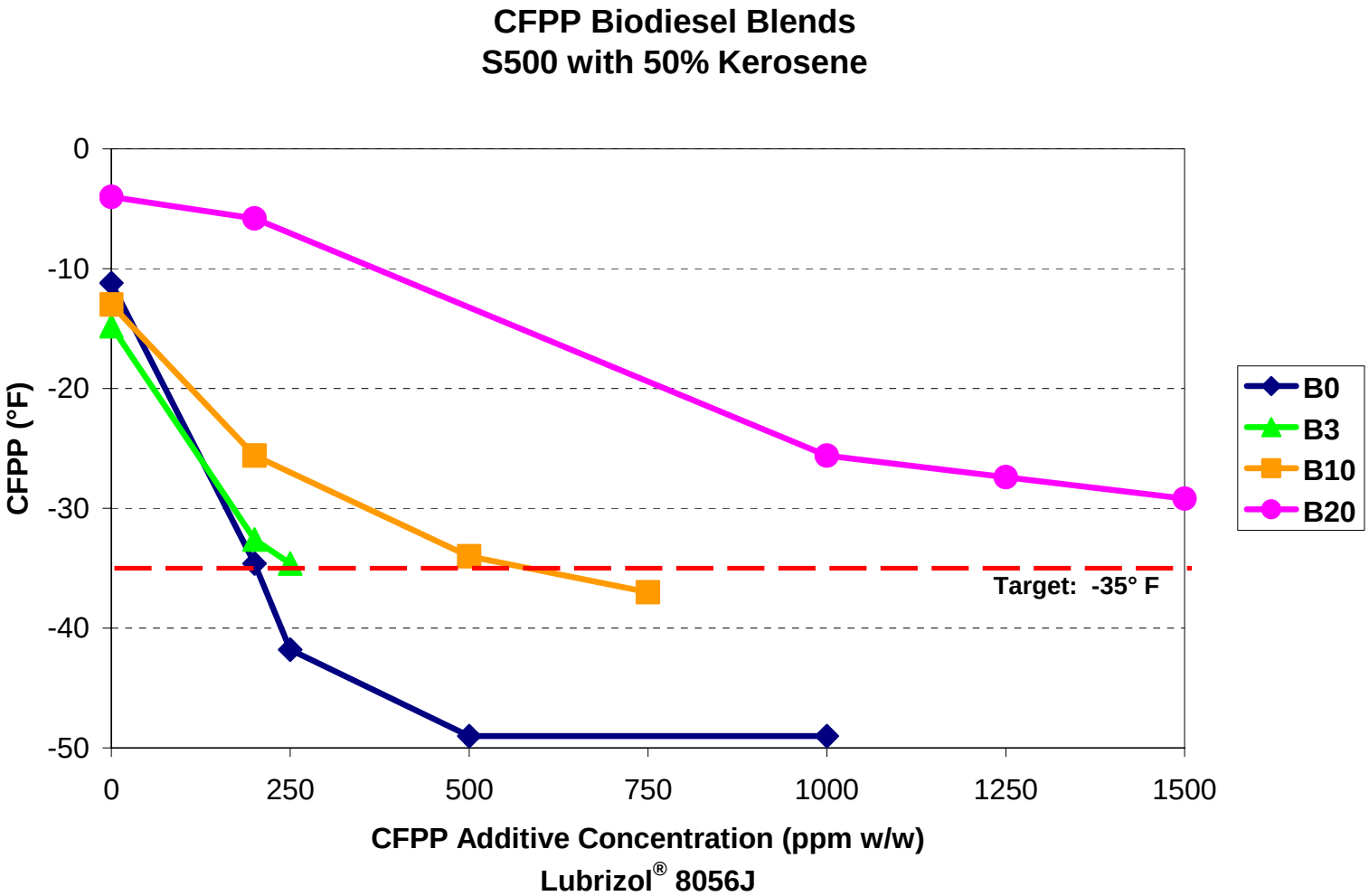
SME vs. RME

- Very different composition
- Composition varies from sample to sample
- SME has a higher level of saturates
  - SME CPt = ca -4°C
  - RME CPt = ca-12 °C
- Range of cetane numbers published for each
  - SME = 45 to 67
  - RME = 48 to 62

Saturated fat **Monounsaturated fat** **Polyunsaturated fat**

Information from National Renewable Energy Laboratory

Additive Impact on Biodiesel Blend CFPP

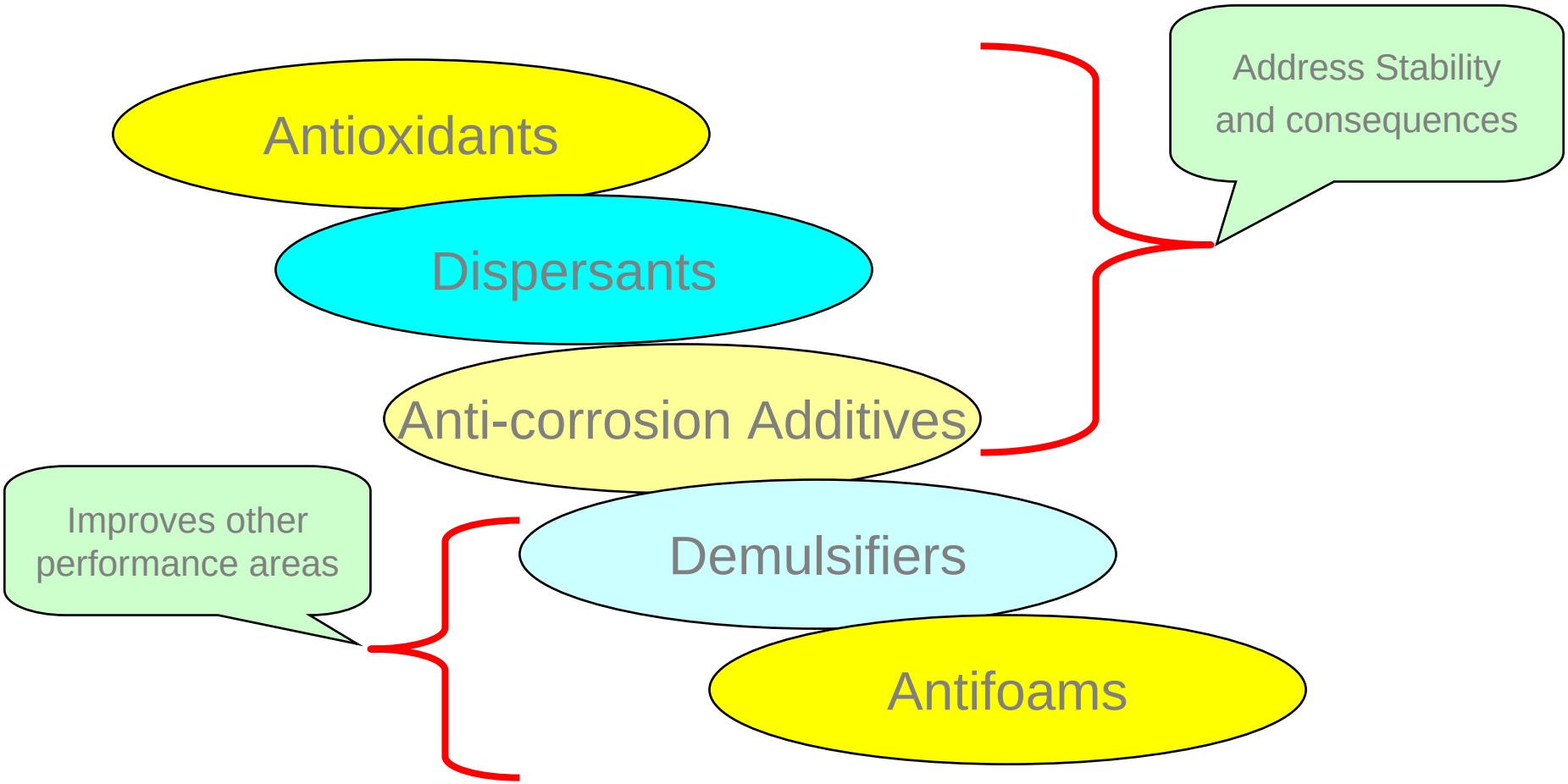


Potential Complication: Cold Flow and ULSD (ULSK)

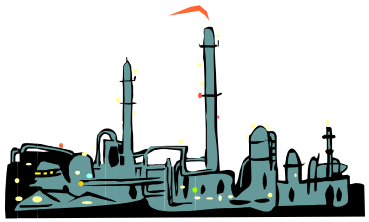
The Minnesota Issue

- B2 mandate was waived 3 times due to quality issues
  - First issue was low flash
  - Second and third waivers due to field problems
    - Filter plugging with “butterscotch pudding” at cold temperatures
    - Tracked to off-specification B100
      - high levels of glycerine and glyceride contamination from incomplete reaction and purification in B100 manufacture
      - Issue resolved, contaminated material removed from the market

Role of Additive Treatment - FAMEs

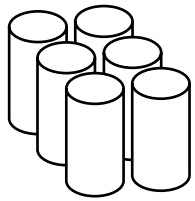


Fuel distribution and additization

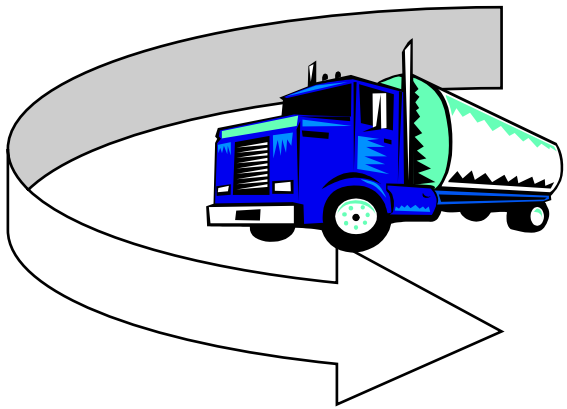


Refinery

Fuel transferred via truck or pipeline



Fuel terminal



After-market bottles

Service station

Summary –Vehicle Operability and Biodiesel

- Oxidation stability appears to be main concern.
  - Small proportion of low stability FAMEs responsible.
    - Damage to FIE has been reported by European OEMs
  - Stability specifications in Europe, developing in US

- Additive treatment can:
  - Deliver significant improvements to the operability of biodiesel in modern vehicle technologies.
  - Protect sensitive vehicle components.
  - Improve consumer confidence in biodiesel.

Lubrizol Focus On Biodiesel Opportunities

- Understand biodiesel stability
  - Fuel additive solutions both to prevent oxidation
  - Protect engine systems from the consequences of low stability biodiesel

- Additive solutions for improved biodiesel blend cold flow

Thank you for your participation