

The Usage of Biofuels in Korea and Future Issues

2007. 2. 23

In-Ho Cho, Ph.D

Fuels Lab, Energy R&D Center

*140-1, Wonchon, Yuseong,
Daejeon 305-712, KOREA
tinos@skcorp.com*



Contents

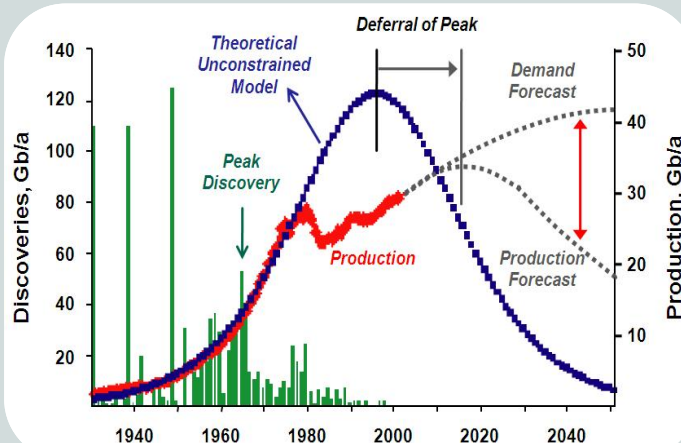
- **1. Current Status in Korea**
- 2. *Quality Issues*
- 3. *Environmental Issues*
- 4. *Feedstock, Policy and Economics*
- 5. *Conclusions*

Key Drivers and Government Policy

- Korean government aggressively drives utilizing biofuels.
- Targeted share of renewable energy is 2% in 2006 and 5% by 2011.
- Only biofuels appear to be feasible option.

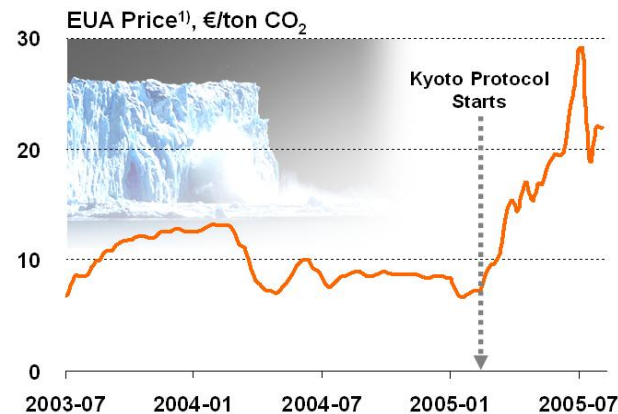
Securing the Energy Future

- Upcoming 'Oil Peak'
- Increasing dependence on the Middle East crude
- Korea is 7th biggest oil consuming nation.



Addressing GHG Emissions

- Global warming and catastrophic climate change
- Kyoto Protocol came into effect.
- Korea expected to be obliged to reduce GHG from 2013.

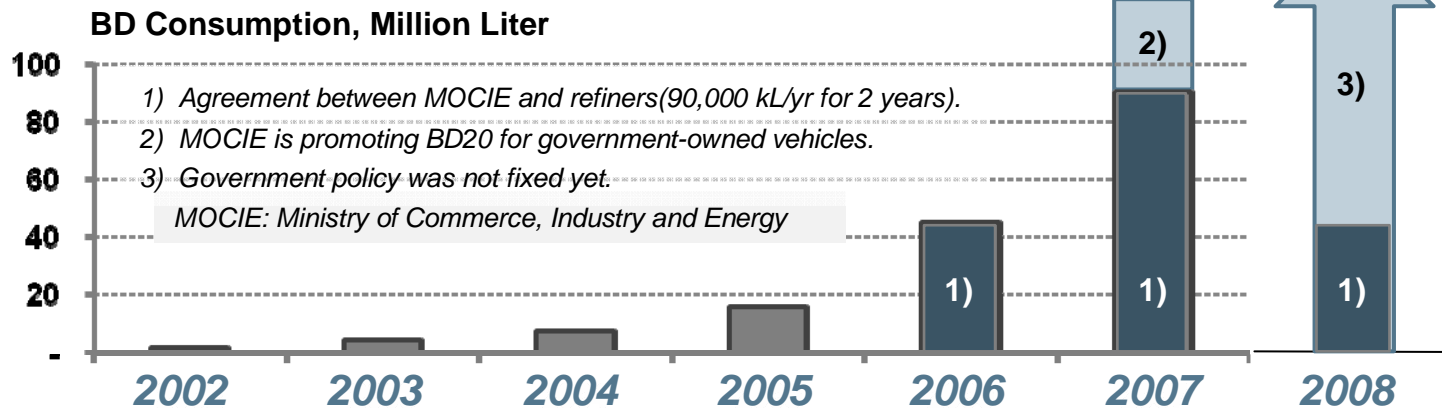
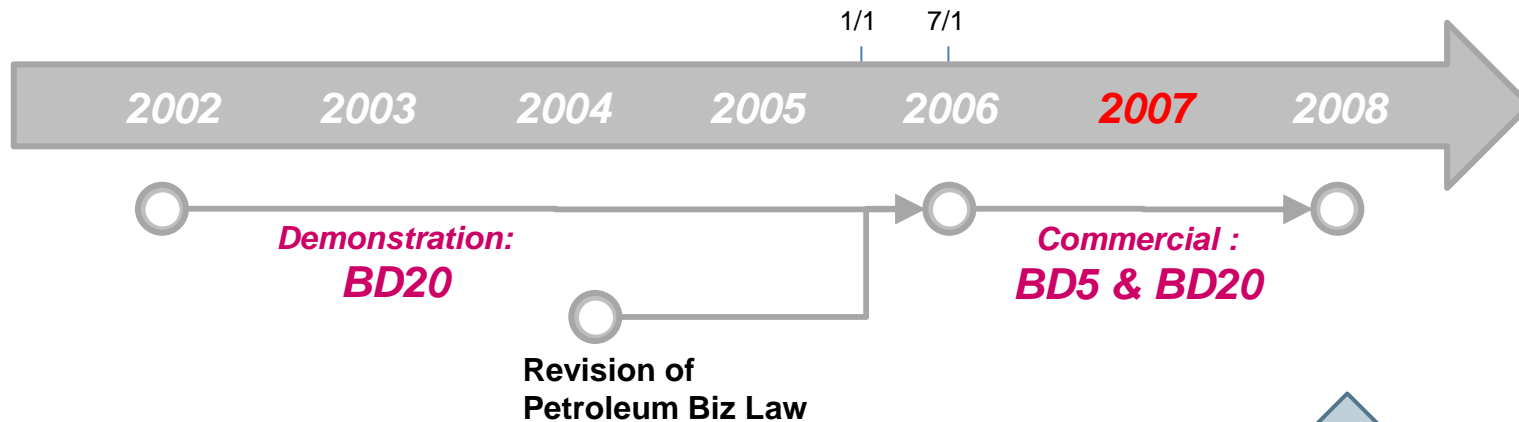


[L] C.J. Campbell, Presentation at the Technical University of Clausthal, Dec. 2000

[R] EUA Price: www.pointcarbon.com

Major Events and BD consumption Increase

- Demonstration supply has been carried out since May 2002.
- On the basis of revised Petroleum Business Law, BD5 and BD20 have been supplied since July 2006.



Agreement on BD Supply

- Refiners and Government agreed on voluntary biodiesel supply.
- Government is considering mandatory blending of BD from July 2008.

“From July 2006, Korean Refineries shall utilize biodiesel 90,000 kL annually (1,540 bpd) for 2 years.”

1,540 bpd corresponds to 0.5% of total petrodiesel sales.

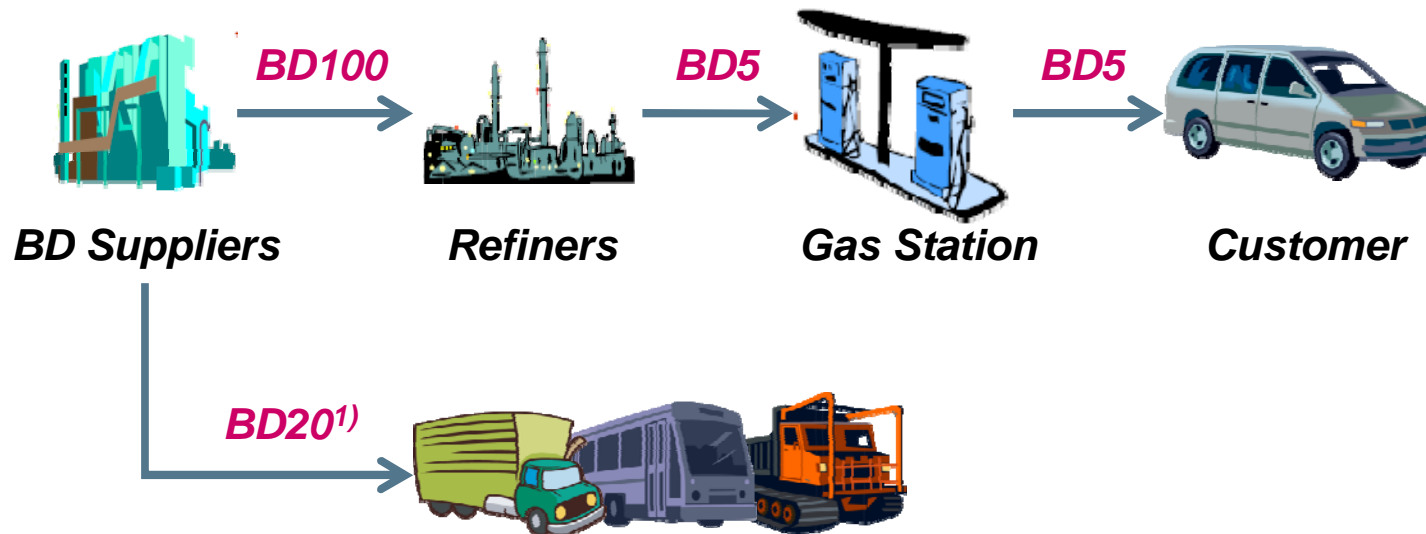
“Government shall make an effort to stimulate biodiesel spread by policy support”

Tax, which accounts for 40% of diesel retail price, is to be exempted.

BD5 and BD20 Supply Chain

- **BD5 is subject to diesel fuel spec, and supplied only by refiners.**
- **Bus and truck company can use BD20¹⁾ on their own accord.**

¹⁾ 10% during winter season(11/1~3/31)



Bus, truck and construction equipment operators who are equipped with 'certified storage tank' and 'self-repair shop'.

Suppliers and Production Capacity of Biodiesel

- As of Jan. 2007, nine suppliers are registered as certified suppliers, and they are aggressively expanding their capacity.
- A few large corporations seems to be allowed to join, thanks to the government's policy of increasing BD supply.

Suppliers	Capacity, kℓ/yr	Source
Kaya Energy	100,000	Soybean, Kitchen (Rapeseed)
B&D Energy	50,000	Soybean, Kitchen (Rapeseed)
Ecoenertech	33,000	Kitchen
BASKO	27,300	Soybean, Kitchen (Rapeseed)
BDK	20,000	Soybean, Kitchen
Others	84,000	Soybean, Kitchen, Palm
Total	314,300 kℓ/yr (5,380 bpd)	

Petroleum and Alternative Fuels Business Law

Automotive Diesel

Property	Spec
Cetane Number	45 Min
Sulfur, wt.ppm	30 Max
Density(15°C), kg/m ³	815~845
D90	360 Max
Vis@40°C, mm ² /s	1.9~5.5
Flash Point, °C	40 Min
CFPP, °C	-16 Max
Polyaromatics, vol%	11 Max
HFRR, microns	460 Max
FAME ¹ , vol.%	5 Max

¹⁾ FAME: Fatty Acid Methyl Ester

Automotive Gasoline

Property	Spec
RON	91~94
Sulfur, wt.ppm	50 Max
D10	70 Max
D50	125 Max
D90	175 Max
EP	225 Max
Benzene, vol.%	1.0 Max
Aromatics, vol.%	30(27) Max
Olefin, vol.%	18(21) Max
Oxygen ² , wt.%	0.5~2.3 (Winter: 1.0~2.3)

²⁾ denotes the amount of oxygen contained in MTBE, ETBE or bioethanol.

Status of BD Spec. and Quality

- Based on EU's, Korean BD spec(mandatory) has a few differences.
- Saybolt color spec is indicator by which SK judge whether BD satisfy EN14214 or not. It can be achieved by distillatory purification.

* SME-R was purified by distillation.

Properties	Europe	Korea	SK	SME-1	SME-2	SME-R
Linolenic Acid ME, wt.%	<12	-	-	6.2	7.8	7.7
Iodine Value, g iodine/100g	<120	-	-	>120	>120	>120
Monoglyceride, wt.%	<0.80	-	<0.8	0.263	0.608	0.154
Diglyceride, wt.%	<0.20	-	-	0.245	0.245	0.011
Triglyceride, wt.%	<0.20	-	-	0.195	0.117	ND
Free Glycerine, wt.%	<0.02	-	-	ND	0.112	0.016
Carbon Residue, wt.%	-	<0.1	-	0.01	0.07	0.0005
Carbon Residue(10%), wt.%	<0.30	-	<0.30	0.93	2.98	0.28
Water & Sediment, vol%	-	<0.05	<0.05	<0.05	<0.05	<0.05
Water Content, wt.ppm	<500	-	-	293	238	124
Total Contamination, wt.ppm	<24	-	-			
Saybolt Color	-	-	>+10	-2.9	-50.3	+16.1
CFPP, °C		<0		RME -12, SME -2, PME +13		

Contents

1. *Current Status in Korea*

2. *Quality Issues*

✓ *Cold Flow Properties*

✓ *Oxidation Stability*

3. *Environmental Issues*

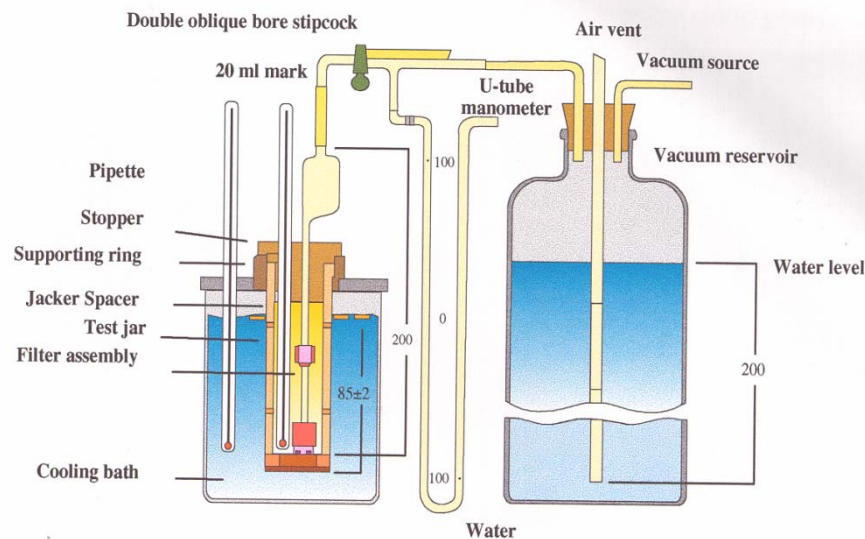
4. *Feedstock, Policy and Economics*

5. *Conclusions*

Managing Cold Flow Properties: CFPP & WDI

- **CFPP** is the only indicator of vehicle cold operability, even though it didn't exactly reflect recent changes in vehicle.
- Not being a regulated properties, **WDI**(Wax Dispersancy Index) is also an important measures which represent cold storage stability.

CFPP Apparatus



WDI Apparatus

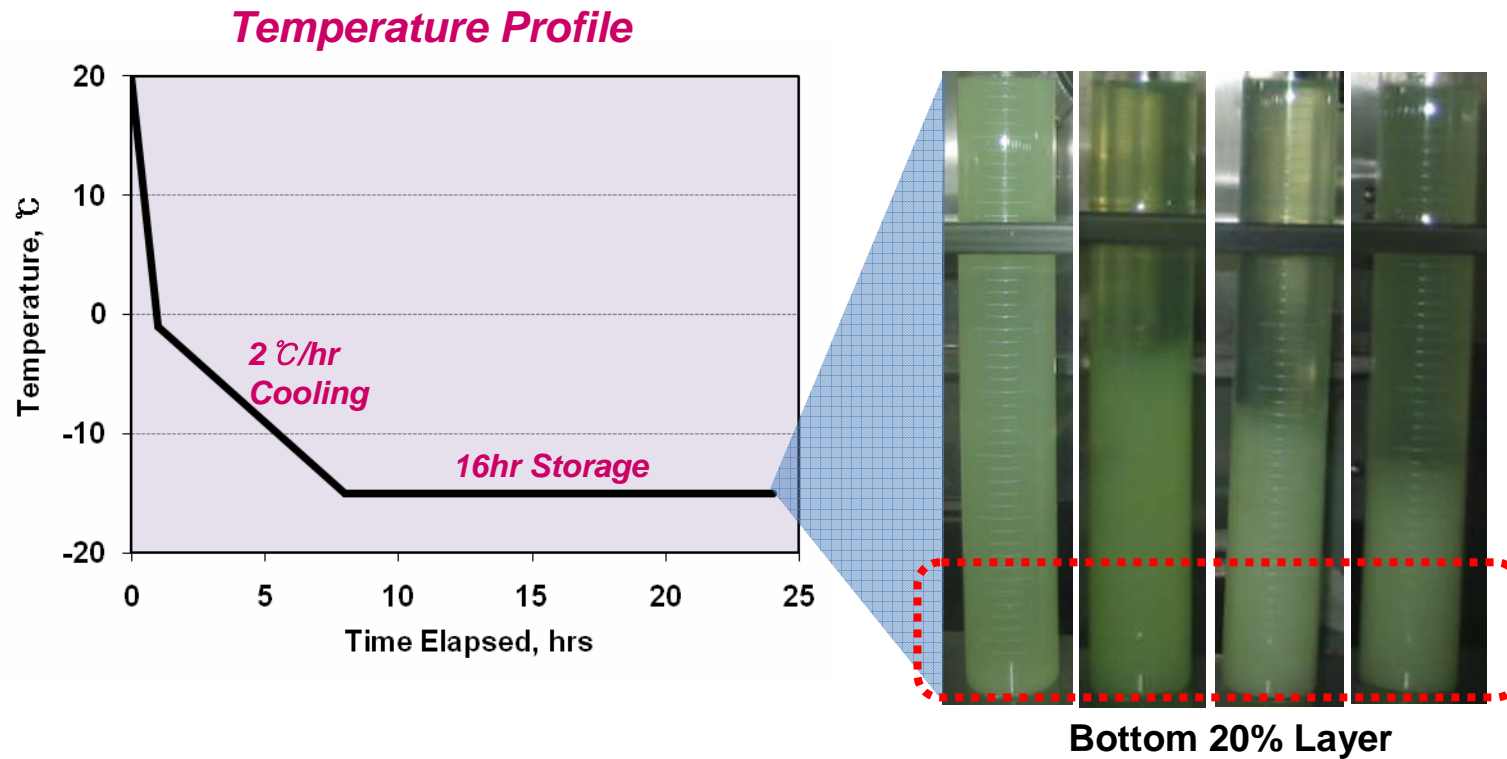


[L] Private Communication, Infineum
[R] SK-owned apparatus

Wax Dispersancy Index

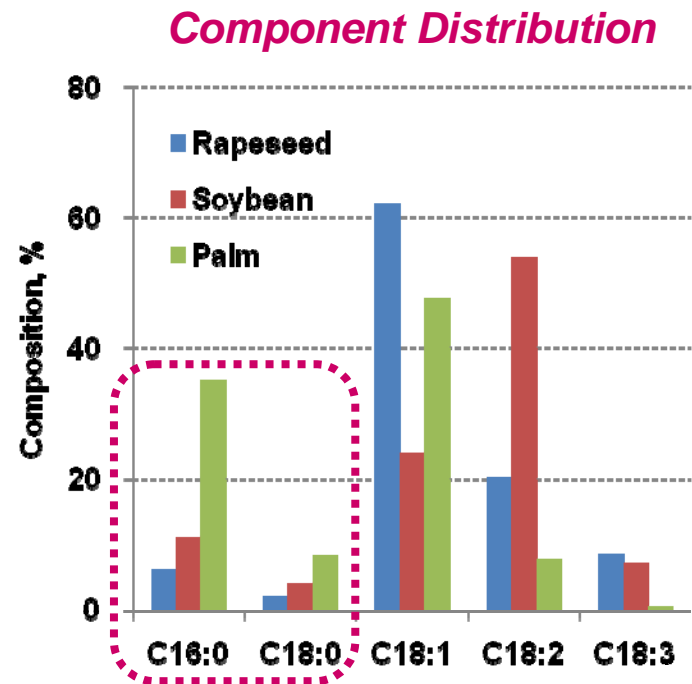
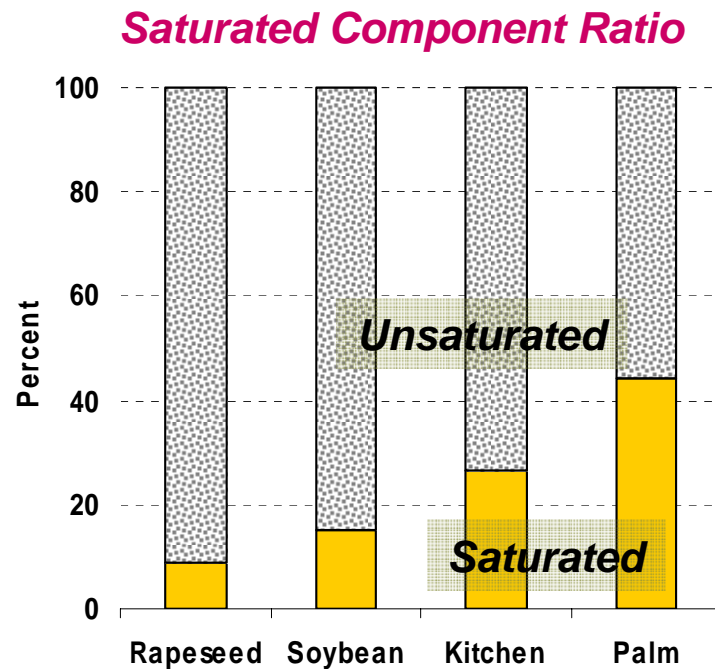
- SK is monitoring delta-CP and bottom-CFPP of diesel products.

$$\begin{aligned} \text{delta-CP} &= \text{CP}(\text{bottom } 20\%) - \text{CP}(\text{original}) \\ \text{bottom-CFPP} &= \text{CFPP}(\text{bottom } 20\%) \end{aligned}$$



Feedstock Composition

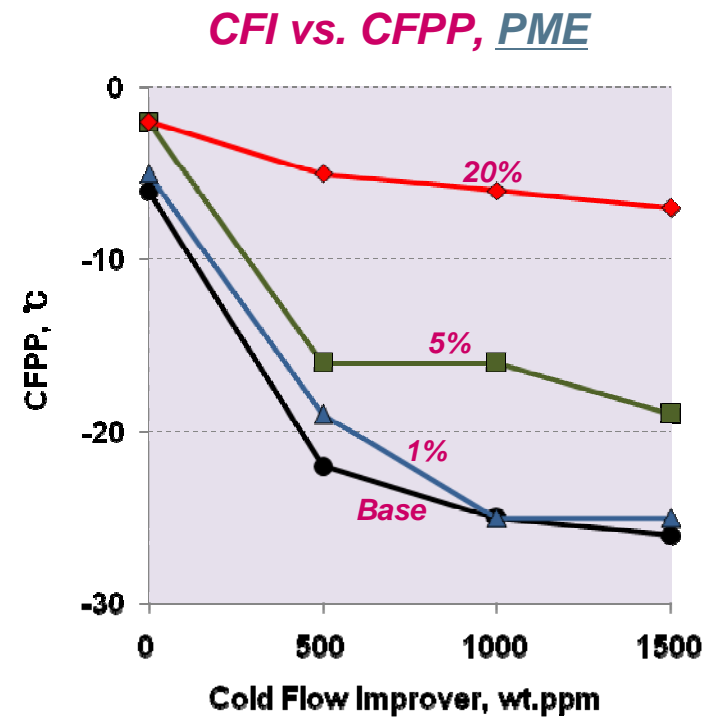
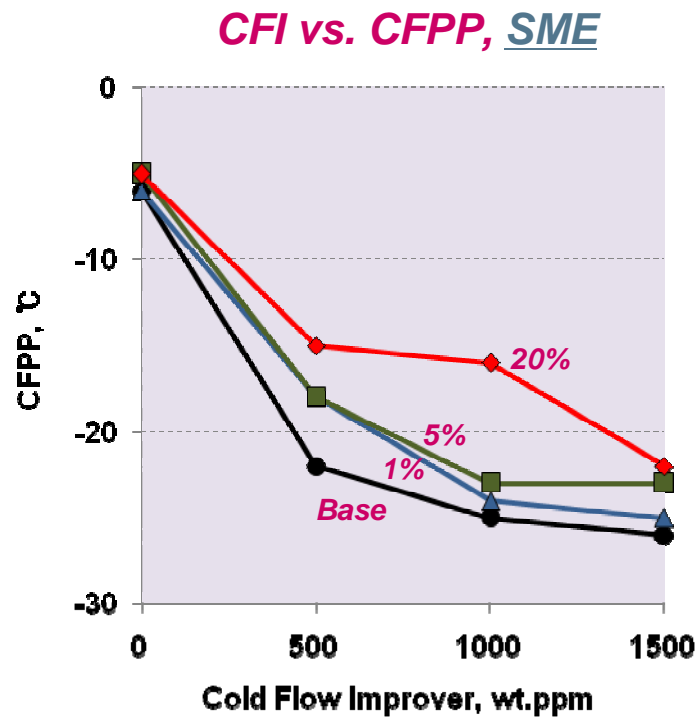
- Saturated components can easily be crystallized and reduce cold flow.
- PME has higher portion of saturated than RME and SME.



Infineum, Worldwide Fuel Quality Trends, Jan. 2005

CFI(Cold Flow Improver)

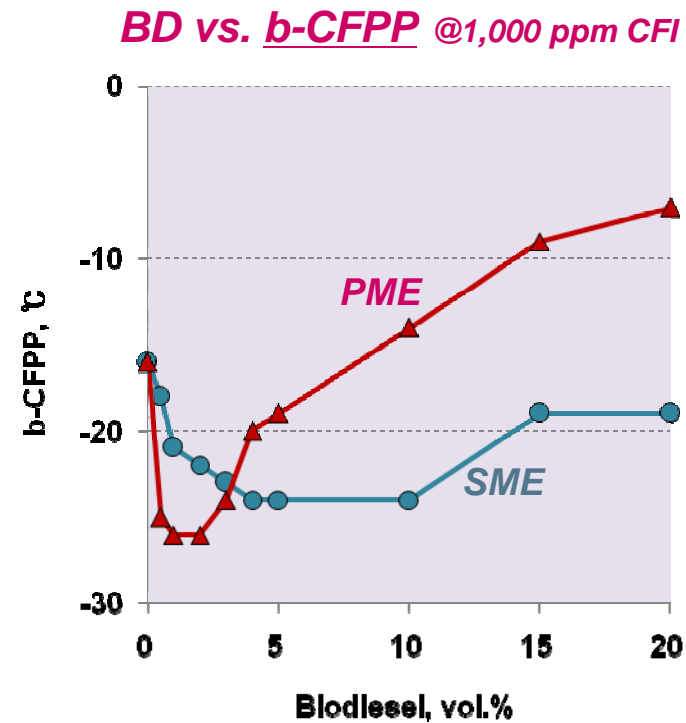
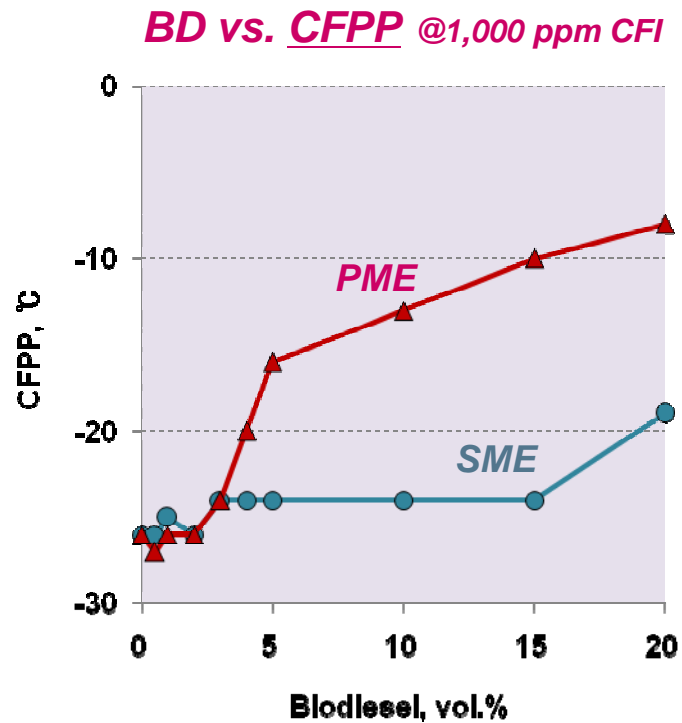
- Cold flow problems can be mitigated by additive solutions.



SK, In-house Test Results

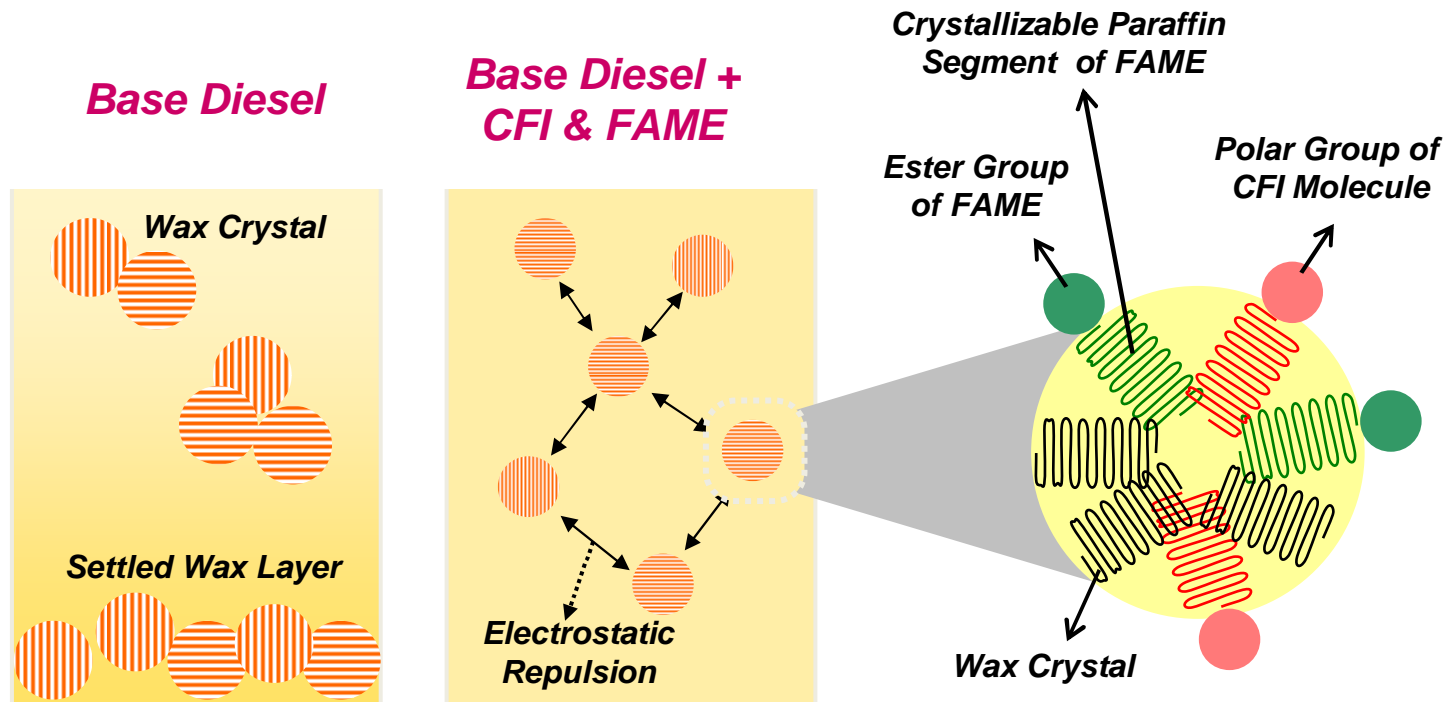
CFPP and WDI

- Even at higher treat rate of CFI, using PME is tough challenge.
- Apart from CFPP, small amount of BD improve WDI performance.



SK, In-house Test Results

Mechanism



Contents

1. *Current Status in Korea*

2. ***Quality Issues***

✓ *Cold Flow Properties*

● ✓ ***Oxidation Stability***

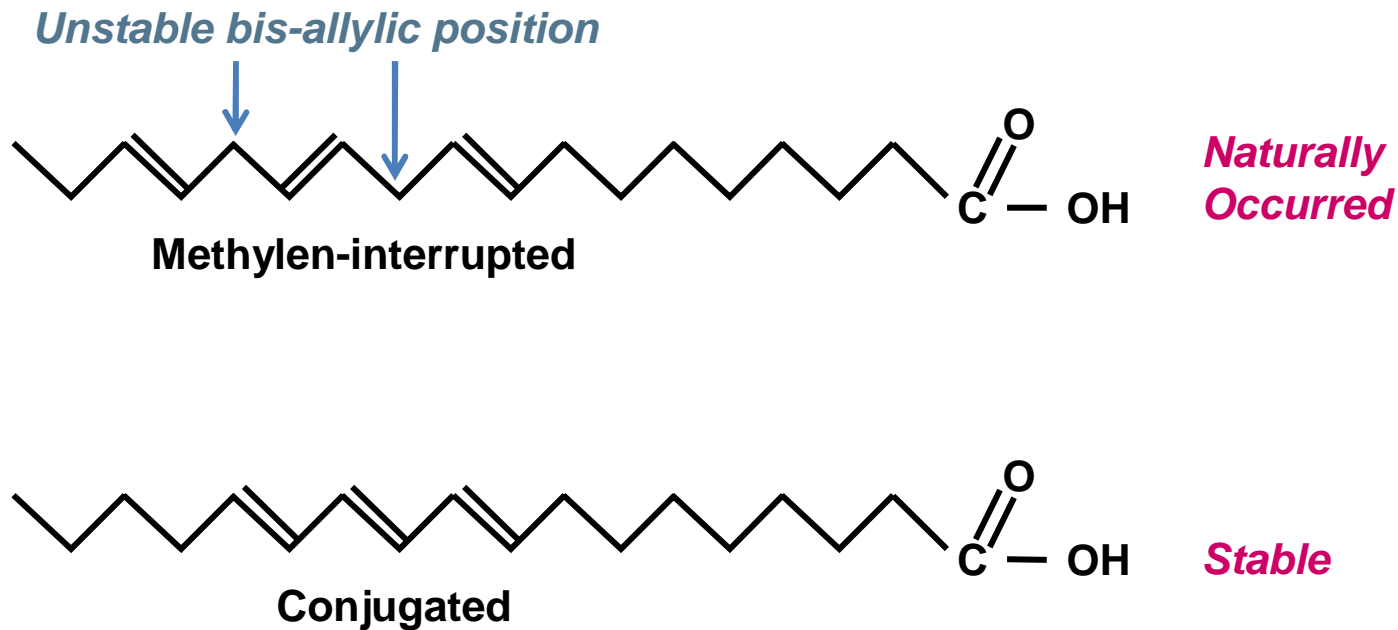
3. *Environmental Issues*

4. *Feedstock, Policy and Economics*

5. *Conclusions*

Chemical Structure of Biodiesel

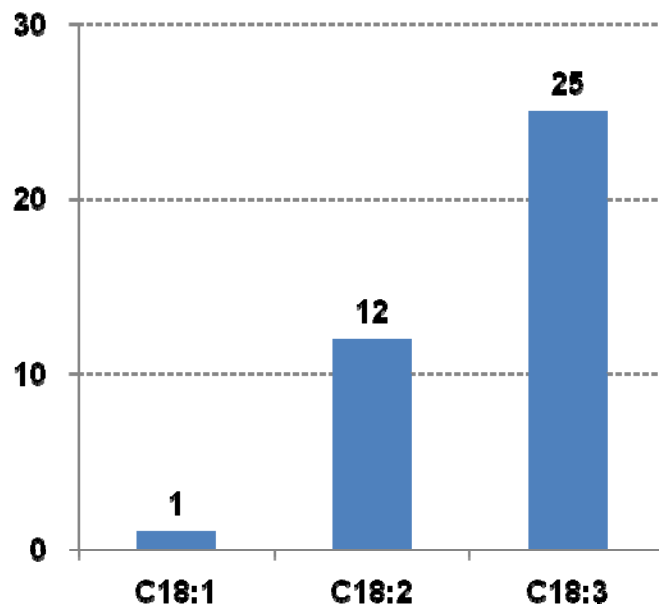
- BD has methylene-interrupted double-bond configuration, which include unstable bis-allylic position carbon atom.



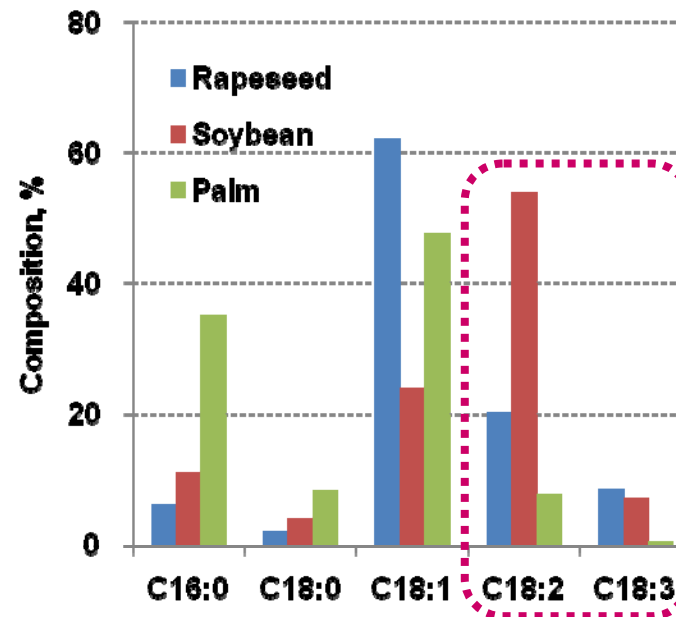
Composition and Oxidation Tendency

- Oxidation rate is proportional to the number of double-bond.
- C18:2 and C18:3 molecules account for 60% of SME.

Relative Rate of Oxidation



Component Distribution

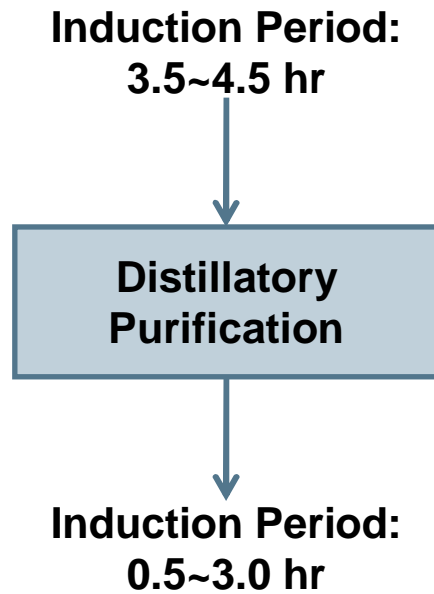


SwRI, Characterization of Biodiesel Oxidation and Oxidation Products, Aug. 2005

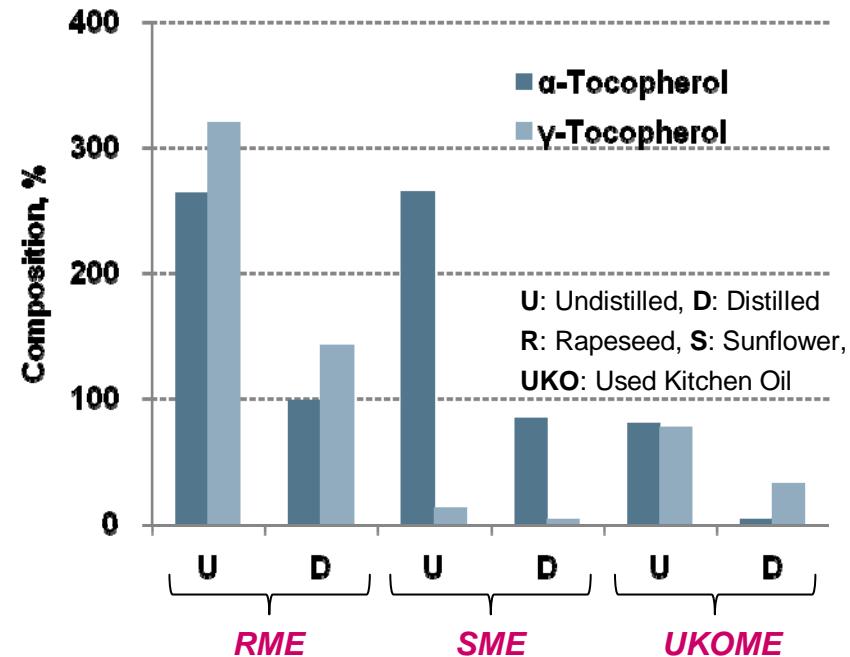
Distillation and Naturally Occurred Antioxidants

- Naturally occurred antioxidants are removed during distillation.

Effects on SME Stability



Changes in Naturally Occurred AO

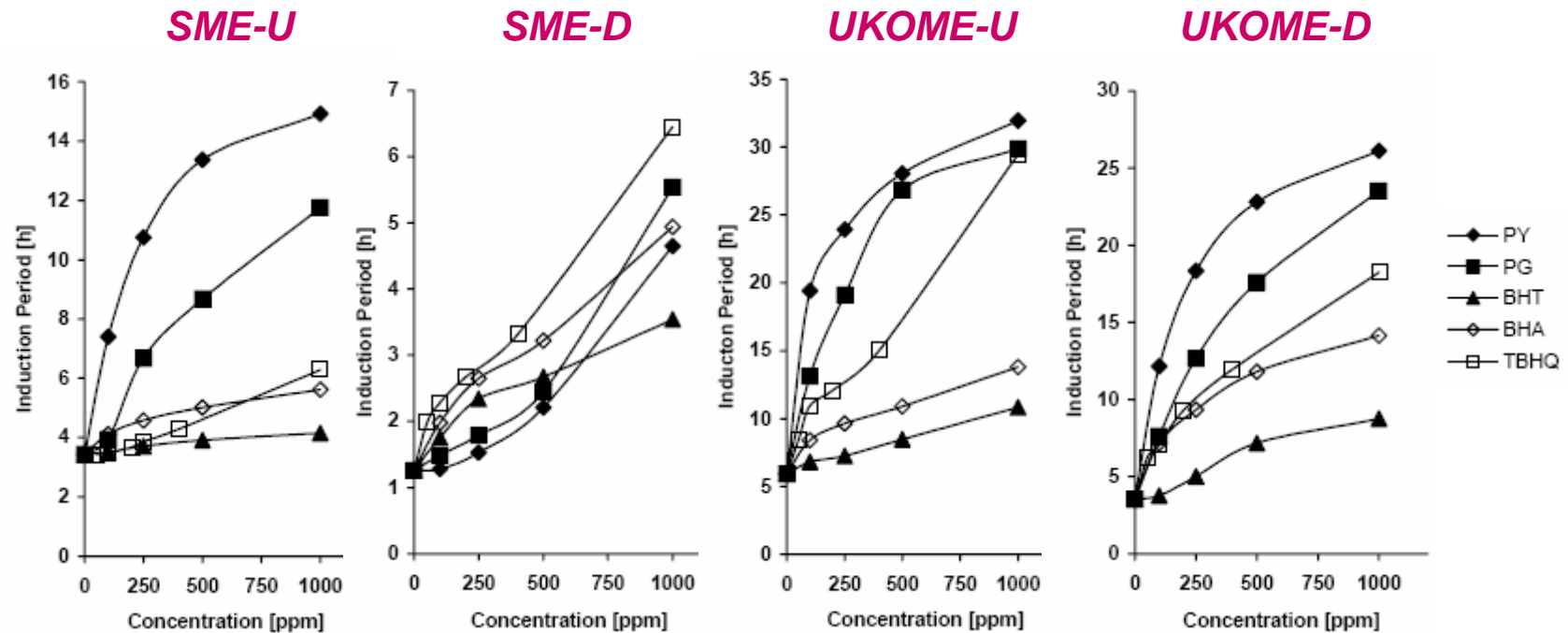


[L] SK In-house Test Results

[R] BIOSTAB Project, Stability of Biodiesel, July 3, 2003

Artificial Antioxidants

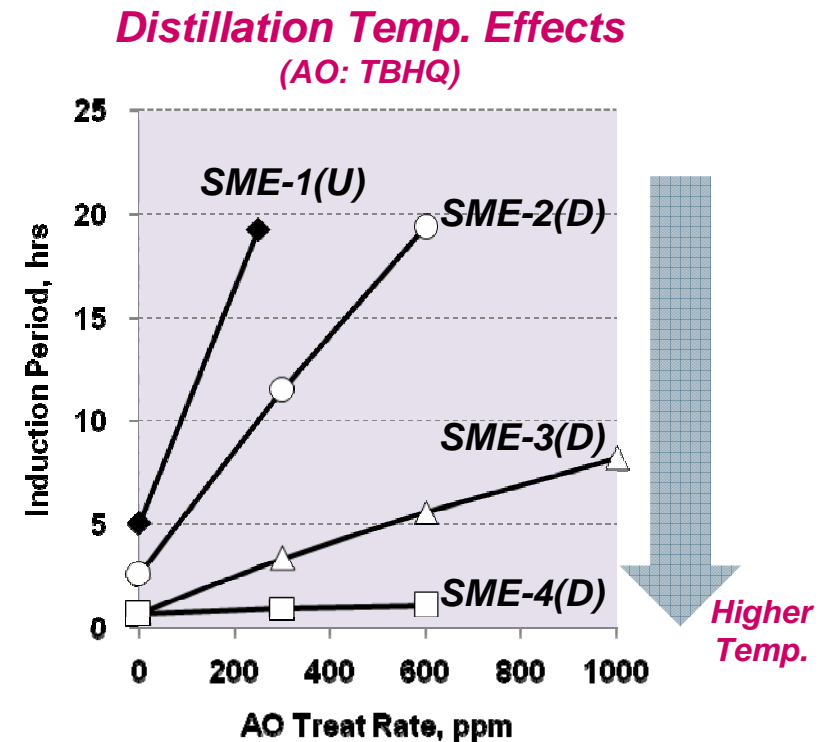
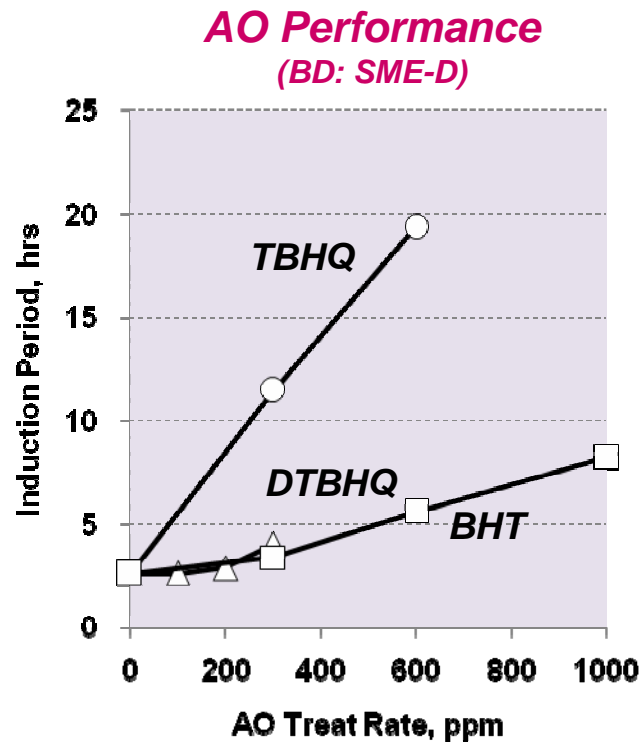
- Optimum antioxidants can be different case by case.
- TBHQ showed best performance in SME-D



BIOSTAB Project, Stability of Biodiesel, July 3, 2003

Test Results

- Like the results of BIOSTAB project, TBHQ showed best performance.
- Distillation temperature is another important factor of stability.



SK, In-house Test Results

Contents

1. *Current Status in Korea*

2. *Quality Issues*

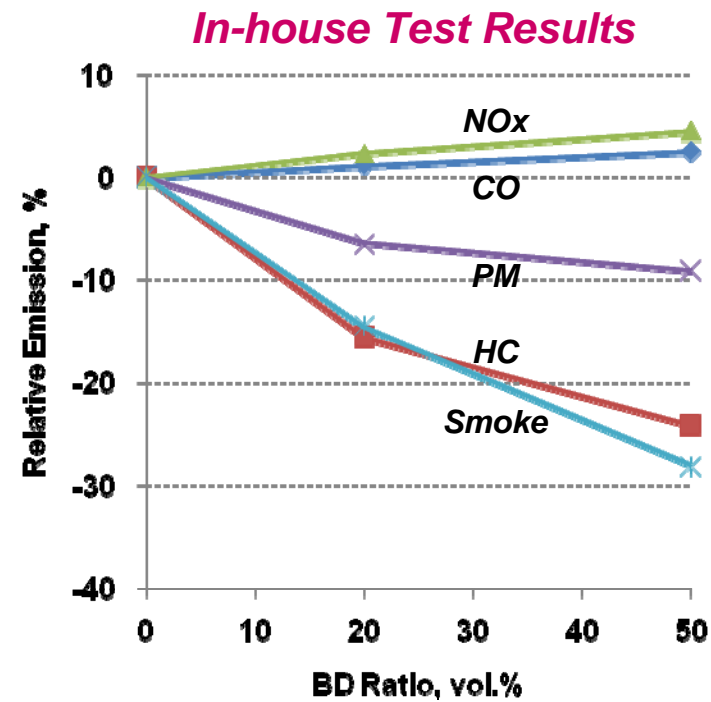
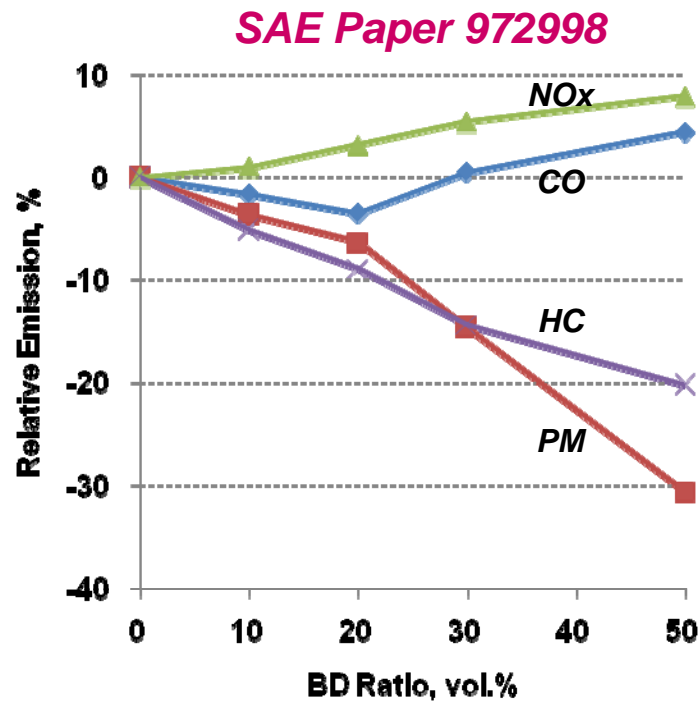
● 3. *Environmental Issues*

4. *Feedstock, Policy and Economics*

5. *Conclusions*

Emissions Benefit

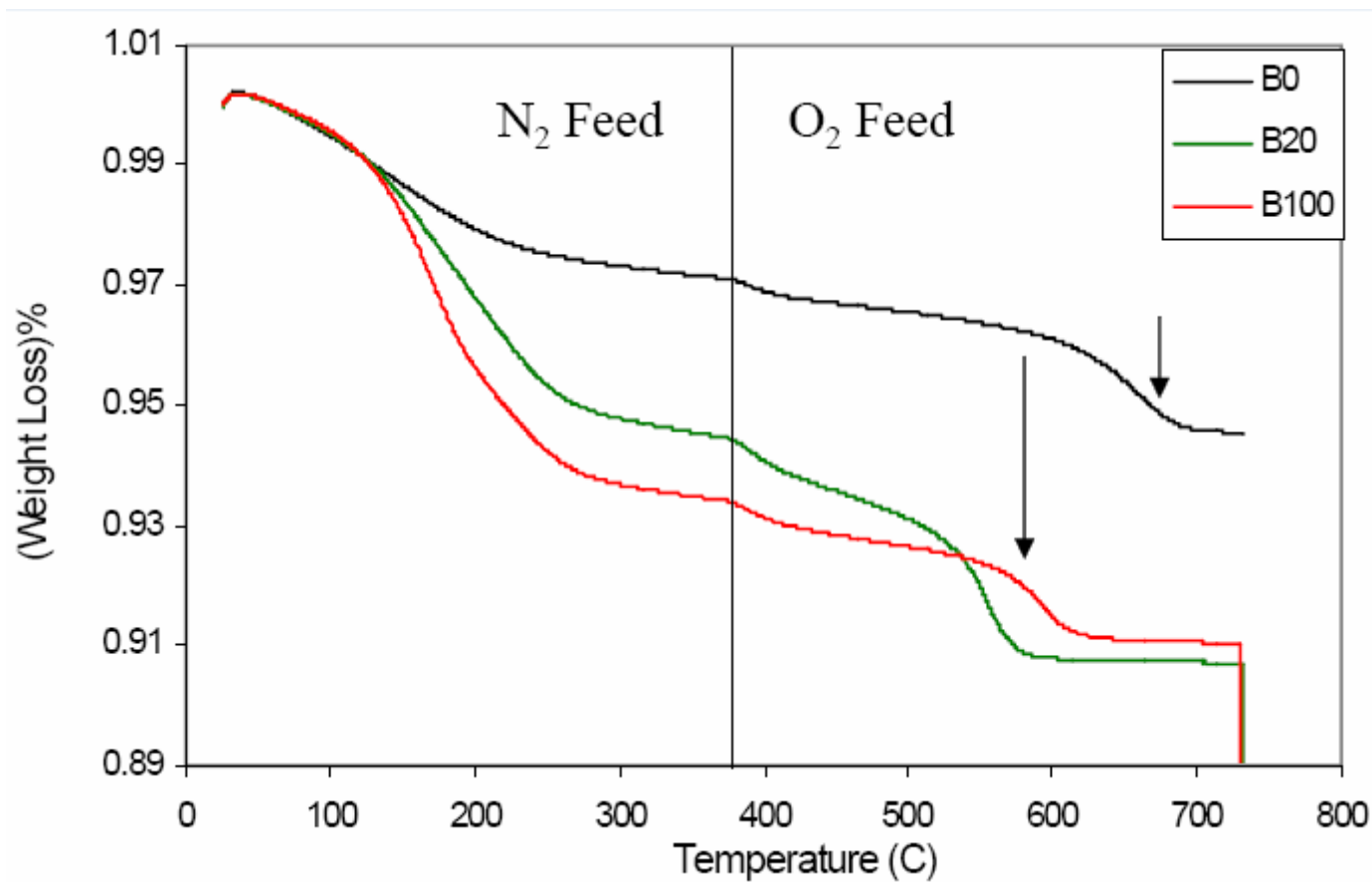
- BD contribute to reduction of HC and PM emissions.



[L] JOMO, Exhaust Emissions of a DI Diesel Engine Fueled with Blends of Biodieseland Low Sulfur Diesel Fuel SAE Paper 972998

Effects on DPF: Soot Characterization

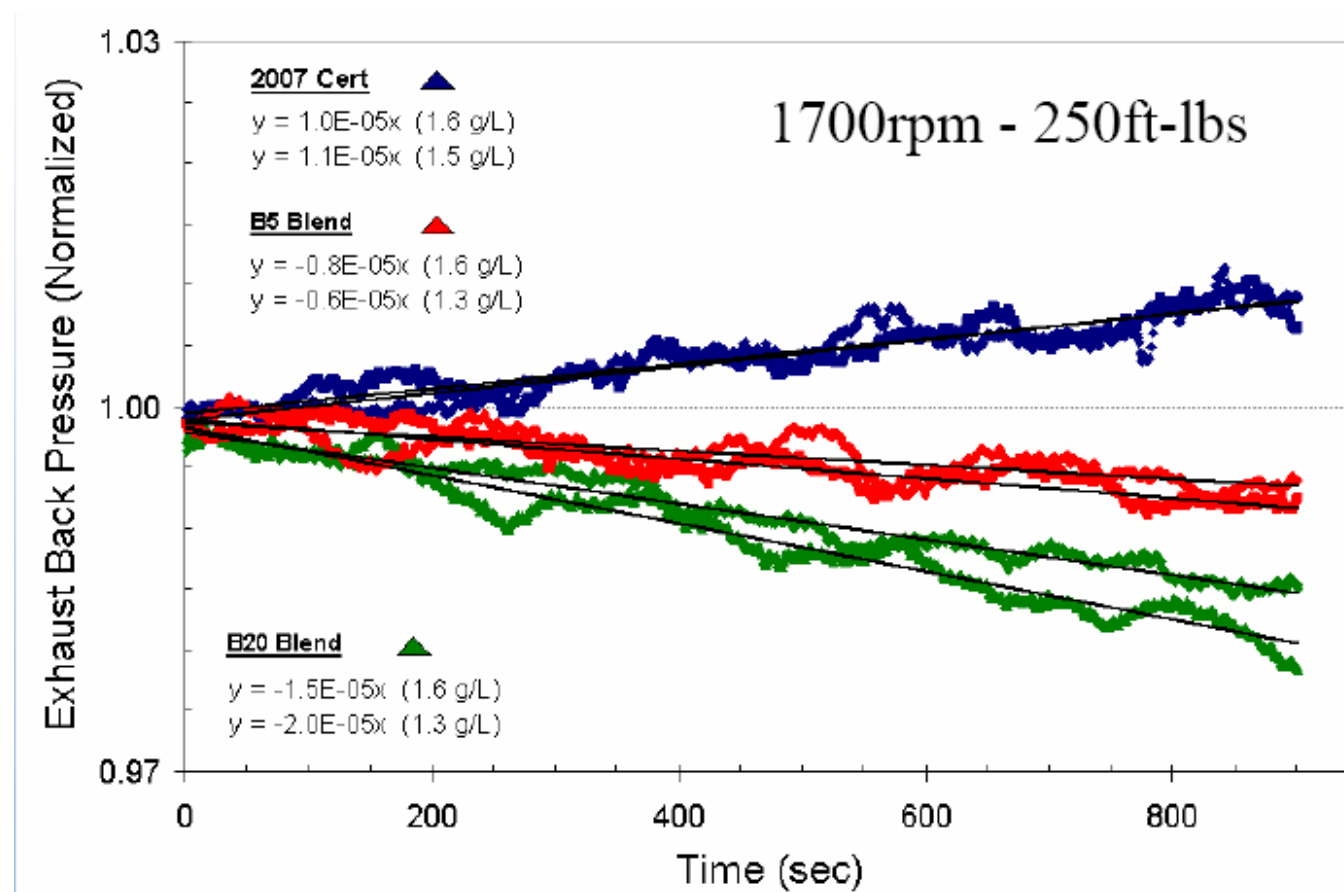
- Higher oxygen content of BD soot lower combustion temperature.



NREL, DPF Performance with Biodiesel Blends, Aug 20, 2006

Effects on DPF: Regeneration Rate

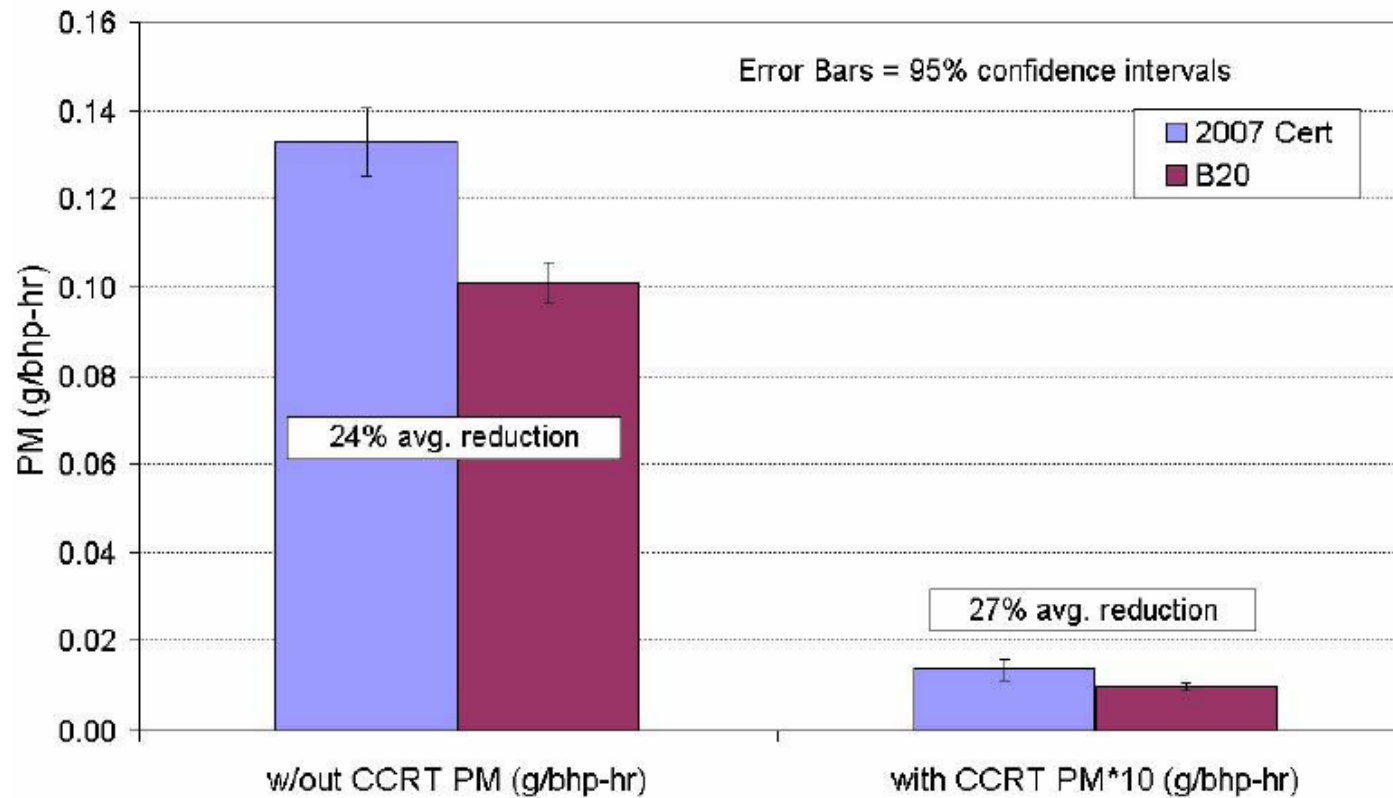
- Regeneration rate increases with increasing BD content.



NREL, DPF Performance with Biodiesel Blends, Aug 20, 2006

Effects on DPF: Performances

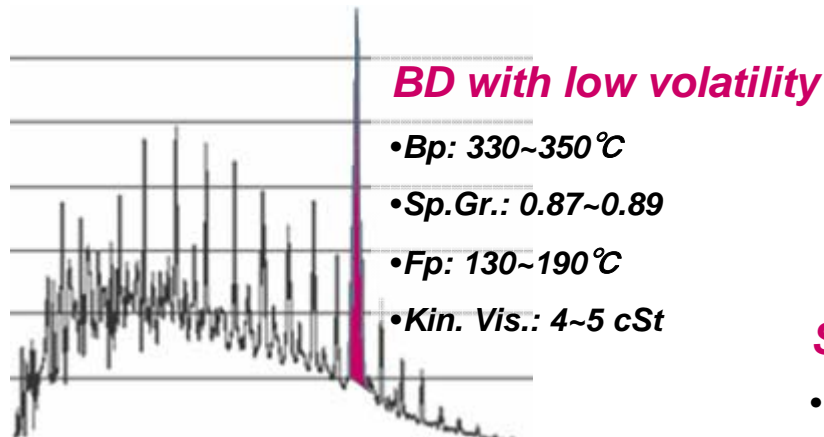
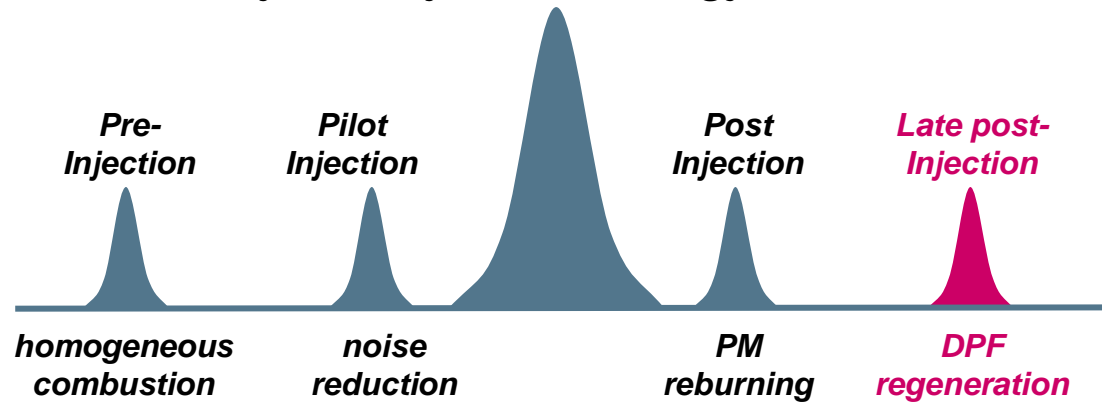
- Apart from DPF, BD provides additional PM reduction benefit.



NREL, DPF Performance with Biodiesel Blends, Aug 20, 2006

Low Volatility – Engine Oil Dilution

3rd Generation CRDI Injector Injection Strategy



Slip into engine oil

- Less evaporation via crankcase ventilation
- Deterioration of oil



BOSCH, Biodiesel in Korea: Requirements Placed by the Fuel Injection System on the Quality of Biodiesel Blends, Jun 30, 2006

Contents

1. *Current Status in Korea*

2. *Quality Issues*

3. *Environmental Issues*

● 4. *Feedstock, Policy and Economics*

5. *Conclusions*

Economic Feasibility: Break-even Crude Price

- As of Feb. 1st, break-even crude price was calculated to be \$88/bbl.
- As biodiesel production cost is tightly tied to the crude price, real break-even point is expected to be far higher.

	Current	Break-even
Crude Price (Dubai FOB)	<i>\$52/bbl</i>	<i>\$88/bbl</i> ←
Diesel	\$1.21/lit	\$1.60/lit
Refinery-gate Price	<i>0.57</i>	<i>0.97</i>
Tax	0.64	0.64
SME	\$1.60/lit	\$1.60/lit ←
Soybean Oil & Others	0.96	0.96
Tax(Assumption)	0.64	0.64

To equalize

Economic Feasibility: Social Benefit Approach

- Unit production cost of \$0.59/lit, which balances benefit and cost, should be achieved to justify government subsidy.

To Substitute 1% Diesel

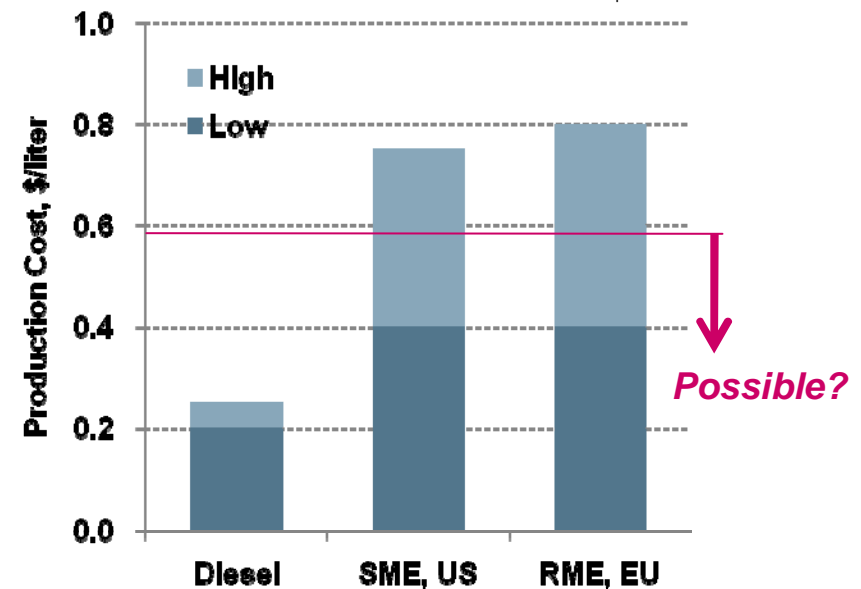
Unit: Million Dollars

	Self-Supply	Import
Total Social Benefit	129.0	-41.2
<i>Domestic Production ↑</i>	96.4	-56.0
<i>GHG Reduction¹⁾</i>	16.8	0.0
<i>Emission Reduction</i>	15.8	15.8
Unit Production Cost (Benefit = Cost)	\$0.59/lit	n.a.

1) Assumption: 25 Euros / ton CO₂

Production Cost, 2002

Dubai FOB in 2002: \$24/bbl



[L] SERI, Reasonable Implementation Strategy for Biofuels, Nov 8, 2006

[R] IEQ, Biofuels for Transport, 2002

Possibility of Self-supply: Arable Land

- Arable land requirement for the supply of BD2

Rapeseed, 74%



Soybean, 43%



Kitchen Oil, 89%



- When all the fallow lands are utilized:

	Rapeseed	Soybean
Biodiesel Production¹⁾, bpd	271	461
Motor Diesel Sales, bpd	352,000	
% of Biodiesel	0.08	0.13

¹⁾ University of Strathclyde(www.esru.strath.ac.uk), Biofuels for Transport, IEA, 2004

Possibility of Self-supply: Taxation and Financial Support

- Most probable scenario is to cultivate rapeseed in the rice field during winter season, instead of barley.
- To substitute 1% diesel with self-supplied RME, \$300 mil. of tax exemption and financial support for rapeseed farmer is required.

To Substitute 1% Diesel

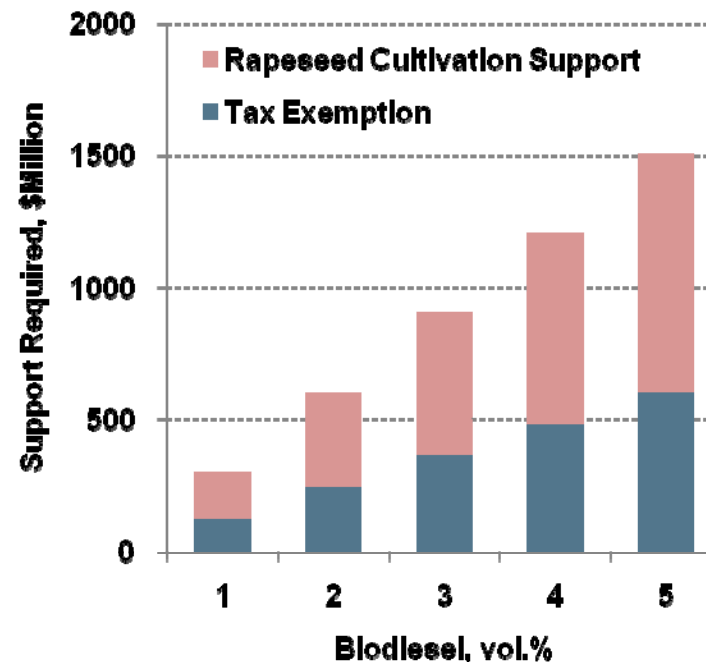
A. Tax Exemption¹⁾

1% of Diesel	228 mil.liter
Tax Exemption	\$0.53 / liter
228 mil. X 0.53 =	\$120 mil.


B. Rapeseed Cultivation Support²⁾

Area for 1% of Diesel	100,000 ha
Support per Area	\$1,810 / ha
100,000 X 1,810 =	\$181 mil.

- 1) Domestic diesel consumption of 2006: www.petronet.co.kr
Tax imposed on transport diesel is \$0.53/liter.
- 2) Total arable rice field for rapeseed cultivation is 300,000 ha.
Support to compensate a farmer for barley/rapeseed income difference.
weekly.chosun.com, July 24, 2006



Contents

- 1. Current Status in Korea*
- 2. Quality Issues*
- 3. Environmental Issues*
- 4. Feedstock, Policy and Economics*
-  *5. Conclusions*

Conclusions

- **Under the Korean government's strong policy drive, nationwide distribution of BD was started from July 2006.**
- **Based on EU's, Korean BD spec has a few differences with it. To be on the safe side, SK is managing BD quality by our own specifications.**
- **Despite the technical achievements so far, special attention has to be paid to cold flow property and oxidation stability.**
- **BD policy should be established on the long-term insights about engine technology, because characteristics of BD can affect the performance of newly developed engine and after-treatment devices.**
- **Considering gross social benefit, BD seems not to be rationalized under Korean circumstances. Self-supply shall require enormous taxation and financial support.**