Development and Outlook of Renewable Fuels in KOREA

Ock Taeck LIM (University of Ulsan)

Chan Gyu PARK, Jae-Kon KIM (K-Petro)

Contents

Seminar on bio-oil for power generation

Energy situation in Korea

10th in energy consumption
* 9th in petroleum consumption, 9th in electricity consumption

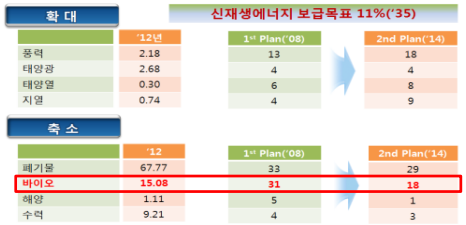
97% dependence on foreign energy

7th in GHG emission

Energy Security

2nd Master Plan for National Energy('14)

NRE* 11% in power sector(~'35)



Bioenergy 18%

NRE 3020 strategy ('17)

NRE 20% in power sector(~'30)

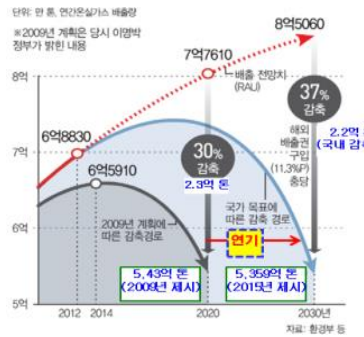
*NRE: New and Renewable Energy

GHG Reduction

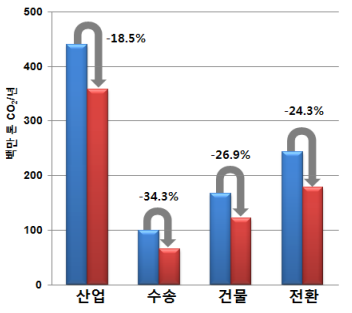
National GHG Reduction Target('15)

BAU* 37%(~'30)

GHG Reduction Target (Unit : milion)



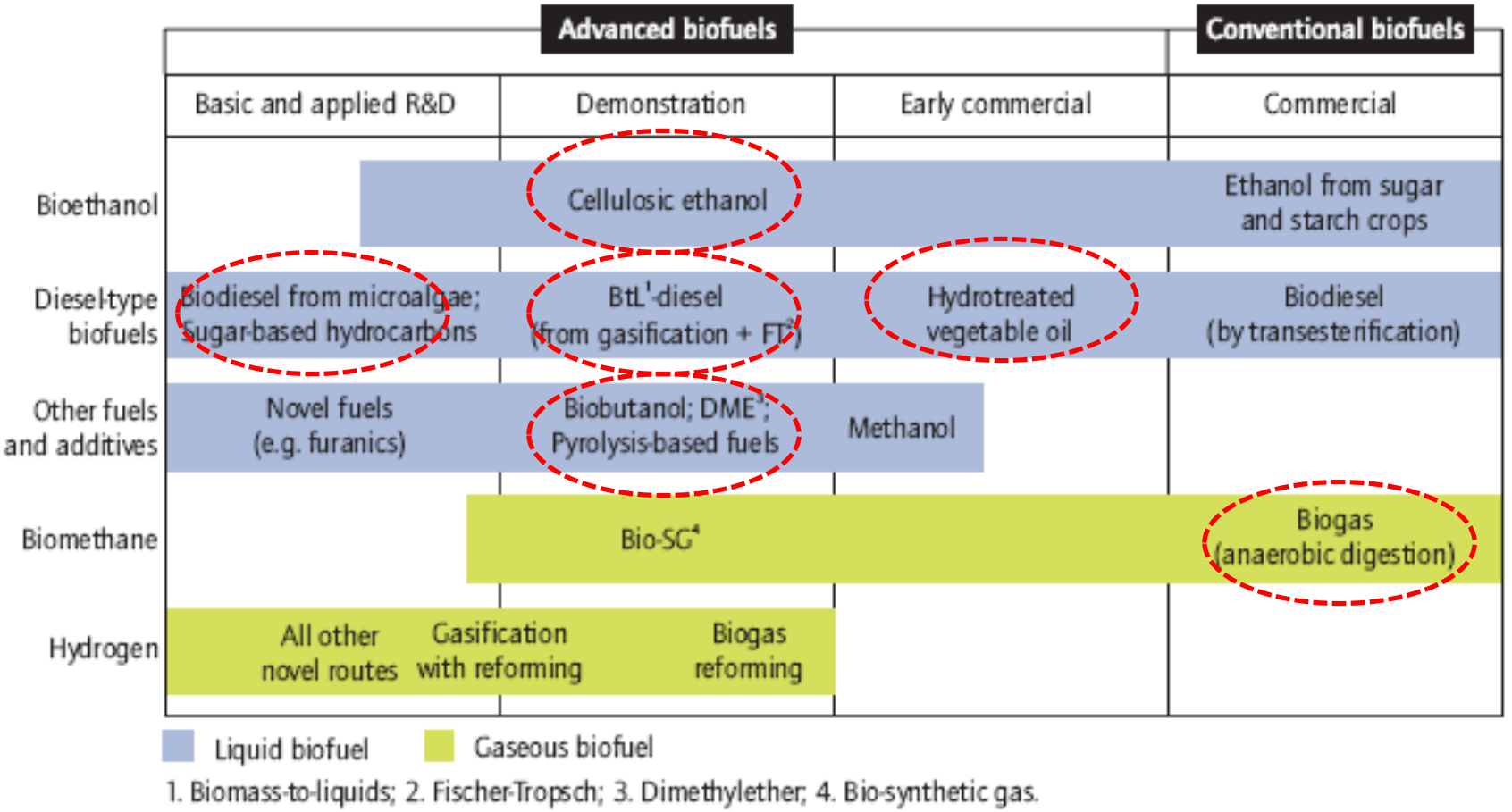
GHG Reduction Target by Sector



*BAU: Business As Usual

Need to expand the supply of renewable energy (RPS, RFS, RHO)

Advanced Biofuels Development in Korea



1. Biomass-to-liquids; 2. Fischer-Tropsch; 3. Dimethylether; 4. Bio-synthetic gas.

Source: Modified from Bauen *et al.*, 2009.

- Recently, advanced biofuels is developing by upgrading technology for transport fuel, compared to liquid conventional biofuels.

The New Government's Energy Conversion Policy

List	Contents
Nuclear power plant zero	• Discontinuation of new nuclear power plant and invalidation of construction plan(Construction of Shin-Kori 5 and 6 stopped) • Immediate shutdown of nuclear power plants that have reached the end of their design life(Wolsung Unit 1 shutdown)
Clean Energy Development	• Stop new construction of coal-fired power plant and review the origin of thermal power plant under construction with a process rate of less than 10% • Nuclear power plants and coal-fired power plants expanded electricity price difference plan for local residents • Establishing and discovering new energy business model including demand resource trading market, solar rental business and energy prosumer
Expansion of renewable energy in electric power production	• Renewable energy ratio raised to 20% by 2030 • Create eco-friendly energy fund • Actively investing in the development of solar power, offshore wind power, etc. and pilot demonstration of environment friendly energy self-reliance • Introduce FIT for a limited time and raise RPS duty ratio target • Realization of power usage optimization based on real-time energy measurement in buildings, house farming, factories and homes, and demand prediction by micro-weather prediction
Establishment of energy ecosystem for the 4th industrial revolution	• A platform-based energy system that connects the Internet and the energy industry together • Eco-cars such as electric cars and hydrogen cars, IoT, smart cars based on big data • Established eco-friendly charging infrastructure including electric vehicle parts including secondary batteries
Eco-friendly energy cleaner maintenance	• Tax hikes for coal-fired fuels, eco-friendly fuels tax cuts • Enforced government subsidy system for purchasing eco-friendly cars
Improve energy consumption industry structure	• Review of dedicated departments of emission trading system for establishing environmental / safety reflectance in energy basic plan and basic power supply and demand meeting • Establishing and discovering new energy business model including demand resource trading market, solar light rental industry and energy prosumer • Prevent the impediment of industrial competitiveness of cost burden of electricity bill, examine policy support such as Small Business

Contents

Seminar on bio-oil for power generation

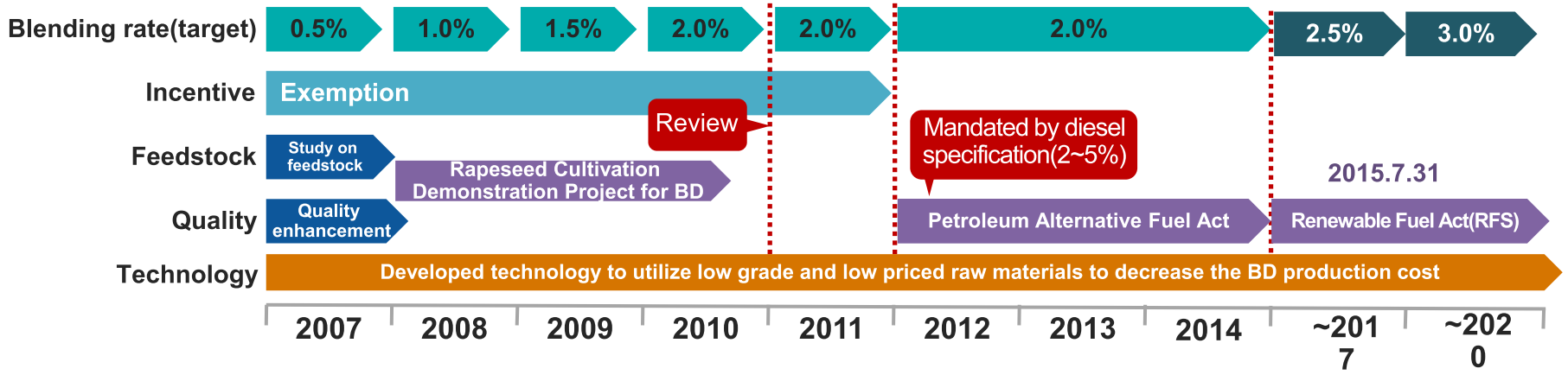
Biofuels Status for Transport Fuels in Korea

Petroleum Products	Alternative Biofuels for transport		
Diesel	Biodiesel	Mandated by RFS	commercial
* Low cost feedstock Develop., HBD(Demonstration stage), Microalgae BD			
Natural gas	Biogas	Partly commercialized	
* Partly in use for city gas and transport(taxi, bus)			
Gasoline	Bioethanol	Demonstration step	Potential
* 2nd generation bioalcohols (biobutanol, cellulosic alcohol etc.) R & D stage			
LPG	Bio-DME(DME)	R&D step	
* Bio-DME is considering as one of the alternative fuel for LPG to carry out the obligatory policy(RFS)			
Jef fuel	Bio-Jet fuel	R&D step	
* Bio-Jef fuel is developing aircraft application test with HEPA jet fuel based on vegetable oil.			

Implementation Status of Biofuels in Korea

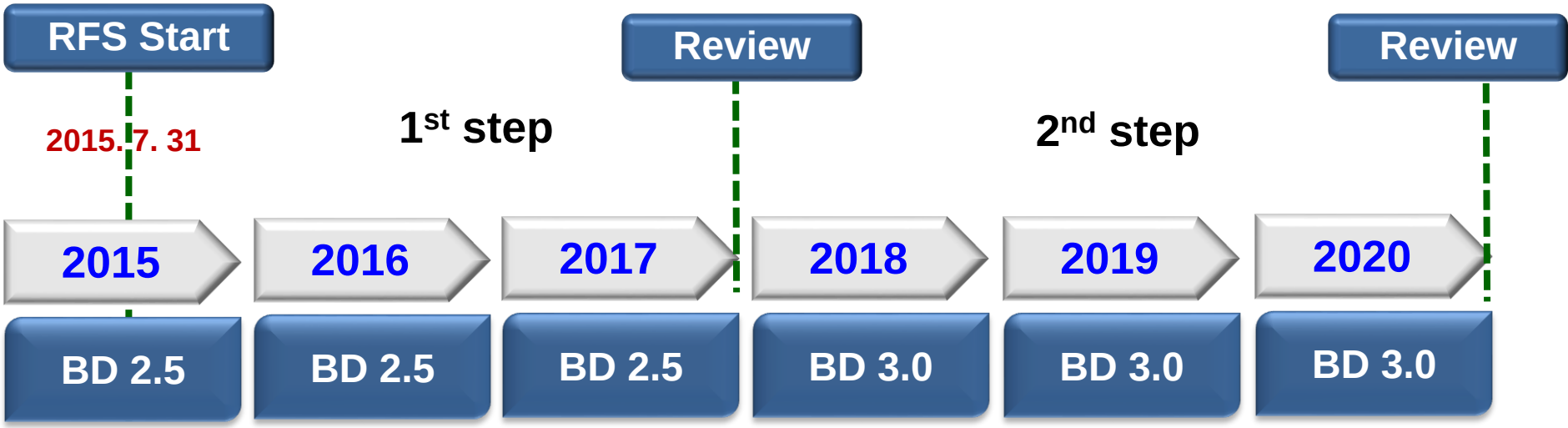
Year	Promotion Status
2002~2004	- BD 20 Demonstration Project(2002~2005) - BE, ETBE permitted as gasoline oxygenate(2004)
2006 ~ 2008	- BD commercialized(2006.07) - 1st BD Medium and Long Term Dissemination Plan(2007) : Voluntary agreement between the government and refiners(Tax free, BD 0.5%→2.0%) - BE Actual Assessment Project(2006~2008)
2009 ~ 2010	- Study on introduction of obligatory policy(RFS, Renewable Fuel Standard) in Korea
2011	- 2nd BD Medium and Long Term Dissemination Plan(2010) - Mandate requiring BD 2~5% in the diesel specifications from 2012 with taxation
2012 ~ 2013	- Study on RFS operation scheme('12.5~'13.3) /RFS proclamation('13.7.30) - Study on the detailed scheme of BE Demonstration Project('13.5~'13.12)
2014	- Pre-announcement of RFS sub-legislation(enforcement ordinance, enforcement regulation and notification) - Demonstration project of bio-fuel oil for power plant(2014.1.1 ~ 2015.12.31)
2015	- RFS implementation('15.7.31) - Extension period of demonstration project of bio-fuel oil for power plant('15.8.20) , ~ 2016.12.31

Biodiesel Supply History



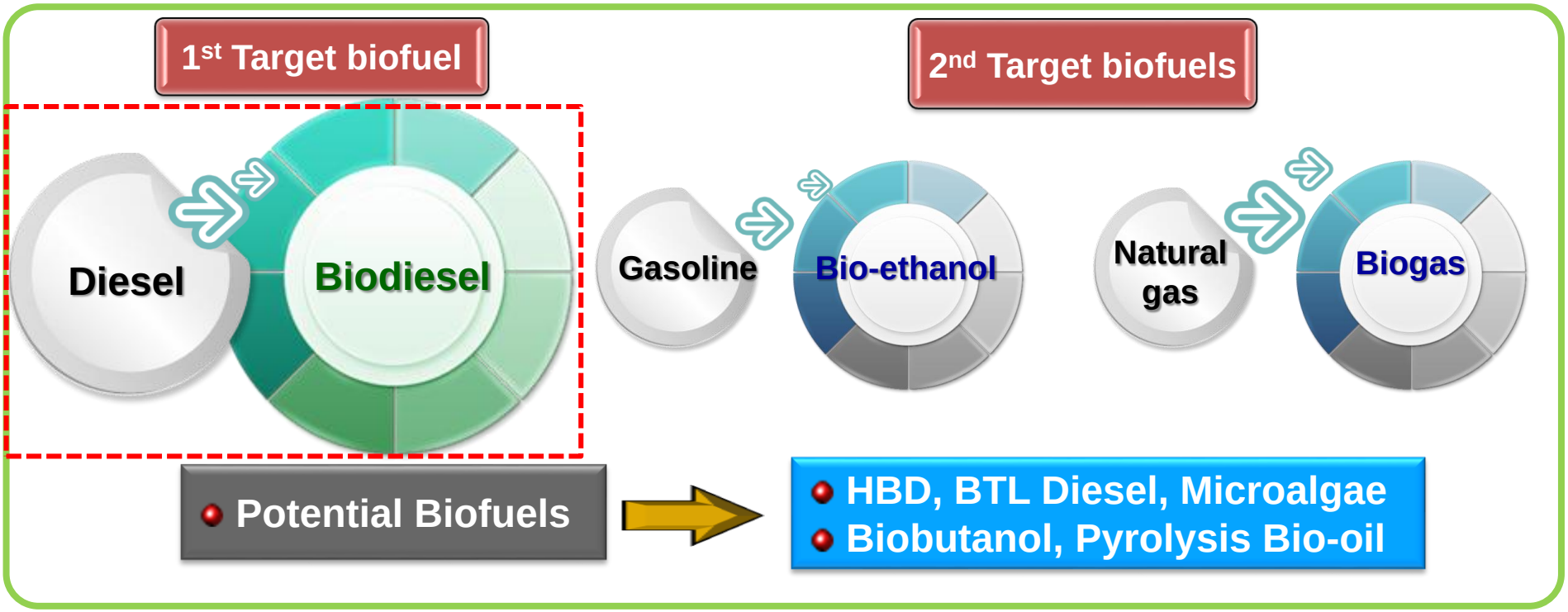
RFS Scheme – Target Volume

- **RFS Target Volume for Biodiesel**



RFS Scheme - Biofuels

- It was applied biodiesel to blend in automotive diesel obligatorily in 1st step from 2015.
- It will be introduced next biofuels with bioethanol and biogas to substituted road fossil fuel after consideration by demonstration project for commercialization.



Status of Biodiesel Industry – Distribution

- B5 is subject to diesel fuel specification, and supplied by refiners.
- B20 is used by bus and truck company on their own accord, and supplied by biodiesel suppliers.

BD suppliers(9)

BD100

Refiners(4)

Diesel (BD2)

Service Station

Diesel (BD2)

Costumer

BD20

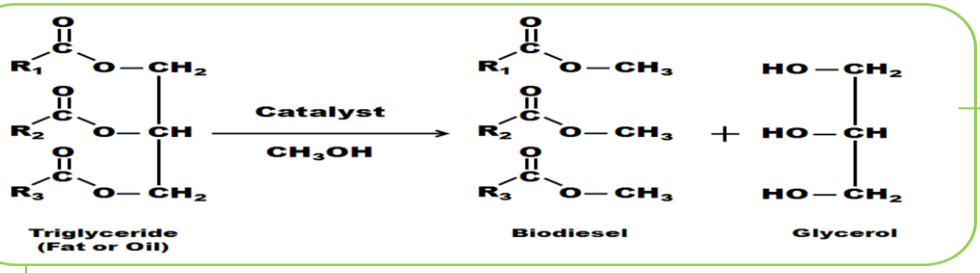
10% during winter season(11/1~3/31)

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

Status of Biodiesel Industry – Companies

No.	Biodiesel Company	Production Capacity (kL/year)	Main Feedstock
1	EMACBIO Corp.	50,000	Soybean, Waste cooking oil
2	M Energy Corp.	100,000	Waste cooking oil
3	Dansuk Corp.	113,068	Waste cooking oil, Palm oil
4	Eco-Solution Corp.	85,000	Waste cooking oil
5	SK Chemical Corp.	136,000	PFAD
6	Aekyung Petrochemical Corp.	130,000	Waste cooking oil, Palm oil
7	JC Chemical Corp.	120,000	Waste cooking oil, Animal Fat
8	GSBIO Corp.	120,000	Palm oil, Waste cooking oil
Total		854,068	

Status of Biodiesel Industry – Process



Status of Biodiesel Industry – Plants

Status of Biodiesel Industry – Specification

- Korean BD Specs is simiar to EN specificaton from 2006.
- CFPP acts as a prevention for palm oil usage in the winter season
  * Palm oil BD has greater than 10℃ CFPP

Properties			Spec. (Different spec. with Taiwan)	Test Method
FAME(wt%)		Min.	96.5	EN 14103
Flash Point(℃)		Min.	120 (101)	KS M ISO 2719
Kinematic Viscosity (40℃, ㎟/s)			1.9 (3.5)~ 5.0	KS M 2014
Carbon Residue (wt%)		Max.	0.1 (0.3)	KS M ISO 10370
Sulfur Content (㎎/㎏)		Max.	10	KS M 2027
Ash (wt%)		Max.	0.01 (0.02)	KS M ISO 6245
Copper Strip Corrosion (50℃, 3h)		Max.	1	KS M 2018
CFPP (℃)		Max.	0	KS M 2411
Density (15℃, ㎏/㎥)			860 ~ 900	KS M 2002
Moisture (wt%)		Max.	0.05	KS M ISO 12937
Sediment (mg/kg)		Max.	24	EN 12662
TAN (㎎ KOH/g)		Max.	0.50	KS M ISO 6618
Total Glycerol (wt%)		Max.	0.24 (0.25)	KS M 2412
Monoglyceride (wt%)		Max.	0.80	KS M 2412
Diglyceride (wt%)		Max.	0.20	KS M 2412
Triglyceride (wt%)		Max.	0.20	KS M 2412
Free Glycerol (wt%)		Max.	0.02	KS M 2412
Oxidation Stability (110℃, h)		Min.	6	EN 14112
Methanol (wt%)		Max.	0.2	EN 14110
Alkali Metals (mg/kg)	(Na + K)	Max.	5	EN 14108, 14109
	(Ca + Mg)	Max.	5	EN 14538
Phosphorus (mg/kg)		Max.	10 (4)	EN 14107

* CFPP is applied to the winter season (11. 15. ~ 2. 28)

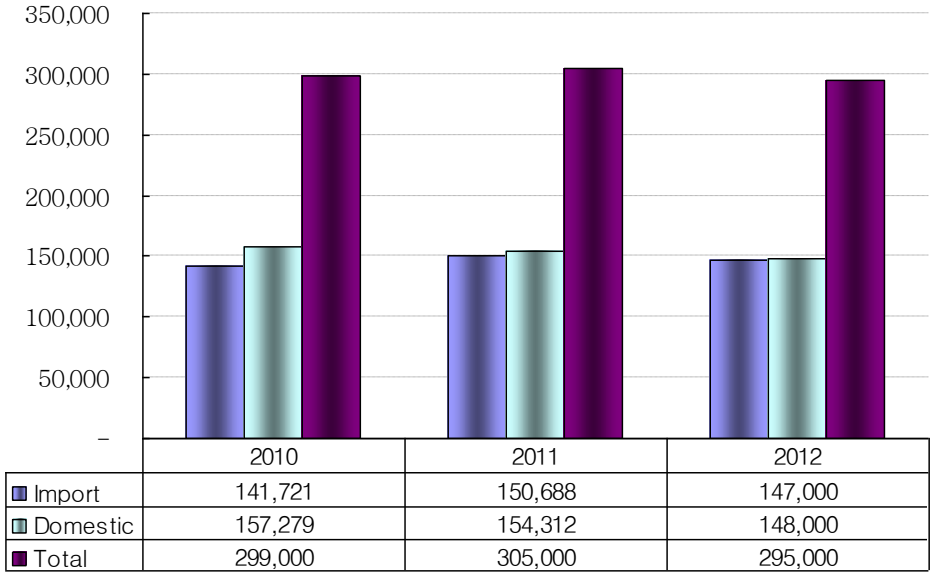
Status of Bioethanol Industry – BE Production

Production

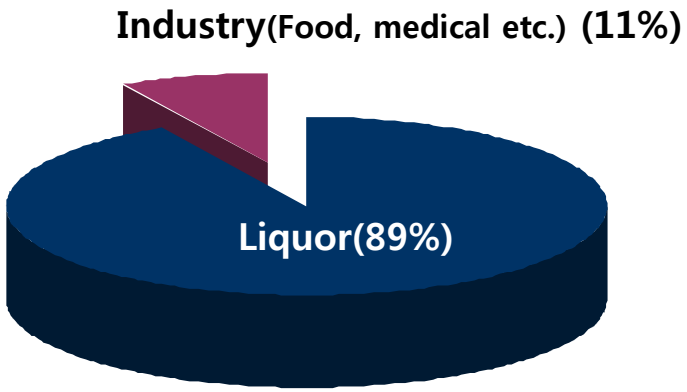
- Domestic bioethanol is produced by 10 companies
  - Import : 49%, Domestic Production : 51%

Consumption

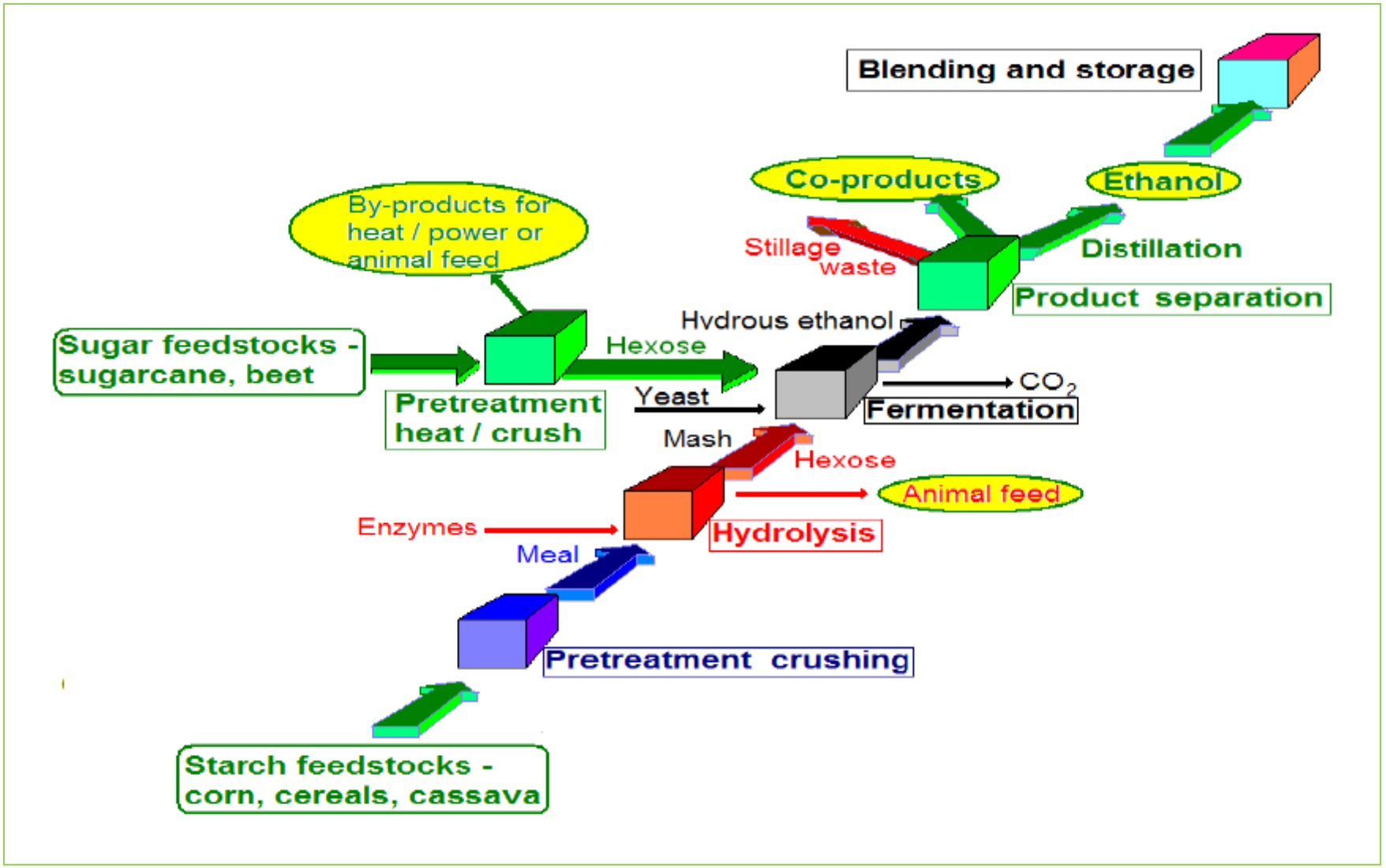
- Annual production of Bioethanol
  → 295,000kL('12)
- When supplying E3 in whole contrury, bioethanol is needed about 300,000 kL



	2010	2011	2012
Import	141,721	150,688	147,000
Domestic	157,279	154,312	148,000
Total	299,000	305,000	295,000



Status of Bioethanol Industry – Process



Status of Bioethanol Industry – Assessment st

- **In 2005, Feasibility study for the Implementation of bioethanol as fuels in Korea was carried out by KIER**

  ⇒ The study suggest necessity of actual assessment study on domestic infra

- **In 2006, actual assessment study on bioethanol blends fuel to introduce in Korea was carried out by K-Petro**

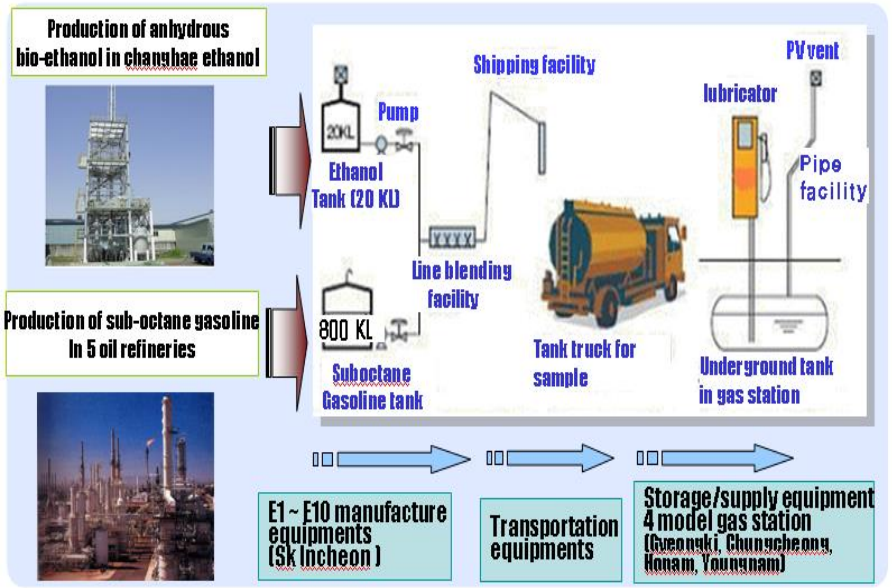
  ⇒ No special problem for management of Bio-ethanol blended fuels (E3 and E5) in 4 gas stations during demonstration (10 months)

Status of Bioethanol Industry – Assessment study

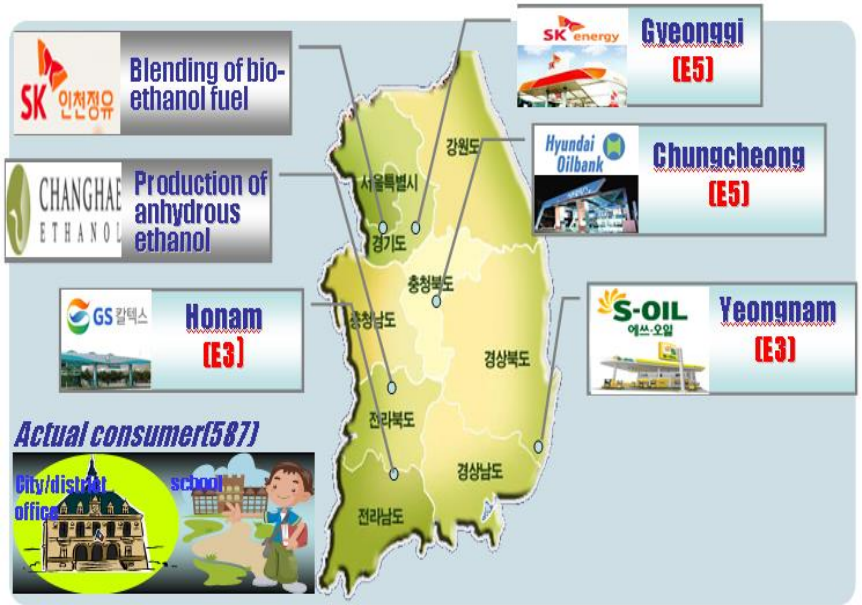
Project Outline

- Project period: August 2006 – July 2008
- BE blended fuels : E3 and E5
- Gas Station/Consumer : 4 gas station nationwide/Public official and office workers 587 people

➢ Scheme for production, transportation, storage and supply



➢ Nationwide 4 gas station and users



Status of Bioethanol Industry – BE Spec.(draft)

Anhydride Bioethanol Quality Specification(Draft)

Properties		Spec.	Test Method
Ethanol Content (vol%)	Min.	92.7 이상	ASTM D 5501
Moisture Content (vol%) (Karl Fischer)	Max.	0.30 이하	KS M ISO 103369, 10337, ASTM E203, D6304
Methanol Content (vol%)	Max.	0.1 이하	ASTM D 5501
Denaturant Content (vol%)		2.0 ~ 5.0	-
Washed Existent Gum (mg/100mL)	Max.	5.0 이하	KS M 2041, ASTM D381
Electrical Conductivity (uS/m)	Max.	500 이하	KS I ISO 7888, ASTM D1125
Sulfate Content (mg/kg)	Max.	4 이하	ASTM D7318, D7319, D7328
Inorganic Chloride Content (mg/kg)	Max.	10 이하	ASTM D7319, D7328
Copper Content (mg/kg)	Max.	0.1 이하	KS I ISO 8288, ASTM D1688
Acidity (as acetic acid) (wt%)	Max.	0.0070 이하	KS M ISO 1388, ASTM D1613
pHe		6.5 ~ 9.0	ASTM D6423
Phosphorus Content (mg/L)	Max.	0.50 이하	KS M 2403, ASTM D3231
Sulfur Content (mg/kg)		10 이하	KS M ISO 20846, ASTM D 5453
Appearance		Clear and Bright	Recognizable Color

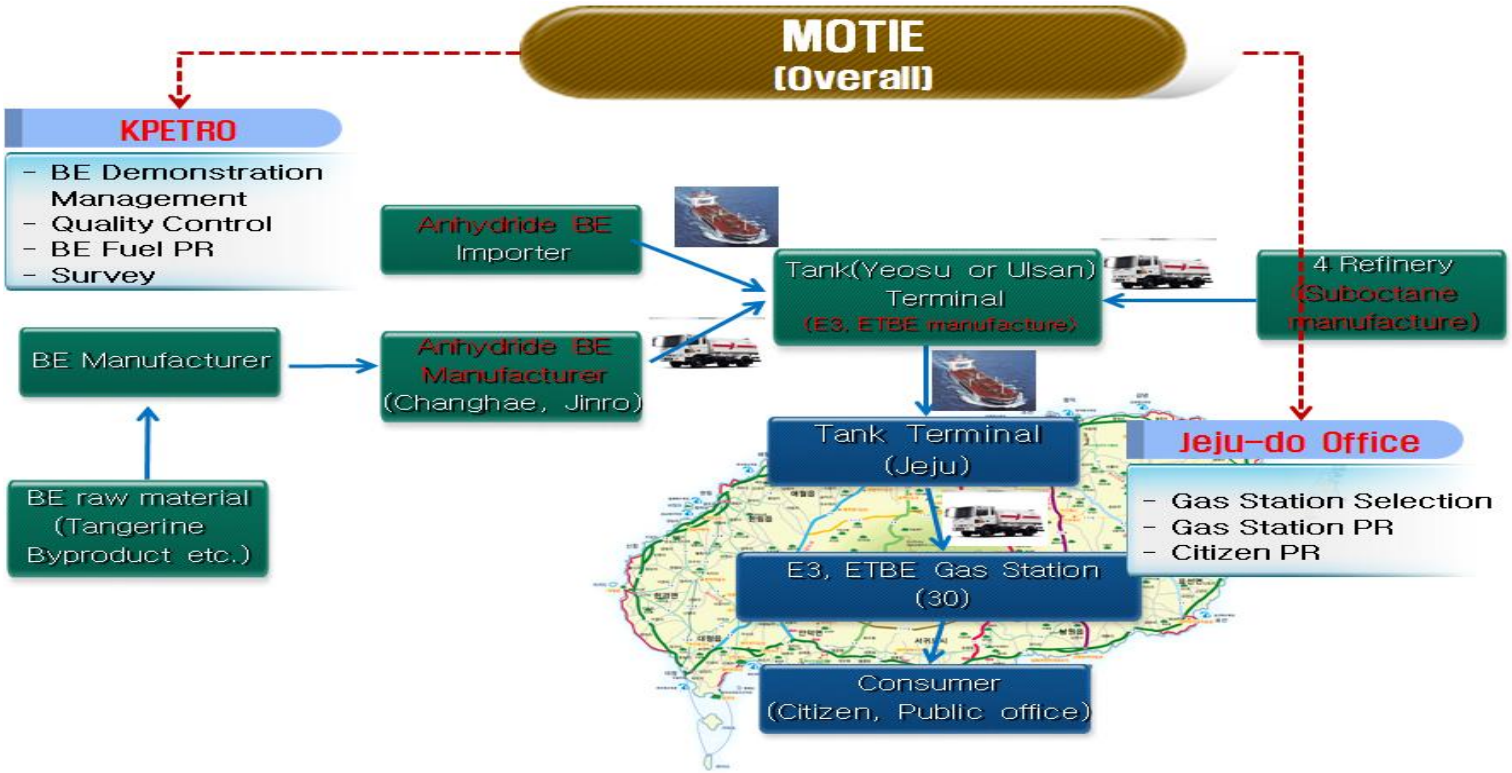
* Denaturant refer to the gasoline that meet the gasoline specification of act

Status of Bioethanol Industry – Future Plan

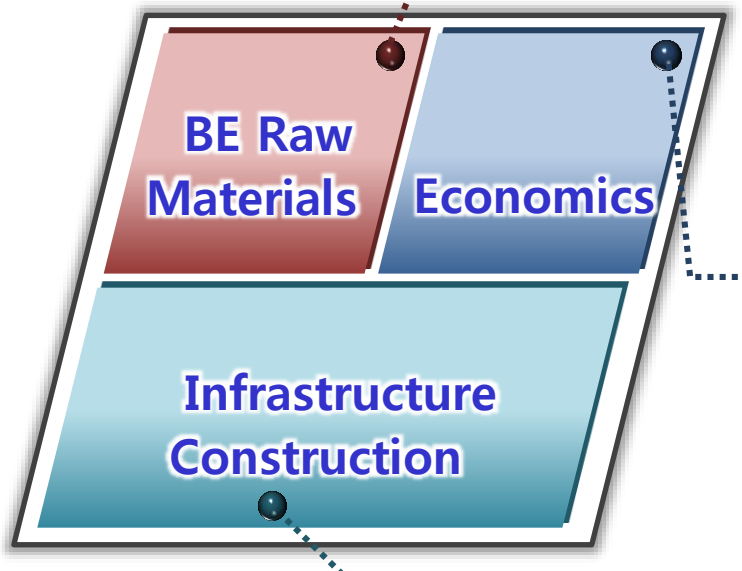
Future Plan of Bioethanol Demonstration Project

Project Outline

- Target Area/Gas station : local government(Jeju-do, etc.) / 30 gas stations
- BE fuel type : E3, ETBE10



Status of Bioethanol Industry – Issues



- Initially, Most of the BE expected to be dependent on imports from Brazil
  - Establish foundation for a stable supply
  - Development of overseas plantation
  - Development of the production technology of domestic raw materials (miscanthus, citrus byproduct, etc.)

- Price competiveness is required
  - Compared to the price of gasoline imported BE is 1.1 × (887won/950won)
    * In case of production with domestic material the price is 1,500won/L

- Promoting regional demonstration project
- Infrastructure to oil reservoirs and gas stations

Status of Biogas Industry – Infrastructure

- **During the research for the utilization of biogas as road transport, various recent governmental initiative and plan were found.**

⇒ Biogas has high potential biofuels in Korea

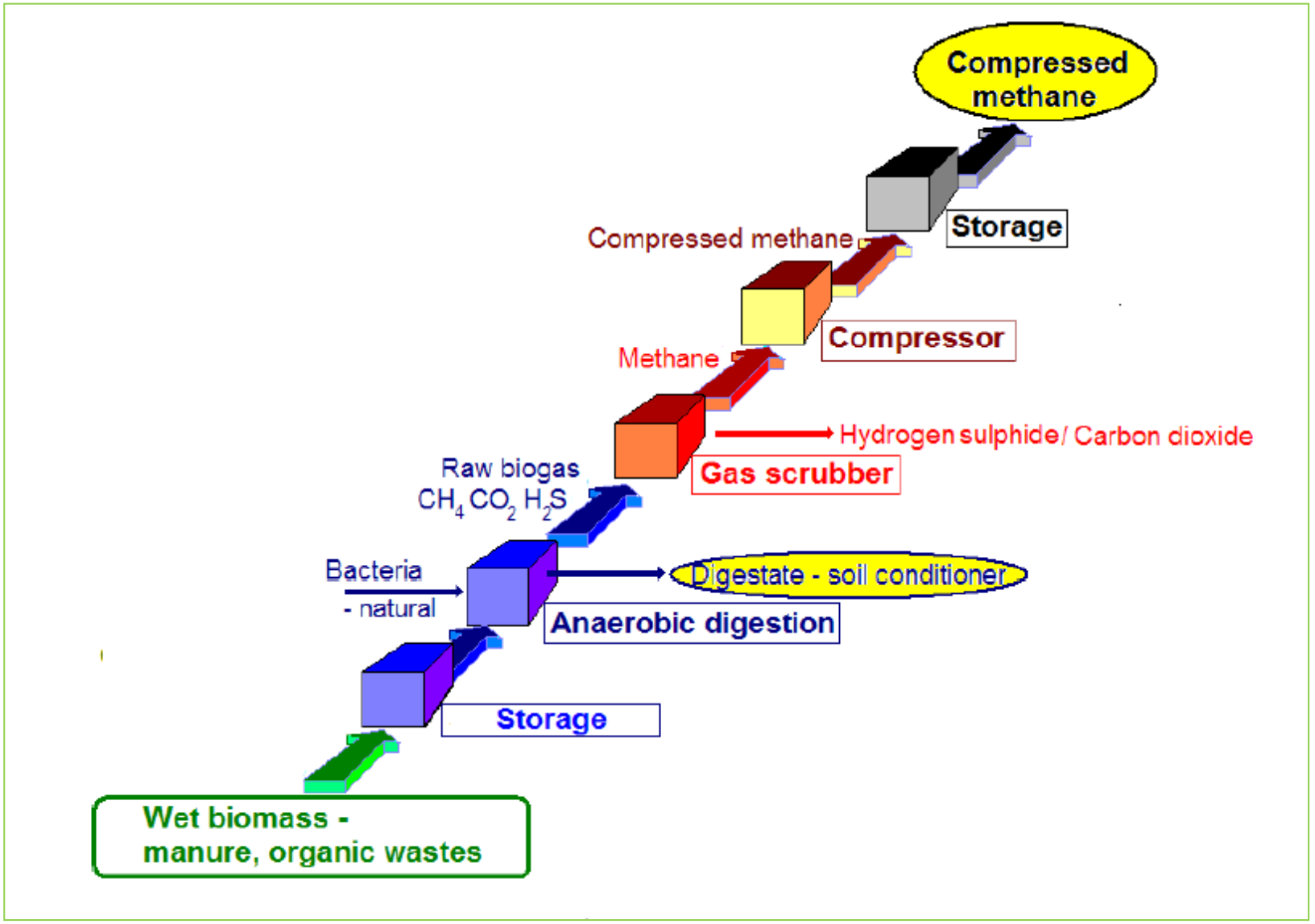
⇒ Upgrading and highly concentrated fuel technology(CBG, LBG)

⇒ Biomethane from biogas can be used as for natural gas vehicle(NGV) in Korea

<Biogas Plant>

<Biomethane gas station>

Status of Biogas Industry – Process



Status of Biogas Industry – LCA

LCA of Biomethane for transport fuel in Korea

Unit: gCO_2/MJ, %

		Plant A	Plant B	Average
Emission		3.4	12.2	9.1
Emission reduction rate (Comparison of fossil fuel)	LNG(71.4gCO_2/MJ)	95%	83%	87%
	LPG(49.0gCO_2/MJ)	93%	75%	81%
	Diesel (73.3gCO_2/MJ)	95%	83%	88%
	Gasoline (70.9gCO_2/MJ)	95%	83%	87%

Source : Keei, 2012.

- With respect to the transport sector, biogas showed 83% ~ 95% of emission reduction rate when compared against LNG, and 75% ~ 95% against other fossil fuels.

Status of Biogas Industry – Biomethane

- **Biomethane(BM) production plants(8 sites) for transport fuel in Korea**

Company	Fuel type	Capacity (Nm^3/d)	Upgrading Process	Plant area
KOGAS / HYUNDAI ENGINEERING & CONSTRUCTION	Transport fuel	4,000 Nm^3/d	VPSA	Wonju sewage plant
Potlatch	Transport fuel	26,000 Nm^3/d	RPSA	Daegu sewage plant
Hansol 한솔이엠이	Transport fuel	4,800 Nm^3/d	RPSA +Cryogenic	SL Corp.
HALLA Halla Energy & Environment	Transport fuel	14,400 Nm^3/d	RPSA	SL Corp.
ECO ENERGY HOLDINGS	Transport fuel (city gas 80%)	5,040 Nm^3/d	PWS	Seonam sewage plant
ECO ENERGY HOLDINGS / 경남에너지주식회사 KYUNGNAM ENERGY CO., LTD.	Transport fuel (city gas 80%)	10,000 Nm^3/d	PWS	Changwon Duckdong sewage plant
HALLA Halla Energy & Environment	Transport fuel	14,400 Nm^3/d	RPSA	Busan suyoung sewage plant
KRICT	Transport fuel	1,440 Nm^3/d	Membrane/PSA	SL Corp.

Status of Biogas Industry – Transport biogas

- **Biomethane production plants for transport fuel in Korea**

Potlatch corp.

KOGAS & Hyundai

SL Corp.

Eco-energy corp.

Contents

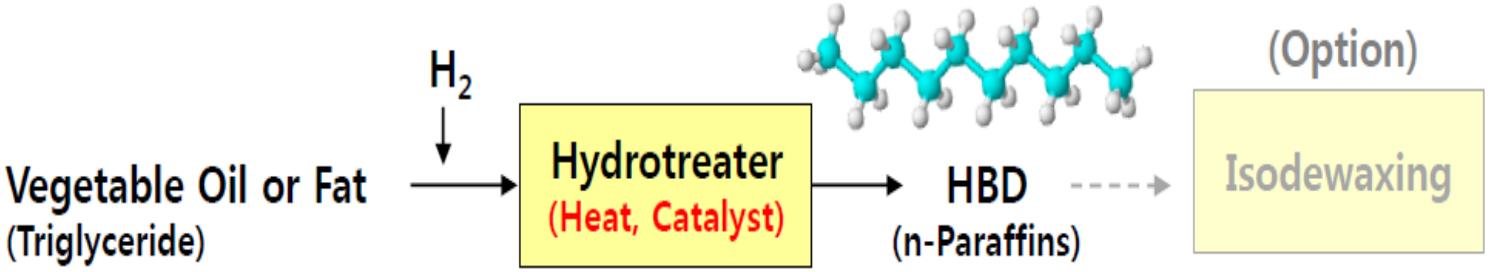
Seminar on bio-oil for power generation

Advanced Biofuels Development for Diesel in Korea

	1st Generation	2nd Generation	3rd Generation		
	Biodiesel (FAME)	Hydro-treated Biodiesel (HBD)	BTL Diesel	Fast Pyrolysis Bio-Oil(FPBO)	Microalage
Process route	Trans-esterification	Hydro Conversion in refinery hydrotreaters	Gasification and FT synthesis	Fast pyrolysis treatment	Trans-esterification
Feed	Vegetable oils	Vegetable oils	Biomass	Biomass	Lipid oil from alage
Product	FAME Biodiesel	HBD, Renewable or Green diesel	Syn. Diesel	Bio-oil, Char, Gas	FAME Biodiesel
Product chemical type	Fatty acid methyl ester	Mainly paraffinic hydrocarbons in diesel boiling range	Mainly linear and branched paraffinic HCs from upgrading waxy FT liquids	Complex high mol. weight HCs, water, char solids	Fatty acid methyl ester
Product quality	Consistency and stability issues	High	High	Low quality energy carrier	Harvesting economy
Lifecycle analysis (CO_2 emission)	1.6 – 2.3 (kg CO_2/kg oil equivalent) Source : Neste[1)]	0.5 – 1.5 (kg CO_2/kg oil equivalent) Source : Neste	-61% to -91% compared to fossil diesel Source : Choren	-	-

Advanced Biofuels Development - HBD

- Development of Hydro-treated-Biodiesel(HBD)

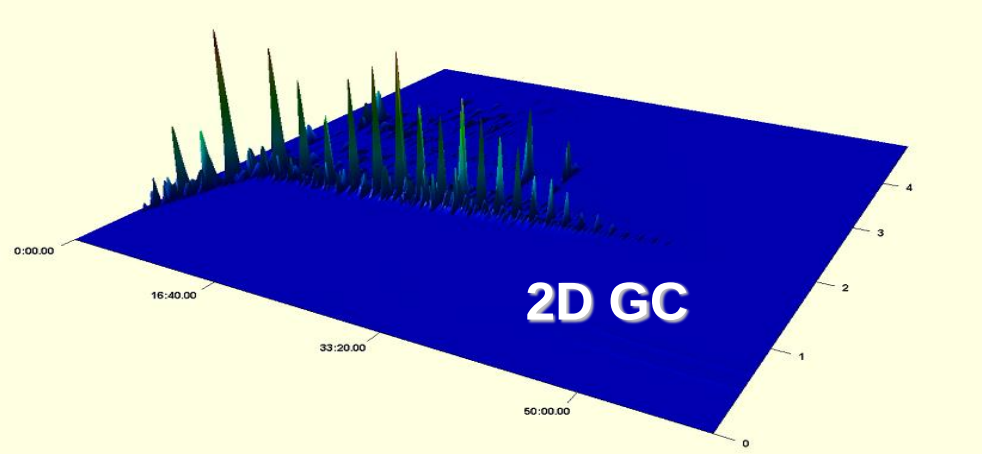


Demo plant of SK Energy in Ulsan complex

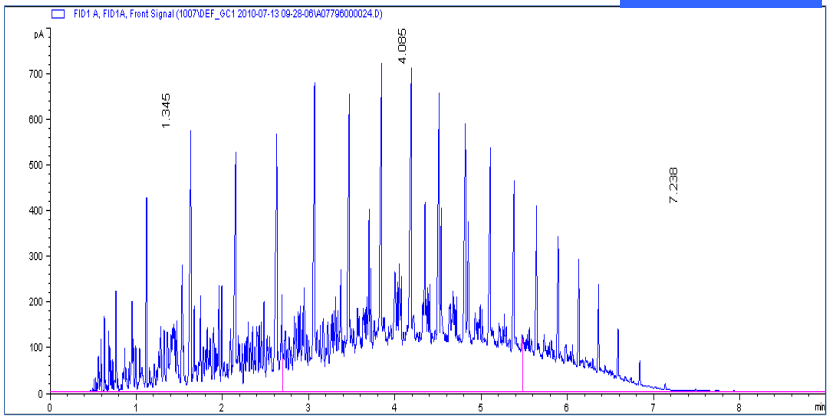
- Plant size : 30 m × 20 m
- Capacity : 20 BPD

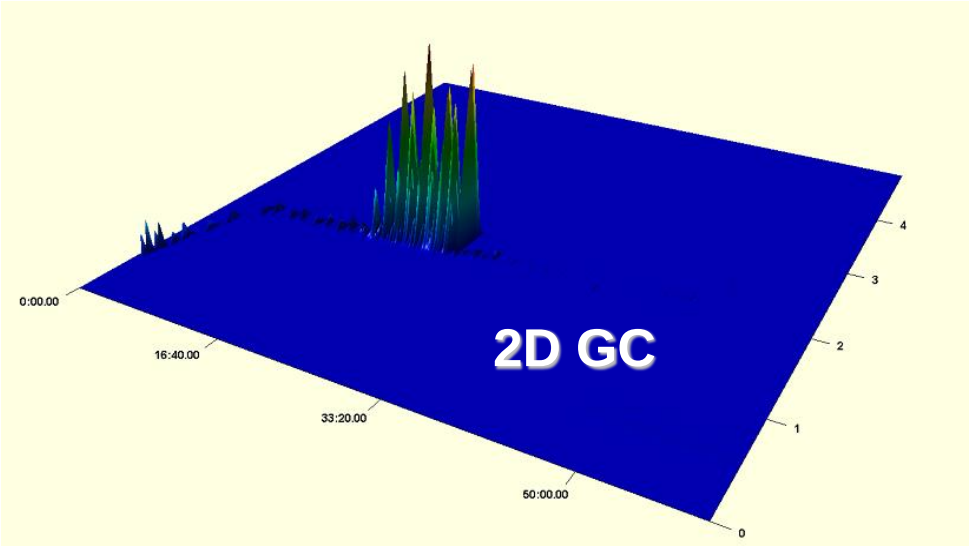
Advanced Biofuels Development - HBD

- GC analysis for HBD composition

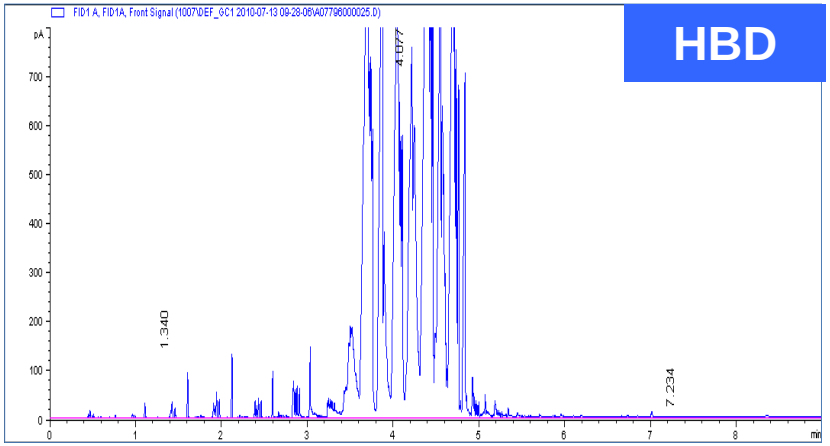


Diesel





HBD



Advanced Biofuels Development - HBD

Property	Diesel	HBD100
Pour point(PP) (℃)	-30.0	-1.0
Cloud point(CP) (℃)	-4.0	3.0
Flash point (℃)	44.0	40.0
Viscosity (40℃, mm^2/s)	2.52	3.07
Distillation (T90, ℃)	347.8	291.2
Carbon residue 10% (wt.%)	0.02	0.02
Sulfur (㎎/㎏)	3.83	5.32
Cetane number (IQT)	50.9	83.0
Copper corrosion (100℃, 3h)	less than 1	less than 1
Cold Filter Plugging Point(CFPP) (℃)	-22.0	3.0
Density@15℃ (kg/m^3)	824.9	779.4
Polyaromatics (wt.%)	1.05	0.00
Total aromatics (wt.%)	20.14	0.00

- Especially, Distillation temperature HBD was low in 50% ~ FBP range compared to conventional diesel.

Advanced Biofuels Development – BTL Diesel

BTL Diesel Production

F-T Process

Syngas(CO+ H_2 = 1 ~ 2)

Fe based Catalyst

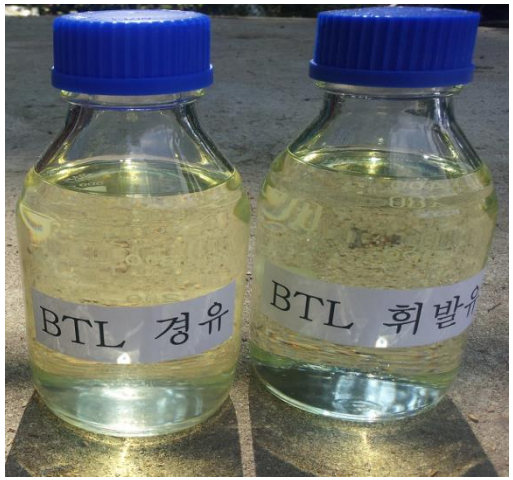
Biomass : Pellet

- BTL Pilot Plant

BTL fuel synthesis

- BTL Wax

Distillation



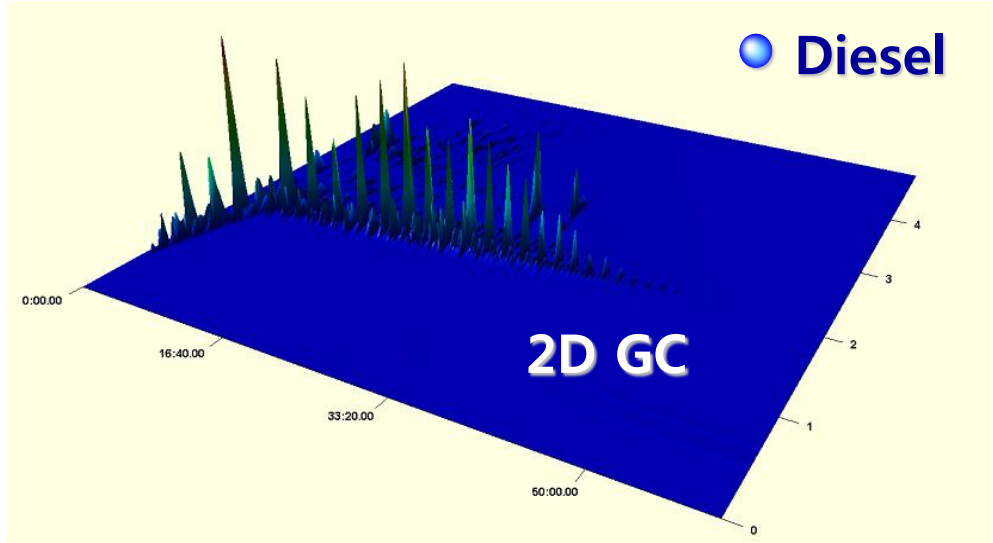
- BTL Diesel (170℃~320℃)
- BTL Gasoline (60℃~170℃)

- Challenge of BTL diesel as a alternative diesel
- Target : 2 BPD (‘10 ~ ’12, R&D level)

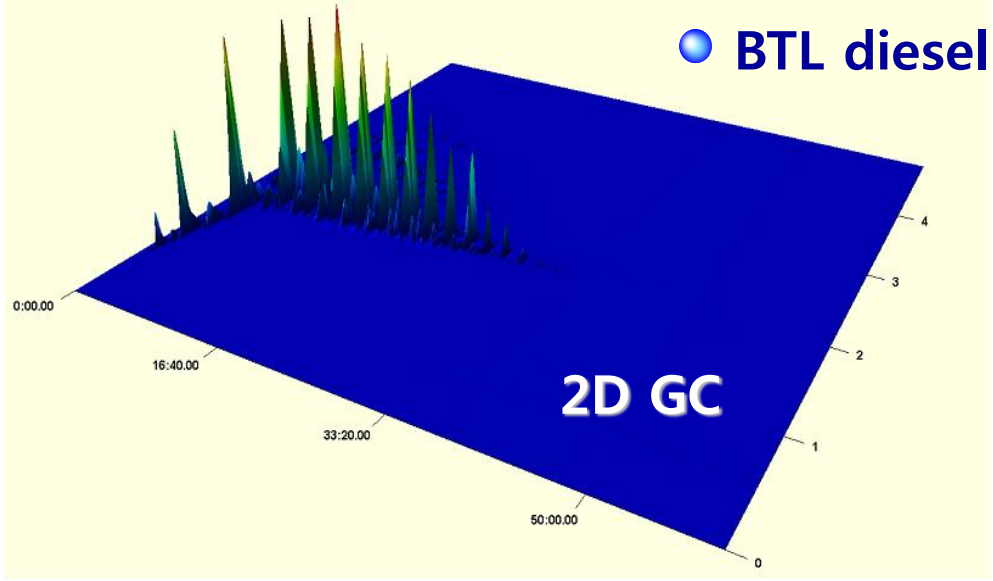
Advanced Biofuels Development – BTL Diesel

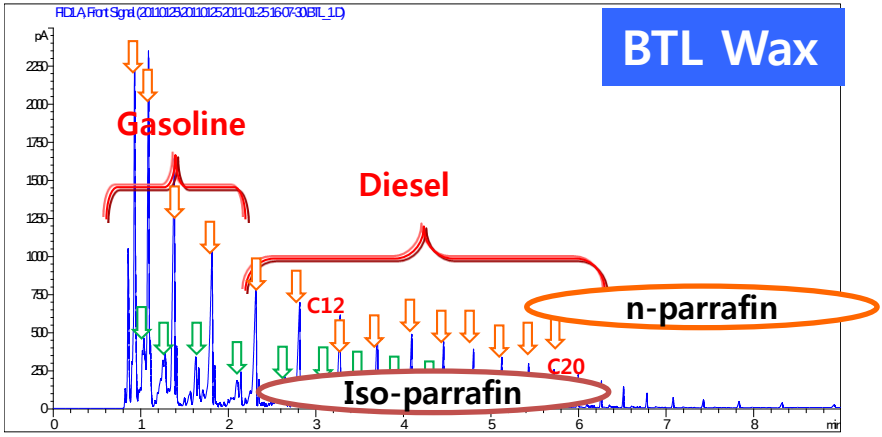
GC analysis for HBD composition

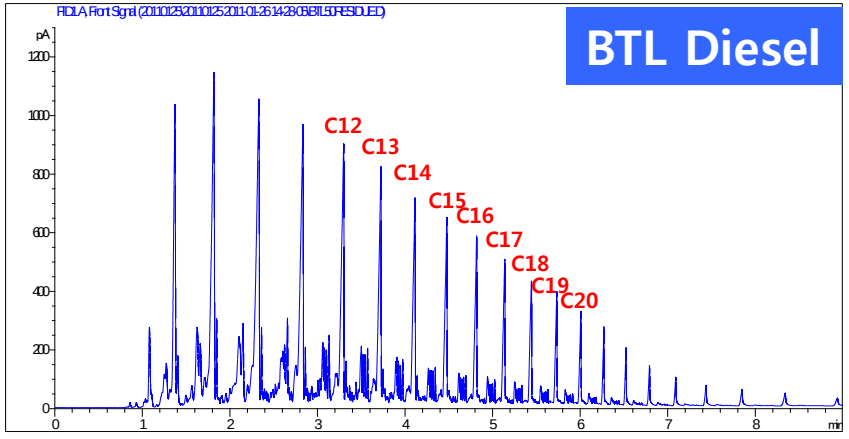
Diesel



BTL diesel







Advanced Biofuels Development – BTL Diesel

Quality Characteristics of BTL diesel(100%)

Property		Unit	Standard	Diesel	BTL Diesel
Pour Point		℃	0.0 Max. (winter : -17.5 max)	-35.0	-22.5
Cloud Point		℃	-	-4.0	-17.0
Flash Point		℃	40 Min	44	50
Kinematic Viscosity(40℃)		mm^2/s	1.9 ~ 5.5	-	-
Distill.	IBP	℃	-	150	171
	10%	℃	-	172	190
	50%	℃	-	243	232
	90%	℃	360 Max.	334	290
	FBP	℃	-	367	312
Carbon Residue in 10% residual oil (wt.%)		Vol.%	0.15 Max.	0.15 Max.	0.15 Max.
Water and Sediment		Vol.%	0.02 Max.	0.01 Max.	0.01 Max.

- Especially, Distillation temperature BTL diesel was low in 50% ~ FBP range compared to conventional diesel.

Advanced Biofuels Development – BTL Diesel

Quality Characteristics of BTL diesel(100%)

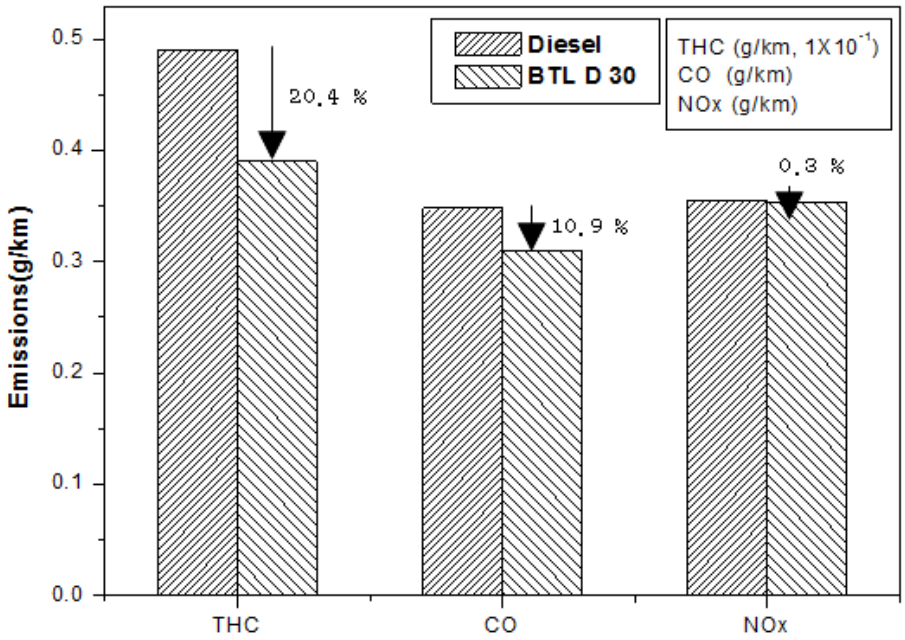
Classification	Unit	Standard	Diesel	BTL Diesel
Sulfur Content	mg/kg	10 Max.	6.4	1.7
Ash (Weight%)	wt.%	0.02 Max.	0.01 Max.	0.01 Max.
Cetane Number	-	52 Min. (winter : 48 min.)	51.9	68.6
Cetane Number (IQT*)	-	-	49.4	54.6
Copper Strip Corrosion	-	1 Max.	1 Max.	1 Max.
CFPP	℃	-16 Max.	-33.0	-17.0
Lubricity @60℃ (HFRR WSD)	μm	400 Max.	234	438
Density	kg/m^3	815 ~ 835	817	779
Polycyclic Aromatic Content	wt.%	5 Max.	1.0	0.2
Aromatic Content	Wt.%	30 Max.	18.7	4.1

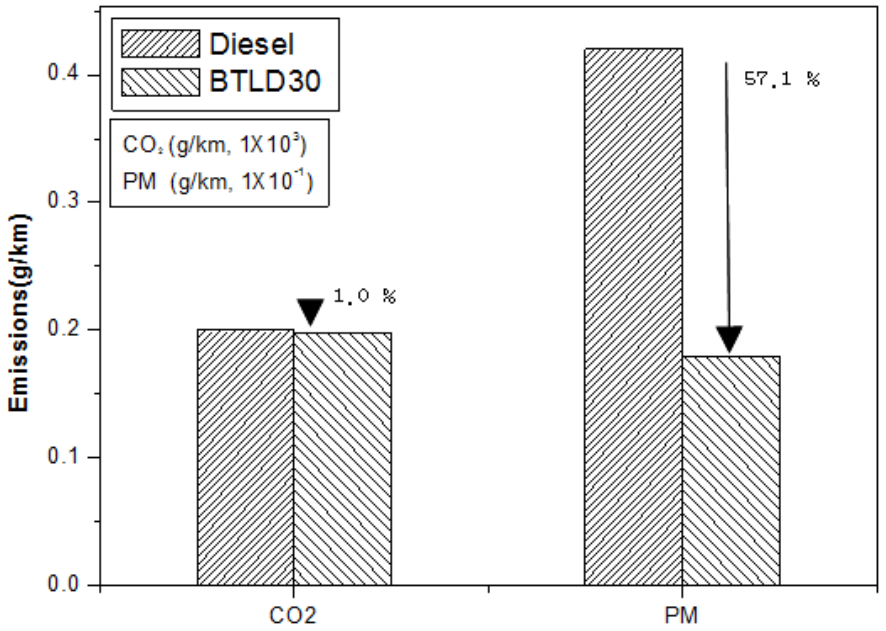
* Measured by IQT (Ignition Quality Tester)

- BTL diesel was within the limit by Korean specification except density because it has a low hydrocarbon number composition compared to conventional diesel.

Advanced Biofuels Development – BTL Diesel

- Vehicle Emission Test

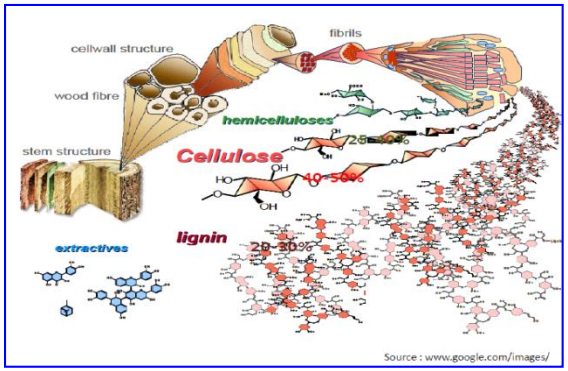




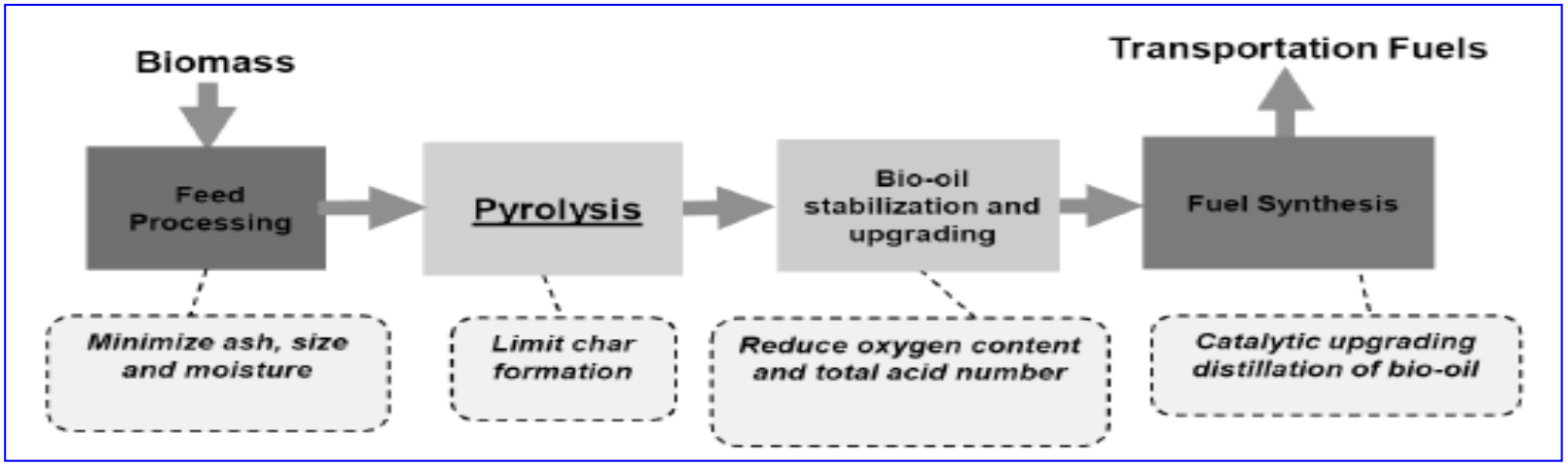
- Emissin of BTL diesel was within the limit by Korean specification and BTL 30 as a blending fuels reduced the emission with THC, CO, NOx and PM in vehicle test, compared to conventional diesel. Especially, PM of BTL 30 decreased by 57% compared with conventional diesel.

Advanced Biofuels Development – FPBO

- Fast Pyrolysis Bio-oil(FPBO) production scheme from biomass



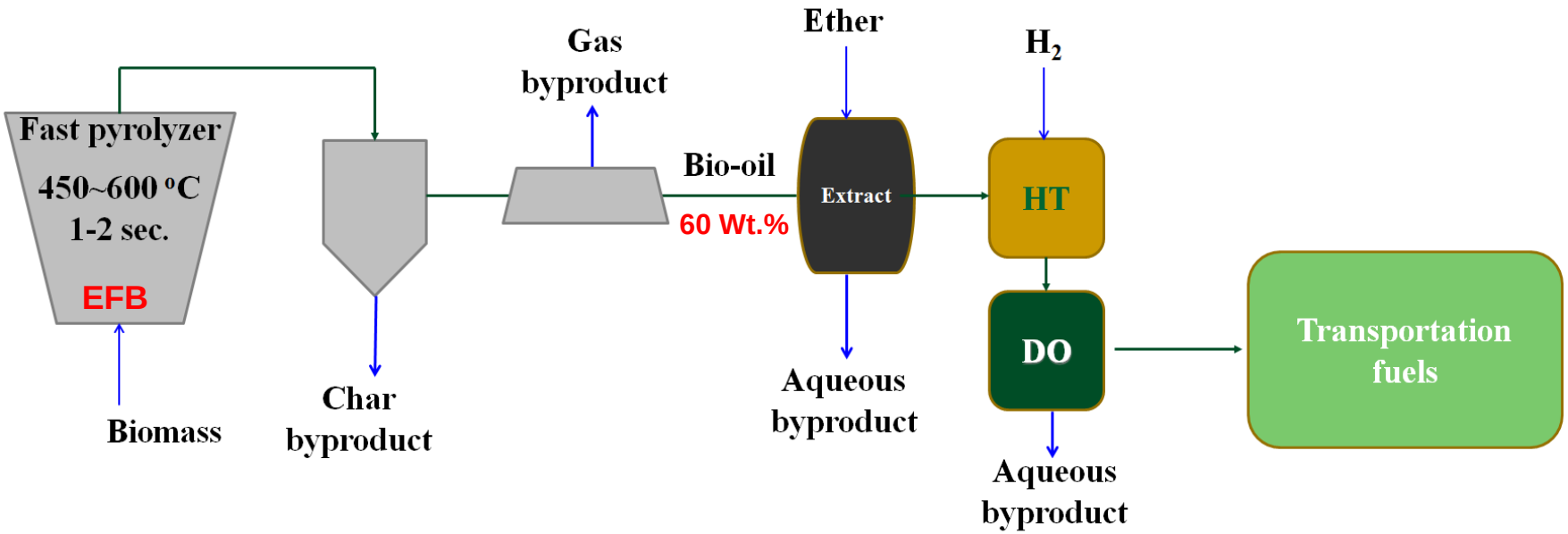
Major constituents of lignocellulosic biomass and their molecular structures

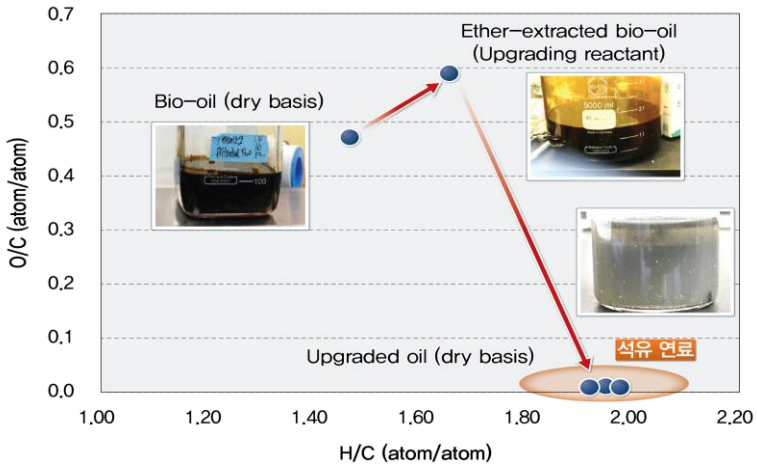


- In fast pyrolysis, bio-oil is produced by rapidly heating biomass to intermediate temp. 450 ~ 600 ℃ in the absence of any external oxygen followed by rapid quenching of the resulting vapor.

Advanced Biofuels Development – FPBO

- Transportation Fuel Development of Fast Pyrolysis Bio-oil(FPBO)





Bio-oil Production from Biomass in Korea

Fuel Properties of Fast Pyrolysis Bio-oil

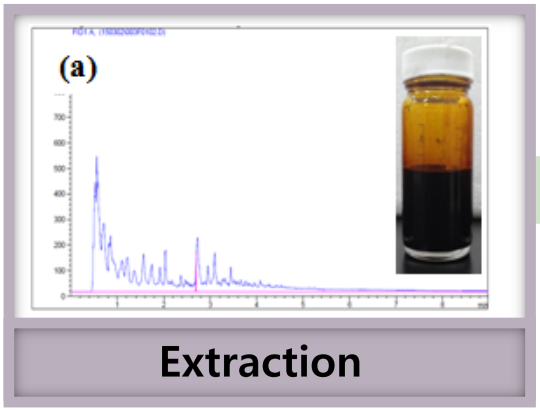
Item		Unit	Fuel Properties		
			ASTM D 7544 (for Burner)	Raw Pyrolysis Bio-Oil	Extracted Pyrolysis Bio-Oil
Gross heat of combustion		MJ/kg (kcal/kg)	Min. 15	16.80(4000.0)	21.98(5233.5)
Water content		Wt %	Max. 30	20.00	1 이하
Viscosity(40 ℃)		mm^2/s	Max. 125	72.49	16.77
Density (15 ℃)		kg/dm^3	1.1-1.3(20℃)	1177.1	1207.7
Sulfur content		Wt %	Max. 0.05	0.04	0.85
Ash		Wt %	Max. 0.25	0.11	0.02
Ph		mg KOH/g	Report	100.0	132.9
Pour point		℃	Max. -9	-22.5	-40
Composition	C	Wt %		36.0	53.5
	H			9.6	11.0
	O			51.2	34.5

* Pyrolysis Bio-oil was produced by DaeKyung Esco with Palm Empty fruit bunch(EFB) in BFB system at 450 ~ 500 ℃.

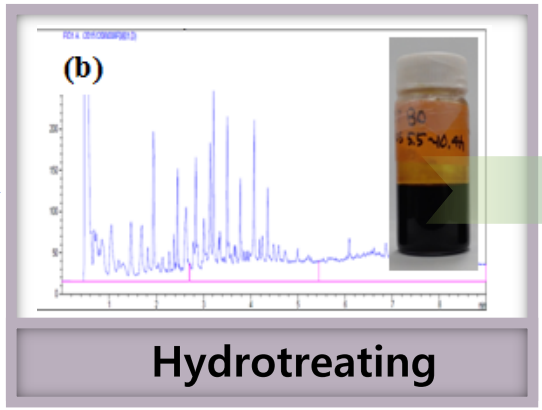
Bio-oil Production from Biomass in Korea

- **Transportation fuel from Fast Pyrolysis Bio-oil**

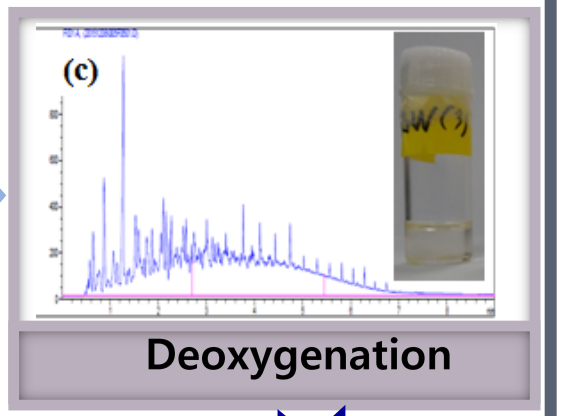
Upgrading oil (GC-FID)



Extraction

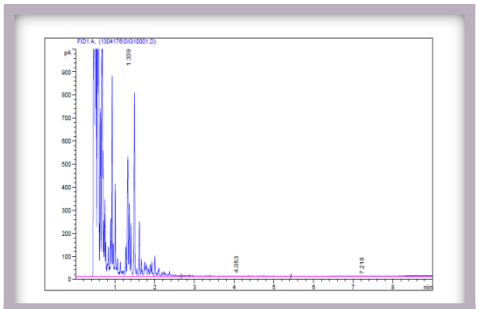


Hydrotreating

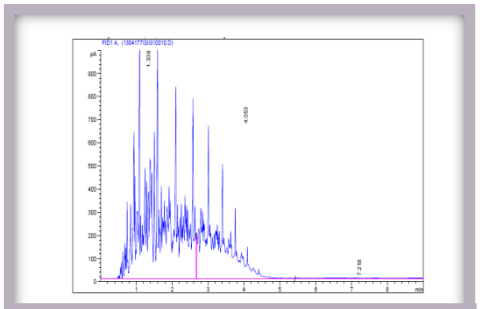


Deoxygenation

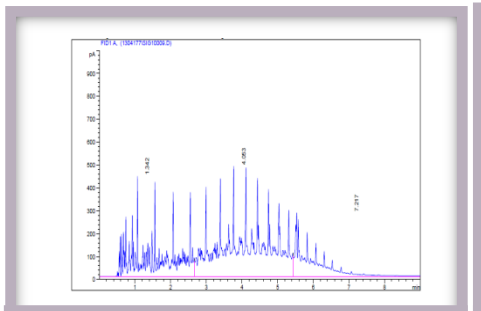
Comparison of Petroleum Products (GC-FID)



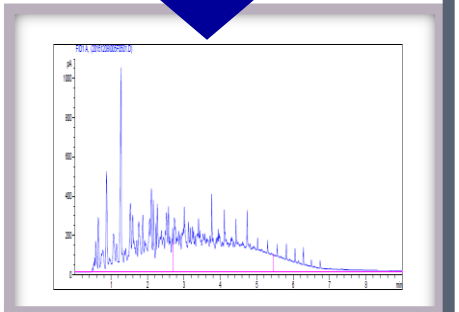
Gasoline



Kerosene



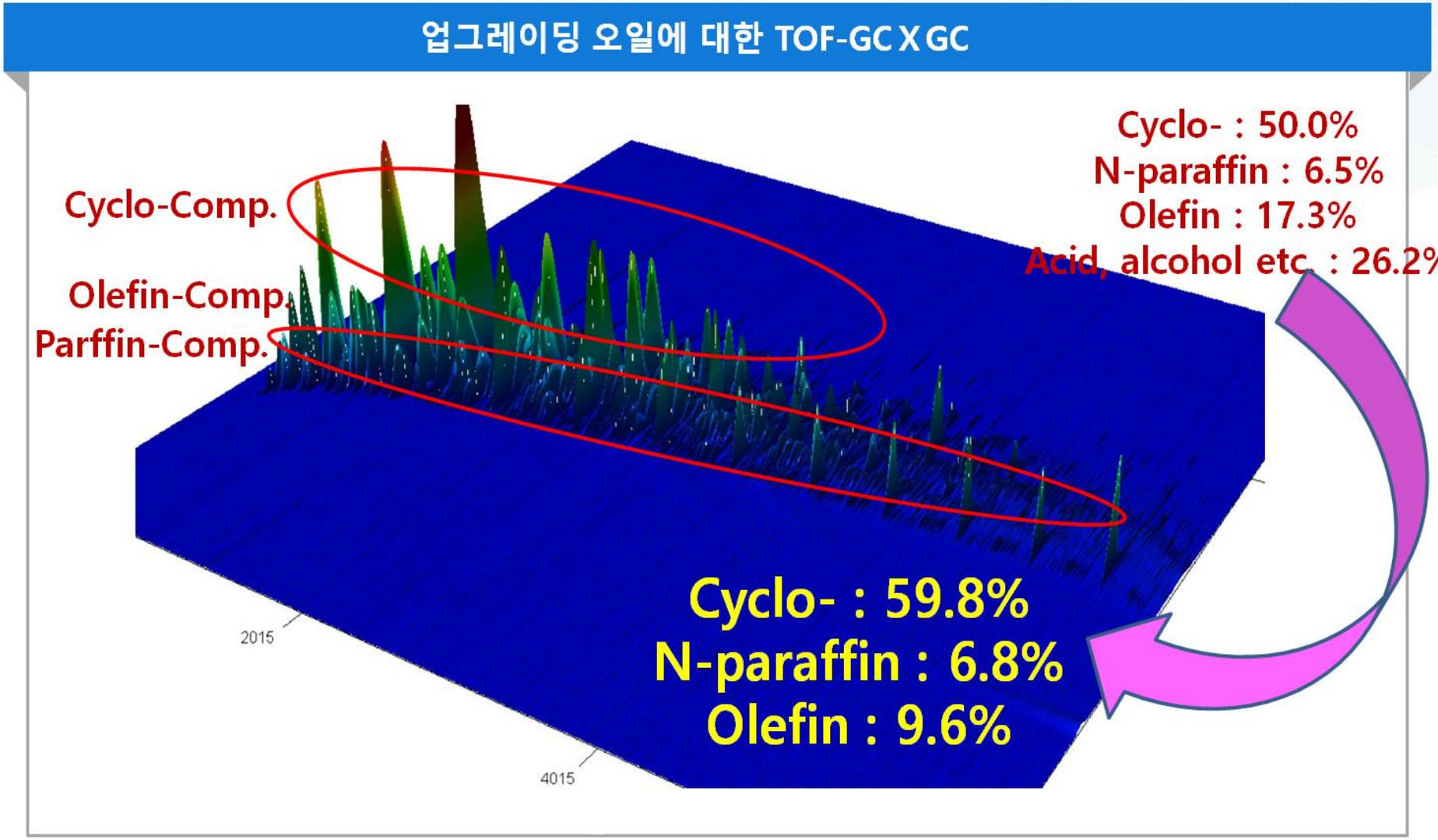
Diesel



Upgrading bio-oil

Bio-oil Production from Biomass in Korea

- **Transportation fuel from Fast Pyrolysis Bio-oil**



Bio-oil Production from Biomass in Korea

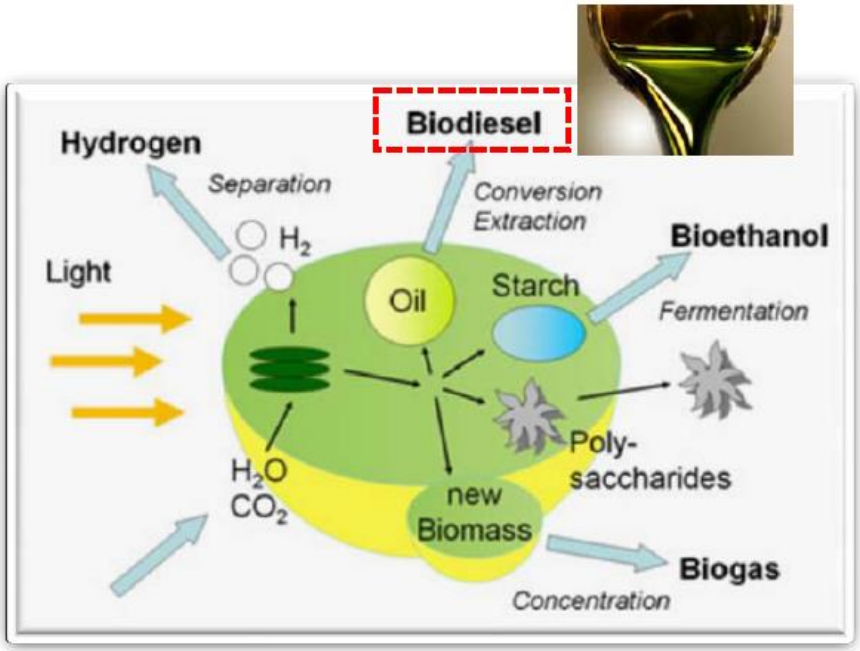
1) Studies on Physical & Chemical Characteristics
2) Lab-Scale Experimental; 1 kg/hr
3) Pilot Plant Experimental; 2 ton/day
4) Bio-Oil Upgrade Technologies

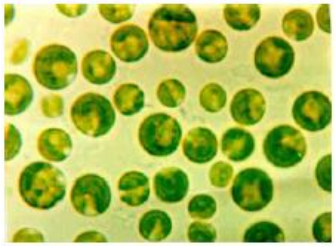
- **Developemnting of upgrading technology for transport fuel**
  (hydro-deoxygenation (HDO), Esterification, catalytic cracking)

Advanced Biofuels Development – Microalgae

- Advantages of Microalgal biomass

- High biomass productivity (vs. land crops)
- Non-food resource
- Use of non-productive, non-arable land and/or ocean
- Utilization of various water resources
- Reduced CO_2 release into the atmosphere
- Production of biofuels (e.g. biodiesel) and valuable co-products

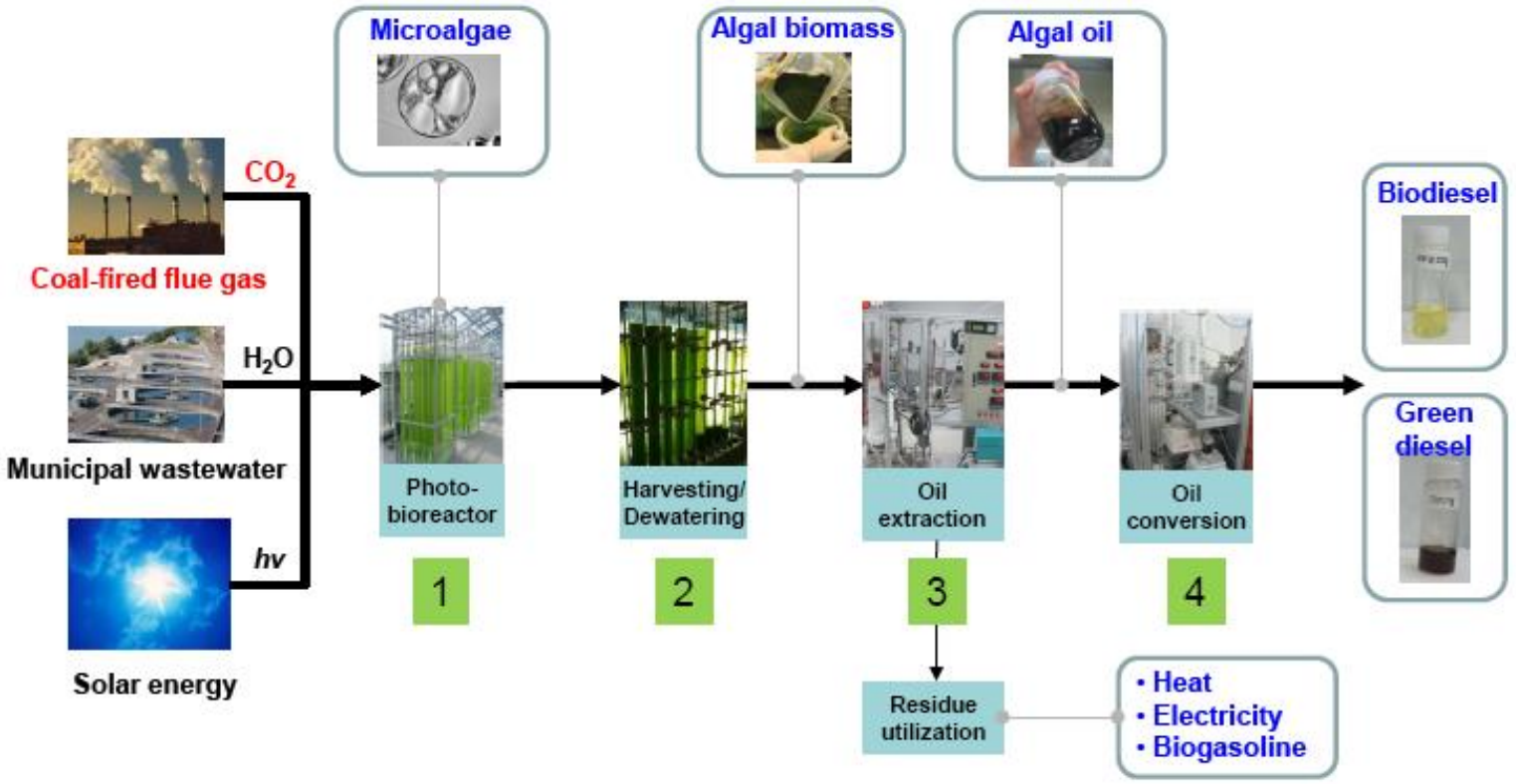




Microalga (*Chlorella*)

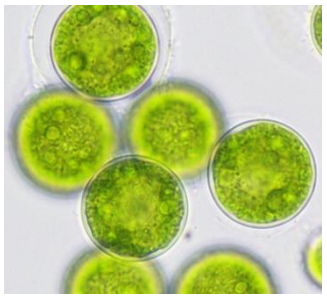
Advanced Biofuels Development – Microalgae

- **Microalgae biofuels is developing alternative diesel on basic research level in ocean and treated wastewater in Korea.**

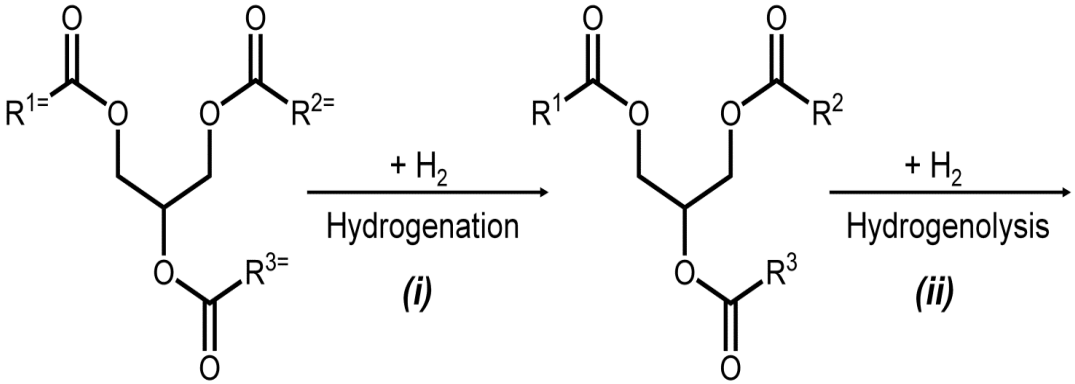


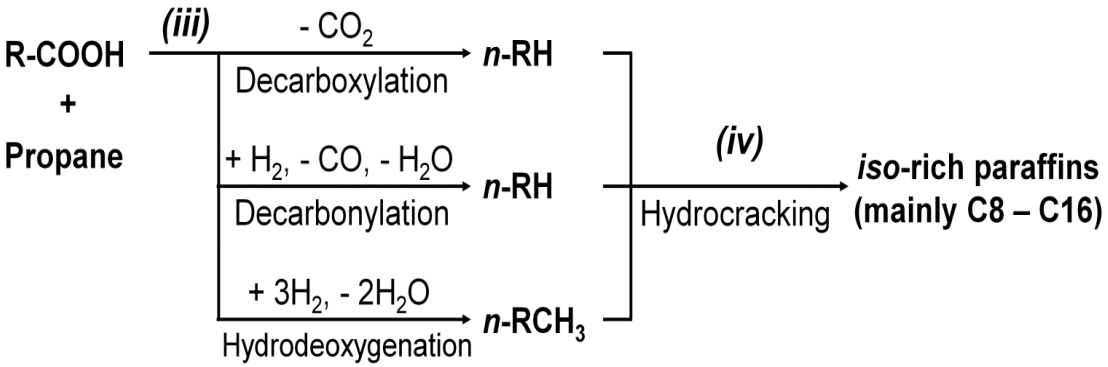
Advanced Biofuels Development – Biojet fuel

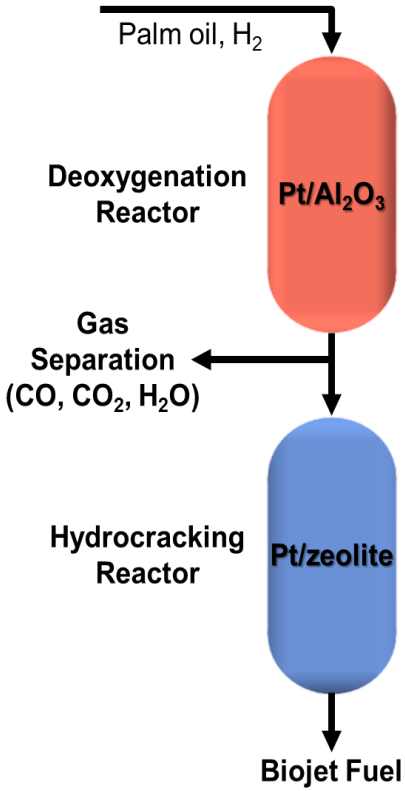
Palm oil



Microalgal oil







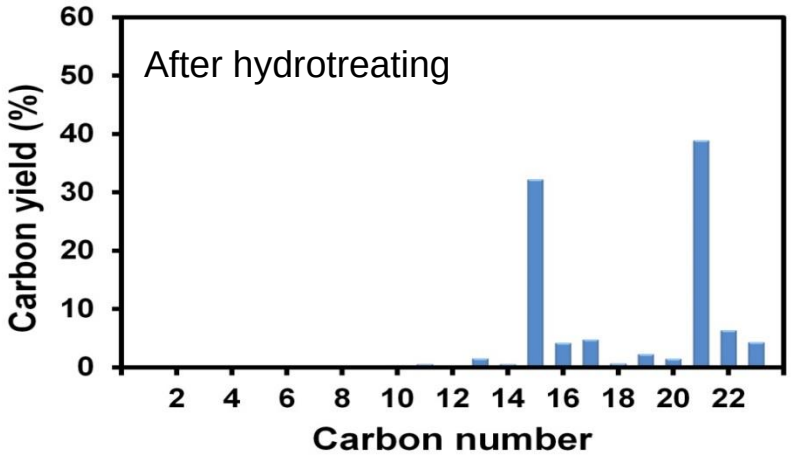
$R^{1=}$, $R^{2=}$, $R^{3=}$: Unsaturated alkyl chain

Methanation: $CO + 3H_2 \rightarrow CH_4 + H_2O$

M. Y. Kim, J.-K. Kim, M.-E. Lee, S. Lee, M. Choi*, ***ACS. Catal.***, 2017, 7, 6256-6267

Advanced Biofuels Development – Biojet fuel

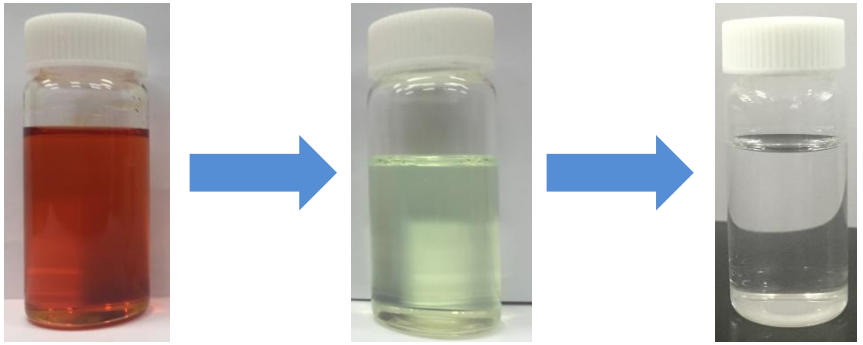
- Bio-jet fuel by HEPA process from Microalgae

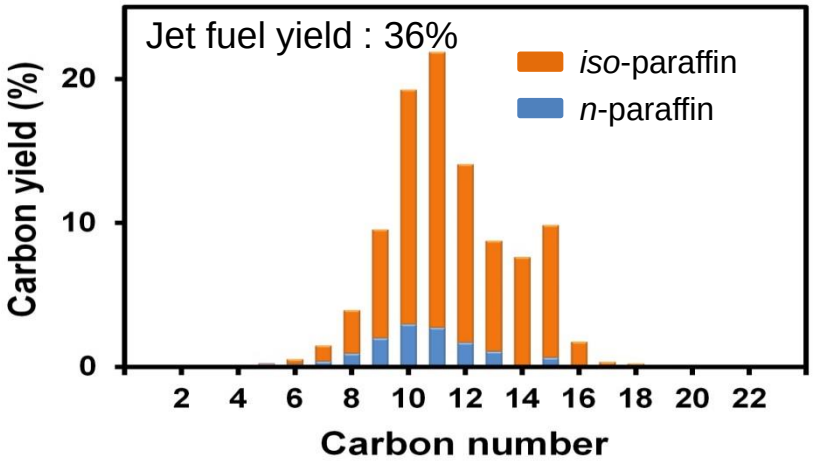


Aurantiochytrium oil

After Hydrotreating

After Hydrocracking





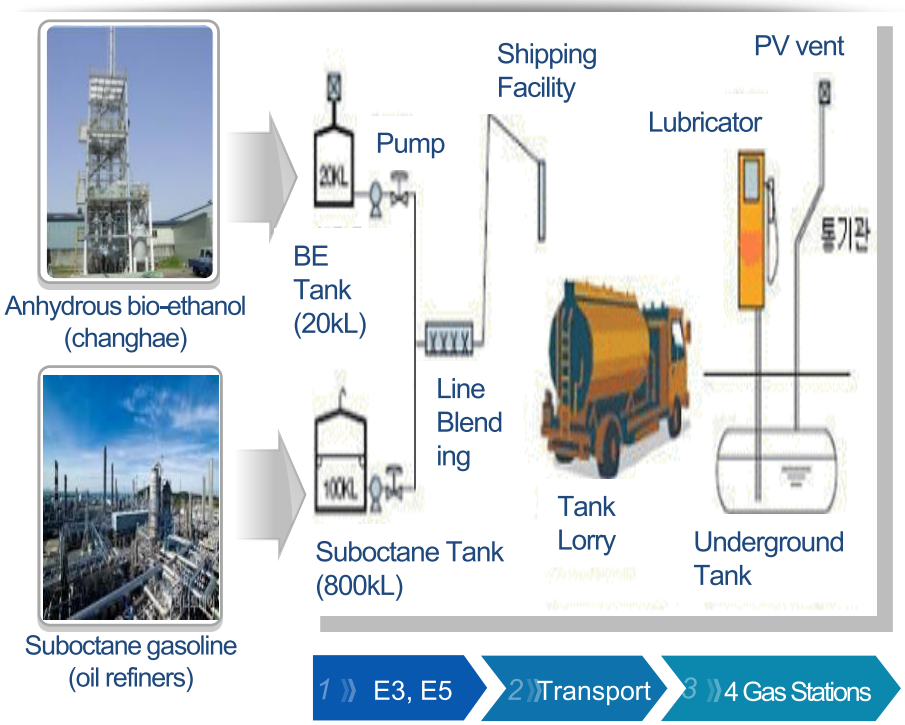
Property	Biojet fuel	Jet A-1 (ASTM D7566)
Density (at 15 °C, kg/m^3)	755.8	730 ~ 770
Freezing point (°C)	-63	< -47
Sulfur (mg/kg)	< 1	< 15
Net heat of combustion (MJ/kg)	47.2	> 42.8

P_{H_2} = 20 bar, Temperature = 250 °C, H_2/hydrocarbon = 100 (mol/mol), WHSV = 2.0 h^{-1}

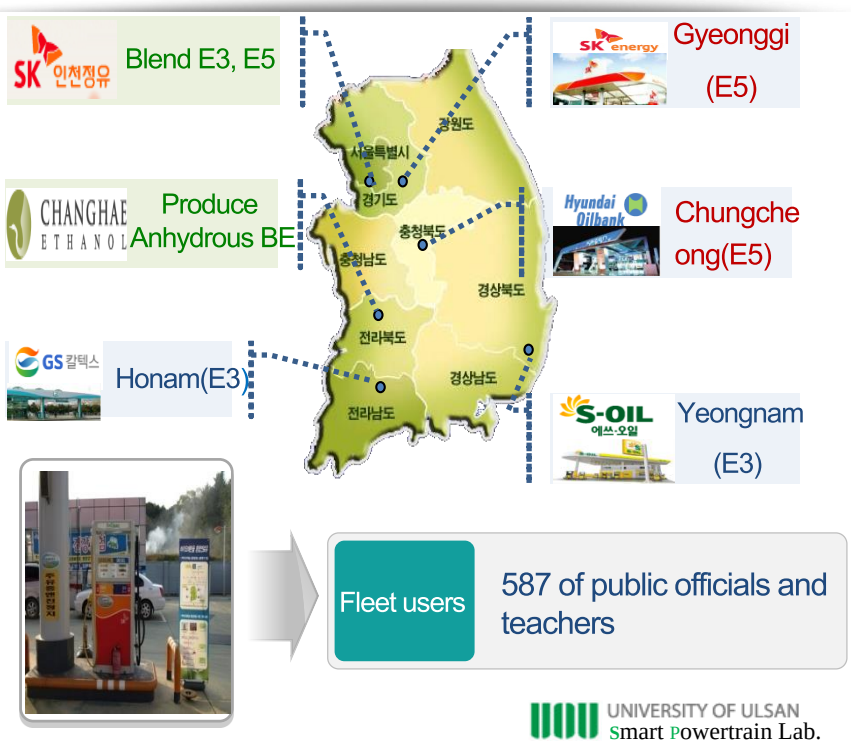
Status of Bio-ethanol Industry – feasibility study

- **Feasibility study** for the implementation of bio-ethanol as fuels in Korea(2005.7~2005.12, KIER)
- **Actual Assessment Study** on domestic infrastructure was conducted (2006.8~2008.7, Kpetro)
  - Found that the bio-ethanol blended fuels(E3, E5) are possible to introduce in Korea
  * Participants : Kpetro(supervision), 4 oil fineries(SKE, GS-Caltex, HD-Oilbank, S-OIL), 1 alcohol company(changhae ethanol)

Distribution Infrastructure (production/transport/use)



Gas Stations



Status of Bioethanol Industry – R&D

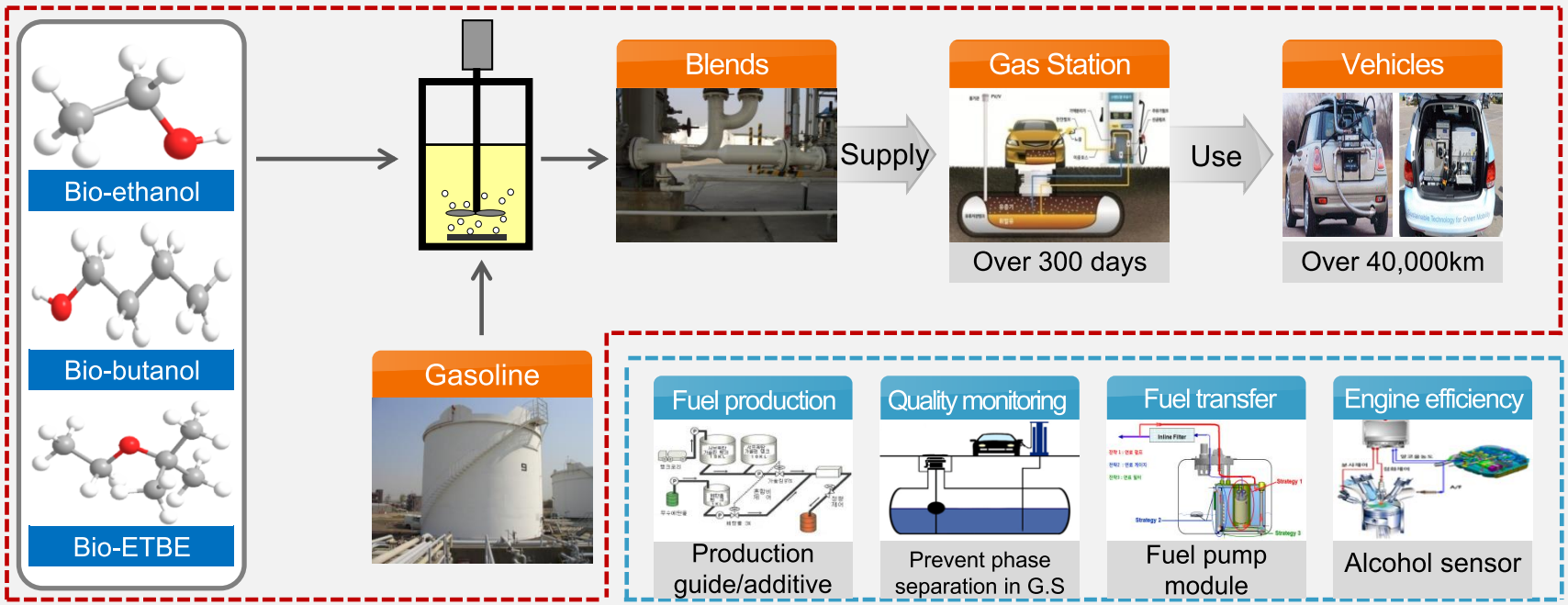
- Supported by MOTIE(2016.5 ~ 2019.4 (3 years))

  * Participants : Kpetro (management), GS-Caltex, Changhae, KATECH, COAVIS, SNU

Goal

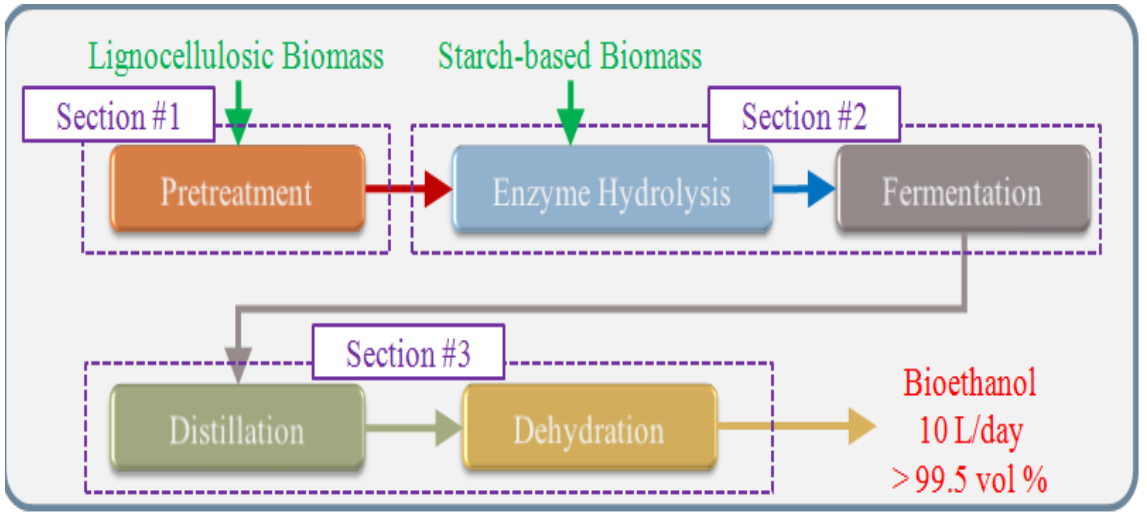
- ✔ Development of distribution technologies for introducing bio-alcohol in Korea
- ✔ Development of element technologies for introducing bio-alcohol in Korea

Main works



Bench-Scale Plant of Bioethanol from Lignocellulosic Biomass

- The 1st bench-scale bioethanol production plant (100 kg/day) was constructed and operated in Korea; 163 L-ethanol/ton of *Miscanthus.*



<Bioethanol production plant of Changhae Corp.>
(Pretreatment, hydrolysis/fermentation, and purification facility)

Status of Biogas Industry – Infrastructure

- During the research for the utilization of biogas as road transport, various recent governmental initiative and plan were found.

⇒ Biogas has high potential biofuels in Korea

⇒ Upgrading and highly concentrated fuel technology(CBG, LBG)

⇒ Biomethane from biogas can be used as for natural gas vehicle(NGV) in Korea

<Biogas Plant>

<Biomethane gas station>

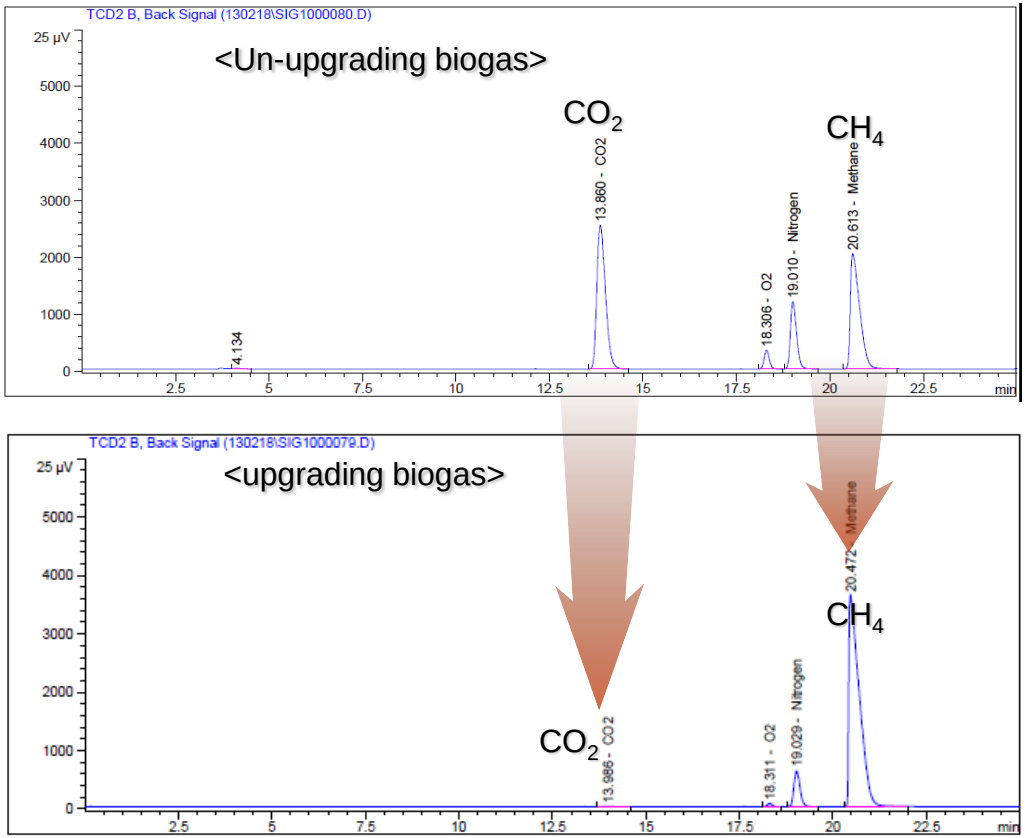
Status of Biogas Industry – Biomethane

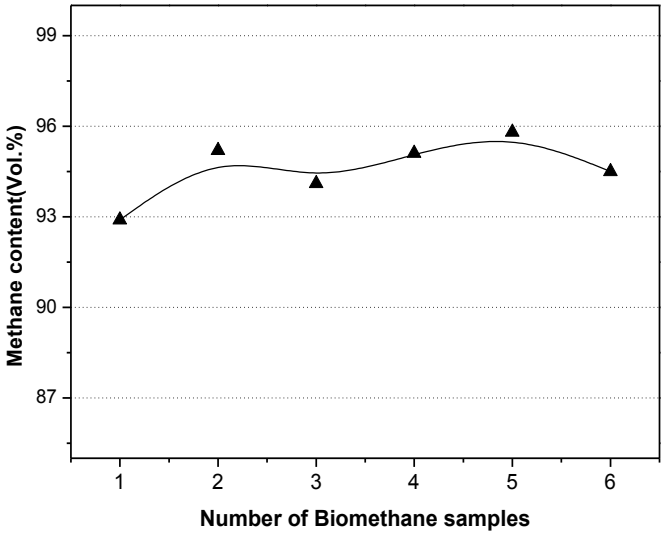
- Biomethane(BM) production plants(8 sites) for transport fuel in Korea

Company	Fuel type	Capacity (Nm^3/d)	Upgrading Process	Plant area
KOGAS / HYUNDAI ENGINEERING & CONSTRUCTION	Transport fuel	4,000 Nm^3/d	VPSA	Wonju sewage plant
Potlatch	Transport fuel	26,000 Nm^3/d	RPSA	Daegu sewage plant
Hansol 한솔이엠이	Transport fuel	4,800 Nm^3/d	RPSA +Cryogenic	SL Corp.
HALLA Halla Energy & Environment	Transport fuel	14,400 Nm^3/d	RPSA	SL Corp.
ECO ENERGY HOLDINGS	Transport fuel (city gas 80%)	5,040 Nm^3/d	PWS	Seonam sewage plant
ECO ENERGY HOLDINGS / 경남에너지주식회사 KYUNGNAM ENERGY CO., LTD.	Transport fuel (city gas 80%)	10,000 Nm^3/d	PWS	Changwon Duckdong sewage plant
HALLA Halla Energy & Environment	Transport fuel	14,400 Nm^3/d	RPSA	Busan suyoung sewage plant
KRICT	Transport fuel	1,440 Nm^3/d	Membrane/PSA	SL Corp.

Biogas Application for Transport Fuel in Korea

- Biomethane composition of upgrading biogas plant in wonju sewage works





- After upgrading biogas, biomethane showed 93% ~ 96% of CH_4 composition by PSA process as an upgrading technology.

Biogas Application for Transport Fuel in Korea

- **Test Fuels**

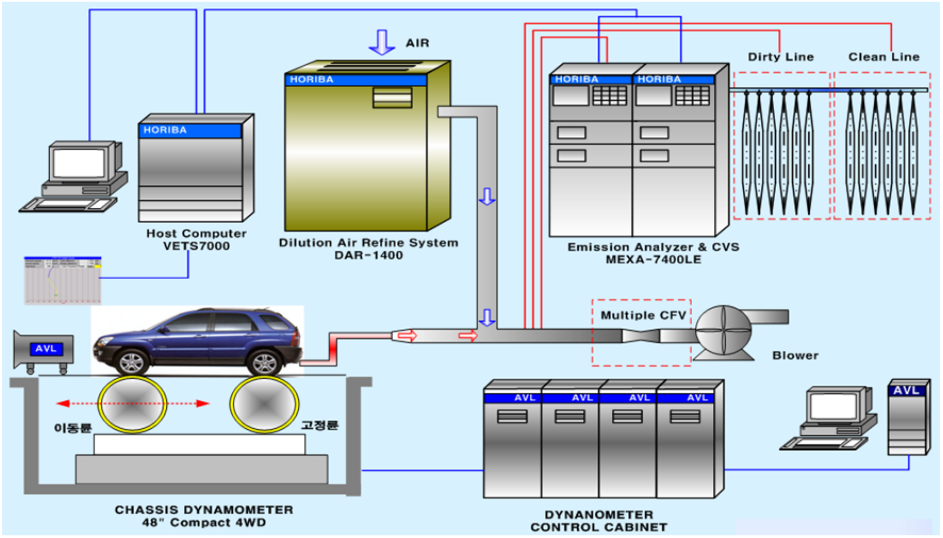
Properties	Test Fuels	
	CNG	Biomethane
Methane content (vol%)	**90.7**	**95.5**
Ethane (vol%)	5.4	0.8
C_3 Hydrocarbon (vol%)	2.5	0.1
C_6 Hydrocarbon (vol%)	-	-
Sulfur content (ppm)	2.1	1.8
$CO_2+O_2+N_2$ (vol%)	1.4	3.6
CO_2 (vol%)	-	3.0
O_2 (vol%)	0.1	0.1
N_2 (vol%)	1.3	0.5

- **For emission test, test fuels used biomethane 100% with 95.5 vol% of CH_4 content to be produce wonju sewage works compare with commercial CNG.**

Biogas Application for Transport Fuel in Korea

Biomethane Emission Test mode & scheme

- CVS-75(FTP-75) mode
- HWFET mode (Highway fuel economy cycle)
- Emission : CO, NMHC, NOx, CH_4, CO_2, THC



<Test Scheme>

- Emission of CO, NMHC, NOx, CH_4, CO_2, THC and fuel efficiency were measured every 10,000 km driving.

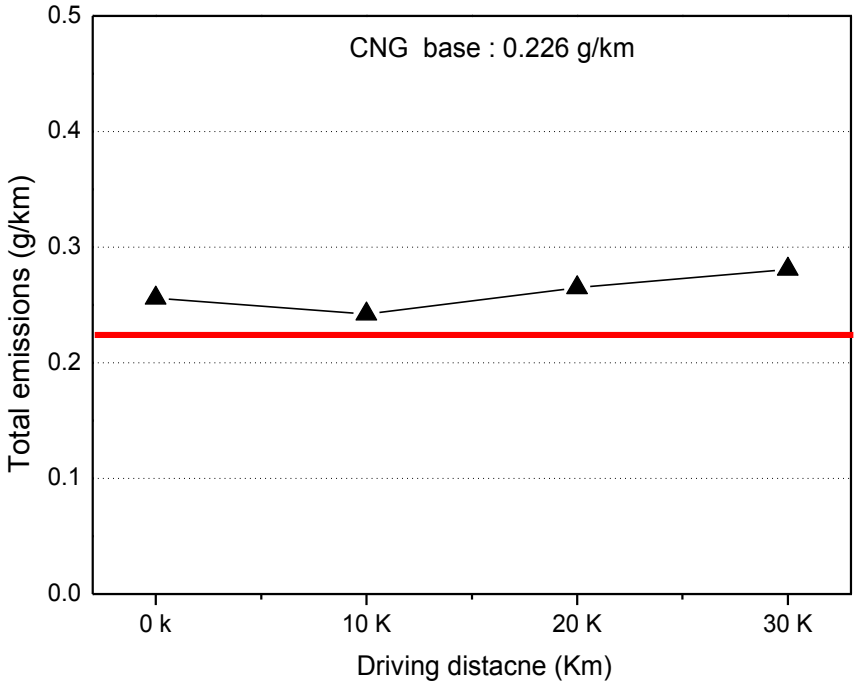
Test vehicle

Biomethane mapping

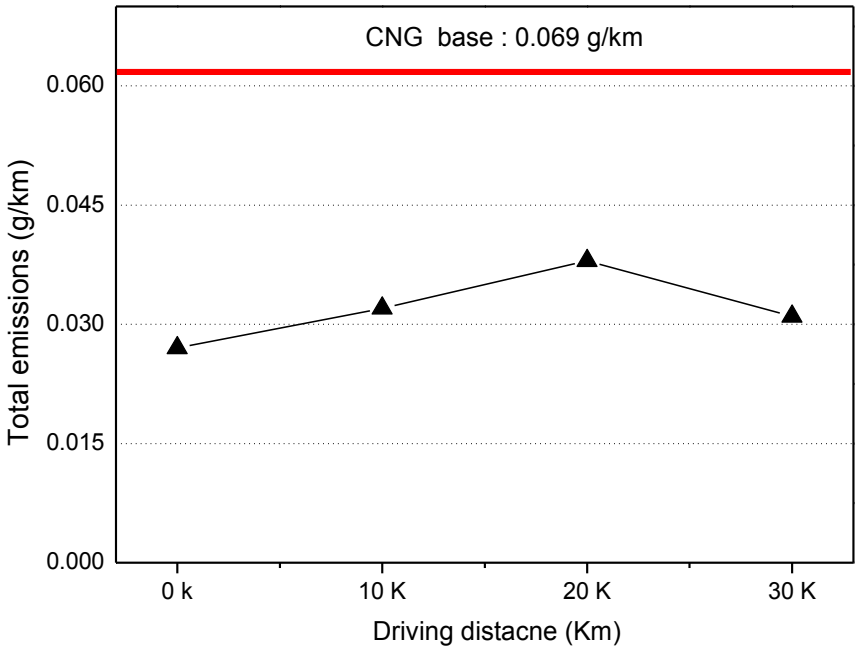
<Test biomethane vehicle with modified LPG car>

Biogas Application for Transport Fuel in Korea

Emission Characteristics (Biomethane vehicle with modified LPG vehicle)



<CVS-75 mode>

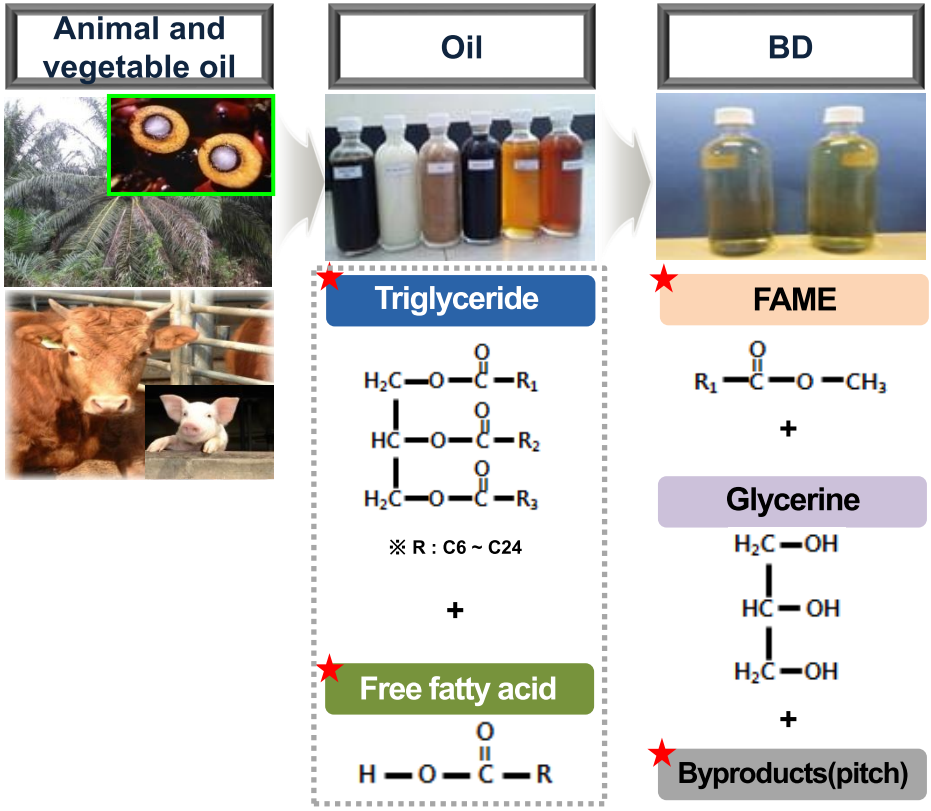


<HWFET mode>

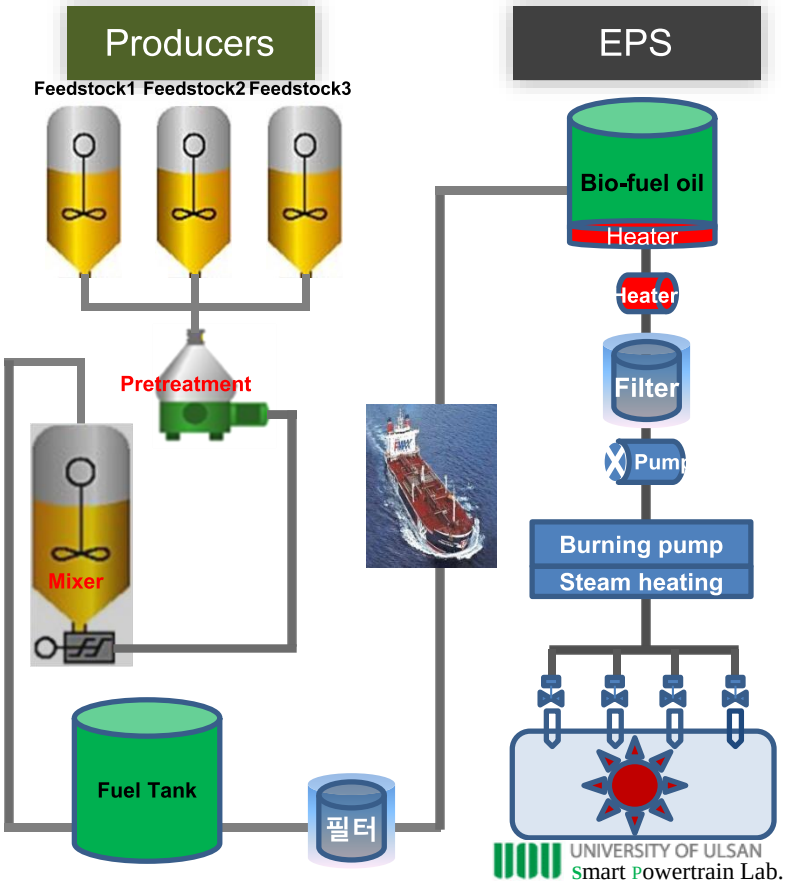
- **Test biomethane vehicle with modified LPG car was low total emission in HWFET mode, comparing with commercial CNG.**

Status of Bio-Power fuel for Electricity

- Main feedstocks are Palm oil(RBD, PS), palm byproducts(PFAD, PAO), byproducts of biodiesel production process(BD Pitch), animal fat, cashew nut oil(CNSL), etc.
- Produced by refining and blending various feedstocks to meet its specifications.



(Main component of bio-fuel oil)



Main feedstock

Palm oil series

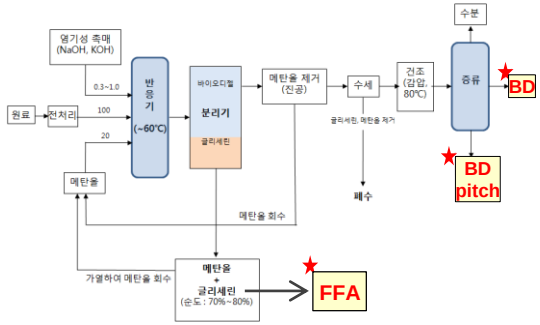
- ✓ **CPO (Crude Palm oil)**
  : Crude palm oil extracted from palm seed
- ✓ **RBDPO**
  : Refined palm oil(degumming, bleaching, deodorization)
- ✓ **PS (RBD stearin)**
  : More saturated oil separated from RBD
- ✓ **PO (RBD olein)**
  : More unsaturated oil separated from RBD
- ✓ **PAO (Palm Acid Oil)**
  : Oil on waste water(pond) from the process of palm oil extraction.

Animal Fat

- ✓ The oil extracted by crushing, steam heating, refining residues from slaughter house and meat shop

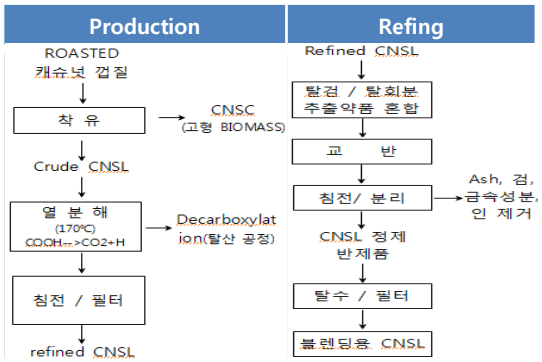
Biodiesel series

- ✓ FAME produced by reacting oils with MeOH
- ✓ Distillation residue of BD production process



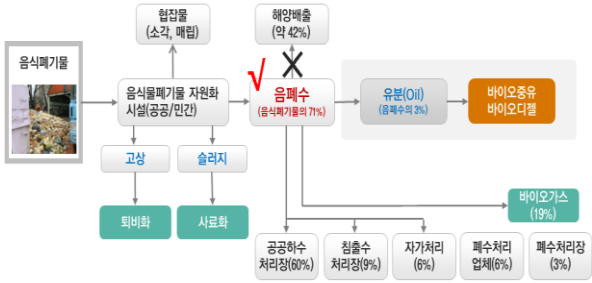
CNSL (Cashew nut shell liquid)

- ✓ The oil extracted by compression, pyrolysis, refining from Cashew nut shells



Food waste oil

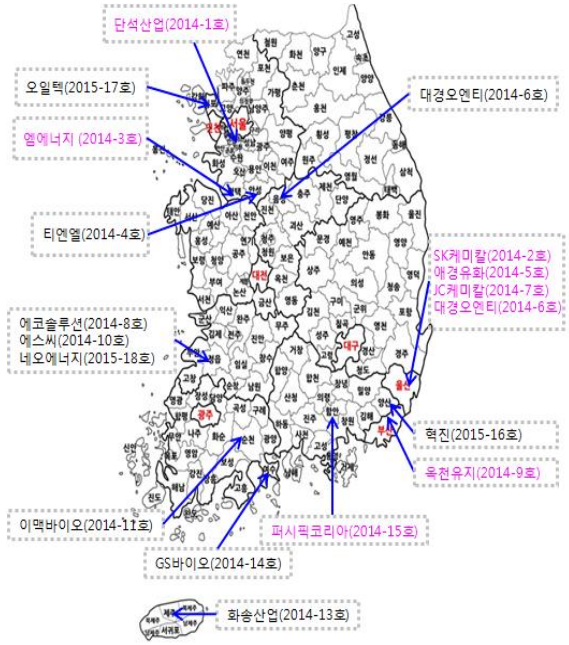
- ✓ The oil collected from waste water of food waste disposal facilities



Status of Demonstration Business

- Business Period : 1 Jan. 2014 – 31 Dec. 2018
- EPS : 4 Power suppliers(jungbu/seobu/nambu/dongseo) and KDHC
- Fuel suppliers : 22 companies are registered and about 350,000kL of bio-fuel oil was supplied in 2015 (supplied by 8 companies)
- Quality Inspection : After initial inspection, monthly and random inspection will be carried out by Kpetro

		Jungbu	Seobu	Nambu	Dongseo	KDHC
Power generators		Jeju Steam power No. 3 (75MW)	Pyeongtaek Steam Power No. 1 (350MW)	South Jeju Steam Power No. 1 (100MW)	Ulsan Steam Power No. 6 (400MW)	Daegu CHP (43.5MW)
Designated date		'14.2.20	'14.2.20	'14.2.20	'14.2.20	'14.6.23
Blending ratio		100%	10~20%	100%	10~20%	10~20 %
Supply (kL)	2014 (179,353)	73,582	1,627	94,061	10,083	-
	2015 (354,495)	110,856	4,958	176,574	61,412	695
	2016 estimate (332,000)	120,000	4,500	170,000	30,800	6,700



Major Benefits of EPS

✓ Secure REC for RPS

		2014	2015	2016
Obligation amount	REC (MWh)	11,577,565	12,375,282	15,081,284
Bio-Power Fuel	REC (MWh)	529,097	1,157,725	1,489,957
	Ratio(%)	4.6	9.4	9.9

✓ GHG (CO2) Reduction

	2014	2015	2016
The amount used(kL)	179,353	347,116	443,618
CO_2 reduction(ton)	452,830	876,398	1,120,047

✓ Save environmental cost by decreasing emission gases(SOx, Nox)

	SOx(ppm)			NOx(ppm)			비고
	Control Limit	Fuel oil	Bio-fuel oil	Control Limit	Fuel oil	Bio-fuel oil	
Jungbu	150	138	0	140	111	110	No need deNOx, deSOx facilities
Nambu	70	21	8	70	47	57	No need deSOx facilities

Contents

Seminar on bio-oil for power generation

Summary

Biofuels		Application	Alternative fuels	R&D Status	Organization	Policy
Solid	Wood Pellet	Heating/Power	-	Commercial	-	RPS, RHO
Liquid	Bioethanol	Transport	Gasoline	Applied R&D	-	RFS
	BioETBE	〃	〃	Applied R&D	-	RFS
	Biobutanol	〃	〃	Applied R&D	GS Caltex	RFS
	F-T gasoline	〃	〃	Applied R&D	-	RFS
	Biodiesel	〃	Diesel(2.5%)	Commercial		RFS
	HBD	〃	〃	Applied R&D	SK Innovation	RFS
	F-T diesel(BTL)	〃	〃	Applied R&D	KRICT	RFS
	BioDME	〃	Diesel/LPG	Basic R&D	KOGAS, IAE	RFS
	Fast Pyrolysis Bio-Oil (FPBO)	Transport/Power	Diesel/B-C	Applied R&D	Daekyung ESCO	RFS
	Pure Vegetable Oil(PVO)	Agricultural machine	Diesel/Heavy oil	Applied R&D	RDA	RPS
	Bio-Power fuel	Heating/Power	B-C	Demonstration	K-Petro	RPS, RHO
	Bio-Jet fuel	Transport	Jet fuels	Applied R&D	KRICT	RFS
	Microalgal biofuels	〃	Diesel/Jet fuel	Basic R&D	KIER, Inha Unv. KAIST etc.	RFS
Gas	Biogas(CBM)	City gas/Transport	CNG	Partialy commercial	Ea	RFS

Thank you