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Study on Future Trend of Marine Fuel and Effective Utilization from the Viewpoint of Fuel Injection & Combustion Technology

Maritime Innovation Japan Corporation
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Influence Factor on Future Trend of Marine Fuel

Examination from the standpoint of fuel supply	Examination from the standpoint of environment preservation	Examination from the standpoint of fuel injection & combustion technology
How does the availability of marine fuel change to be content with market needs?	How does the future direction of marine fuel change from the viewpoint of emission reduction?	What should marine fuel be form the viewpoint of unsteady combustion like diesel engine?
		Do you think that marine fuel with uniform properties and state is best fuel?

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Characteristics of Future Oil Market

- **Worldwide oil consumption will grow gradually.**
- **Worldwide oil production is predicted to decline after 2020.**
  〔Reason〕①Conventional oil discoveries have been declining for the last 50 years.
  ②Energy injected in the process is increasing.
  ＊）The process means the life cycle from oil mining to oil refinement
- **Serious conflicts are most likely.**
- **Prices of oil products will increase gradually.**
- **Sulfur regulation will influence the properties of fuel.**

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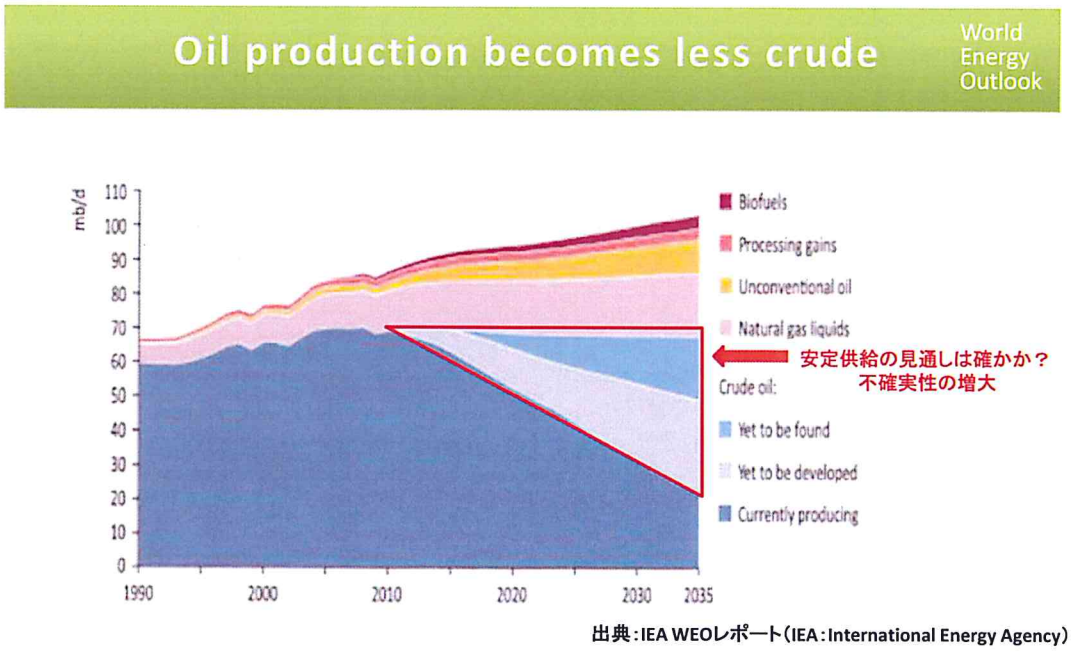
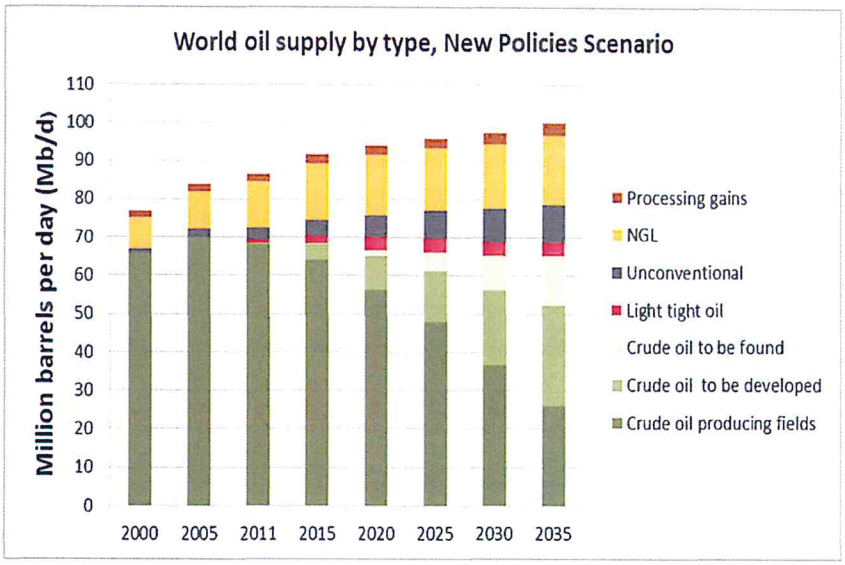
IEAのWorld Energy Outlook



出典：IEA WEOレポート（IEA：International Energy Agency）

World oil supply by type, New Policies Scenario



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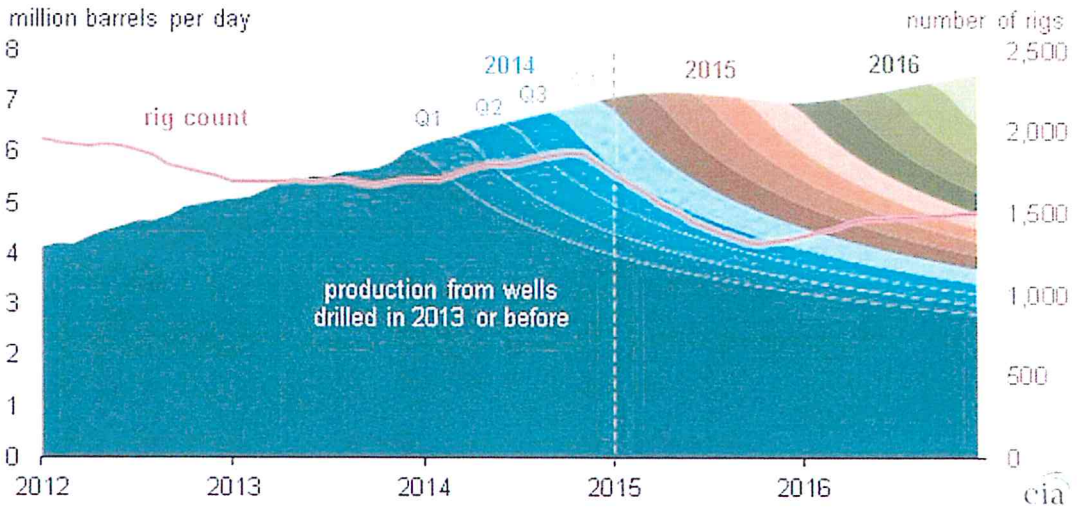
Monthly oil production and rig count in the Lower 48 states, 2012-16



Source: U. S. Energy Information Administration, January *Short-Term Energy Outlook*
Note: Graph does not include production from Alaska and the Federal Gulf of Mexico

出典：EIAレポート

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Emission Reduction by Fuel Change

NOx
- Emulsified Fuel (Fuel-Water Emulsion)
- Water Injection (Stratified Fuel/Water Injection / Direct Water Injection)
- Gas Fuel (Lean Burn System)

SOx
- Low Sulfur Fuel (Marine Gas Oil, Low Sulfur HFO)
- Gas Fuel (LNG, GTL)
- Alternative Fuel (Biofuel, Methanol, DME, ----)

CO_2(GHG)
- Gas Fuel (LNG, GTL)
- Hydrogen
- Biofuel

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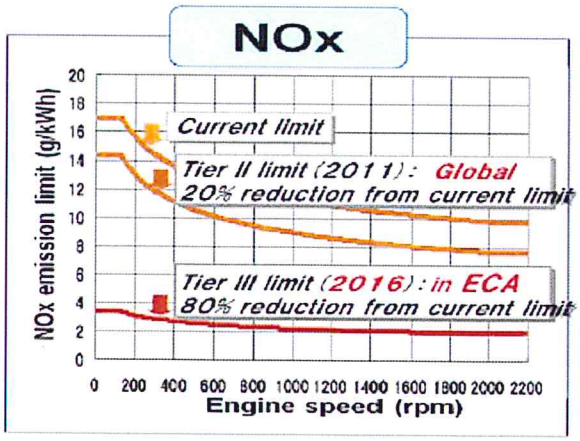
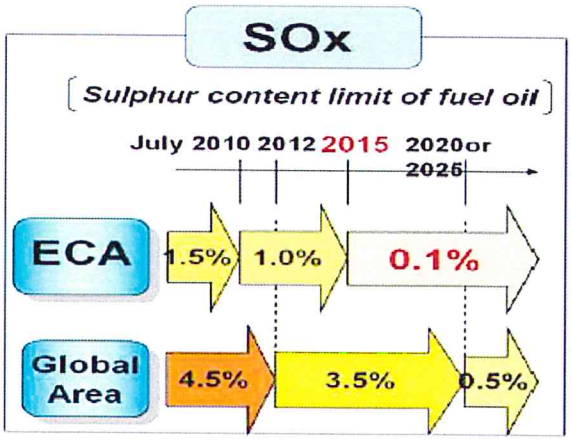
Regulations for the prevention of air pollution from ships NOx





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Countermeasures against sulfur regulation

1. MGO:

Marine engines will burn low-sulfur marine gas oil.

ECA : 0.1%　Fuel switching for ECAs

Global Area : 0.5%　Uncertainty

2. HFO ＋ Scrubber:

On many ships heavy fuel oil can be burnt, as exhaust gas cleaning systems reduce SOx emissions by more than 90%.

3. LNG:

LNG is an alternative option for ships with dual-fuel engines.

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Distillates(MGO) will significantly increase in price.

- Shortage of marine low-sulfur fuels（S:0.5%） is foreseen.
- Distillate fuels will have to compete with road transportation fuels.
- Refinery investments (S : 0.5%) are uncertain.
- Distillates will increase energy use in the refinement process.

(Life Cycle Analysis : Well to Tank)

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Scrubbing technology seems the better strategy.

- **Avoidance of expensive distillate fuels usage**
- **Future management for the 0.5% Global Cap**

Fuel oil with 3.5% sulfur will retain a role as onboard scrubbing become a viable option for owners.

Alternative Fuels or Sustainable Energy

Alternative Fuels :

- **Biofuels** ① Supply ・・・ Limit to the amount
  ② Higher than the cost of fuel oil
  ③ Long-term storage problems
- **GTL** Viable in the near future ・・・ Liquid fuel for marine use
- **Hydrogen** Viable in the future

Sustainable Energy :

- **Solar** Very minor possibility on marine
- **Wind** Effective Challenging issues : Reliability etc.
- **Nuclear** Available (Marine technology exists)・・・Public acceptance
- **Fuel Cells** Issues : Low energy density for marine uses

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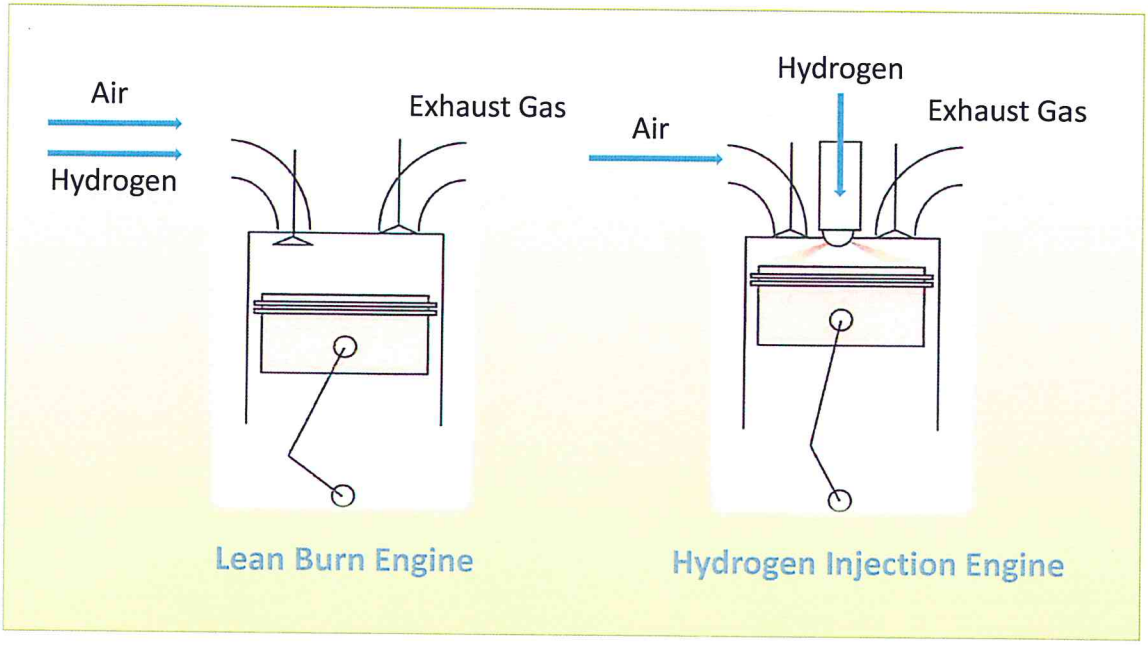
Hydrogen Engine System



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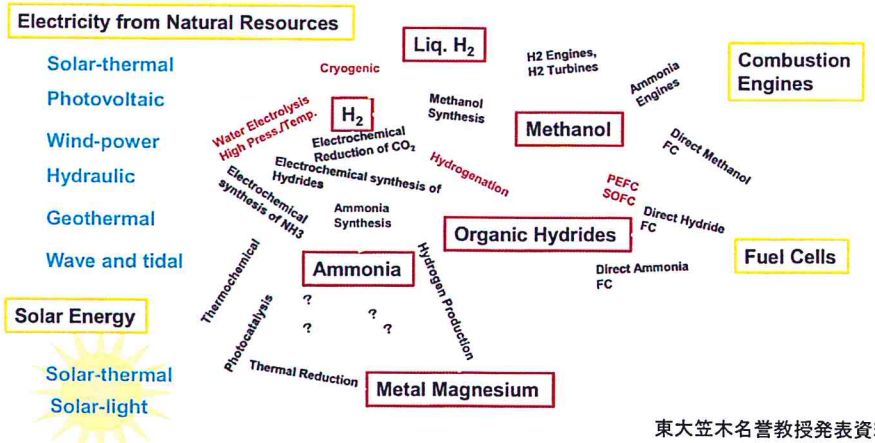
Renewable Energy Carriers for Transportations, Storages, and Utilizations

1. For international and intercontinental transportations
2. For leveling of natural energy in local regions
3. For house energy systems



東大笠木名誉教授発表資料より引用

Will the production of residual fuel oil supply the demand for marine fuel oil in the future?

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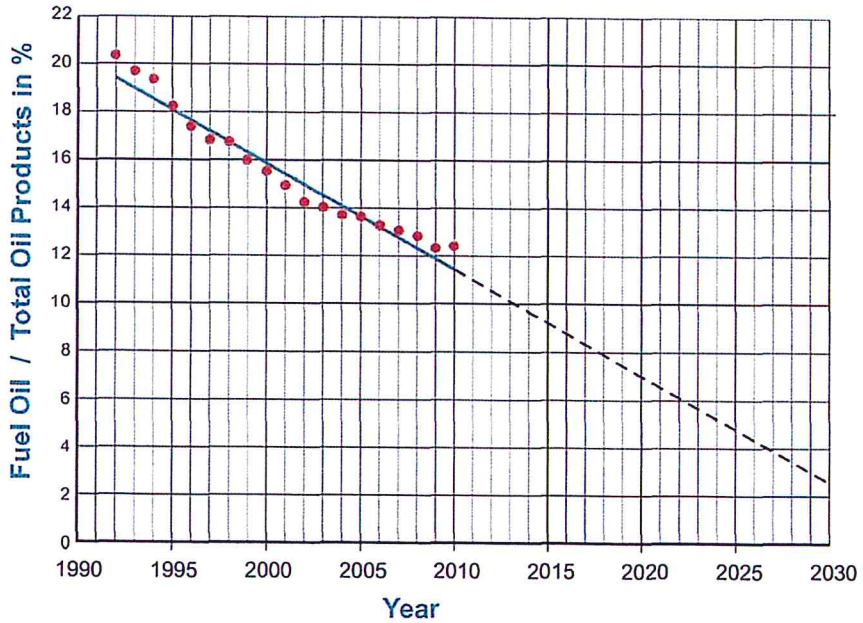
Residual Fuel Oil as a Percentage of all Oil Products

(BP Statistical Review 2010)



出典：ハンブルク工科大学Rulfs教授講演資料

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Chart 1- Demand Shifting from Residuals Distillates

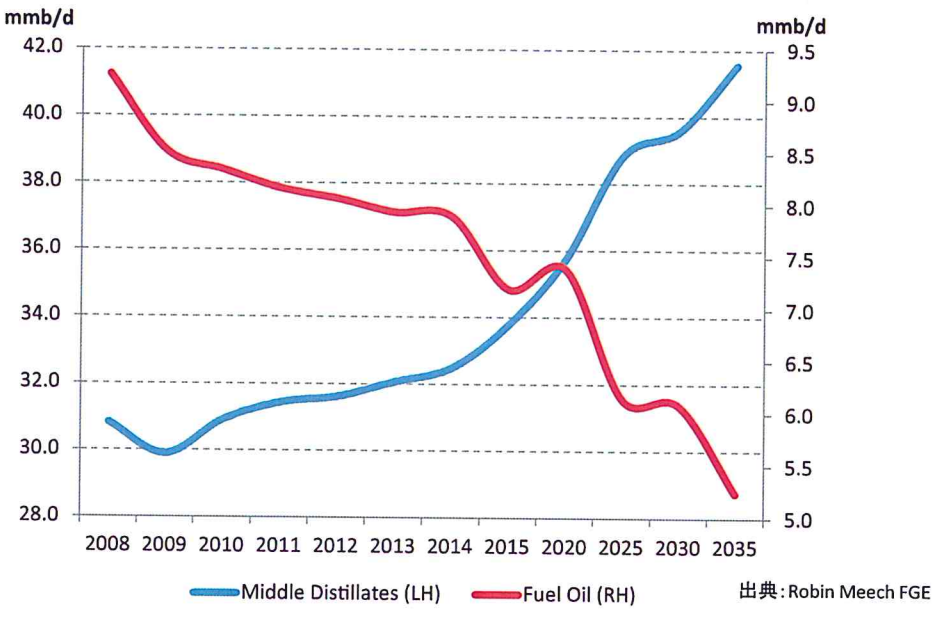

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Chart 2- Can Refinery Investment Meet the Challenges?

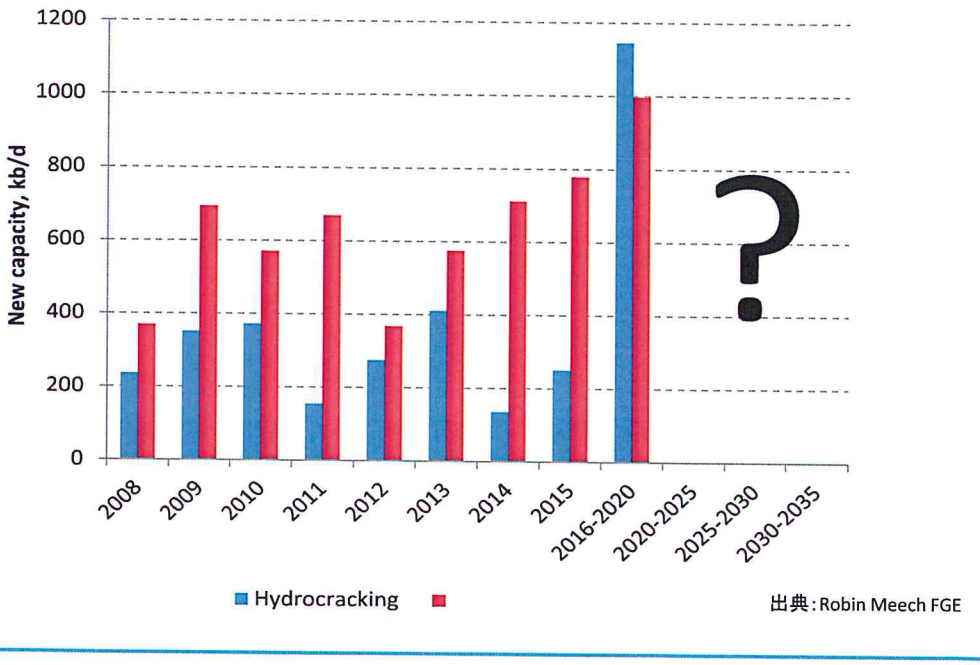

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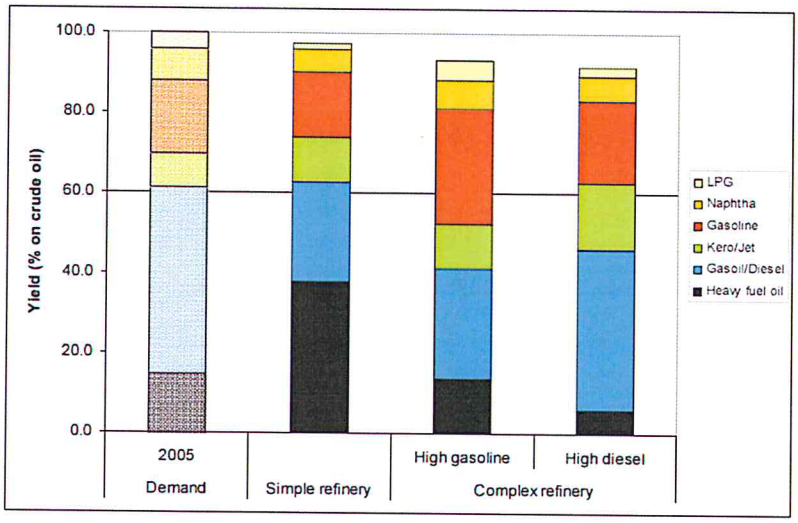
Chart 3- Can Refinery Investment Meet the Challenges?



- Achieving this requires complex process technology and hydrogen
  - "Reforming" to obtain the desired molecules and distribution
  - Residue conversion to "crack" larger molecules into smaller ones
  - Hydrotreating to obtain the desired product quality (e.g. S removal)
- More refinery complexity means that more energy and more hydrogen are needed - and typically more CO_2 emissions

出典：CONCAWEレポート

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Viewpoint : By-products in Refineries

1.The production of residues in refineries continues to decline.

The international marine market consumes roughly one third of all residues. Competitors : Power Plants

What is the viewpoint to solve the marine fuel issues ?

New Viewpoint : Best mixed utilization of various fuels
Effective utilization of by-products in oil refineries

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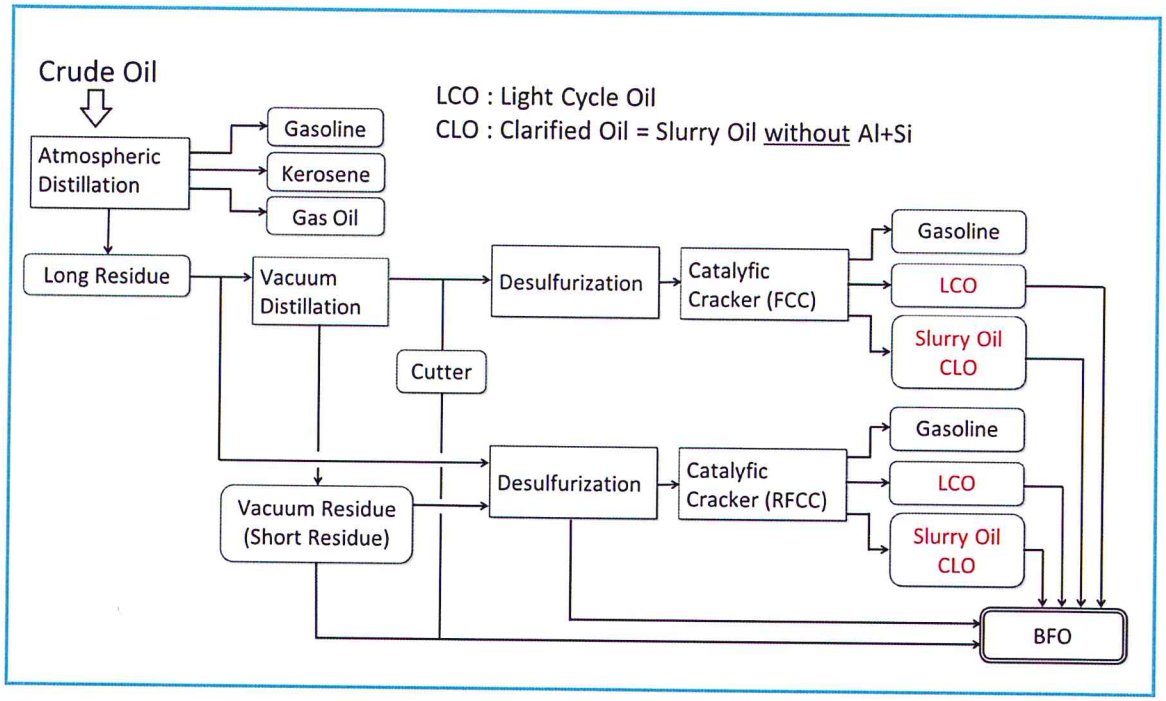
原油精製プロセスの一例



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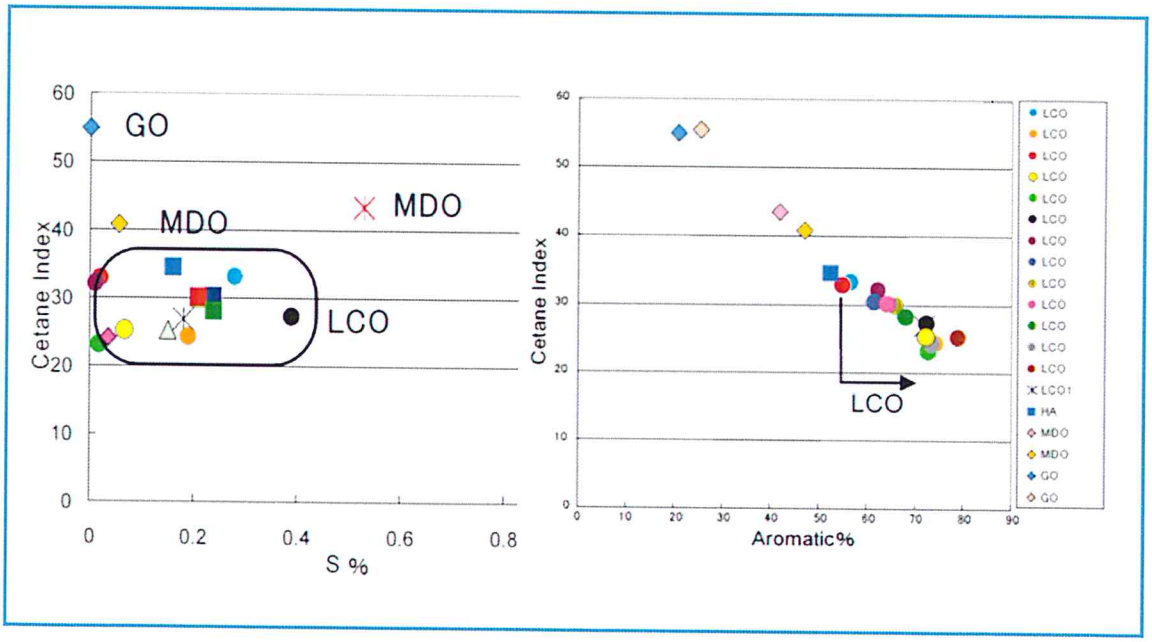
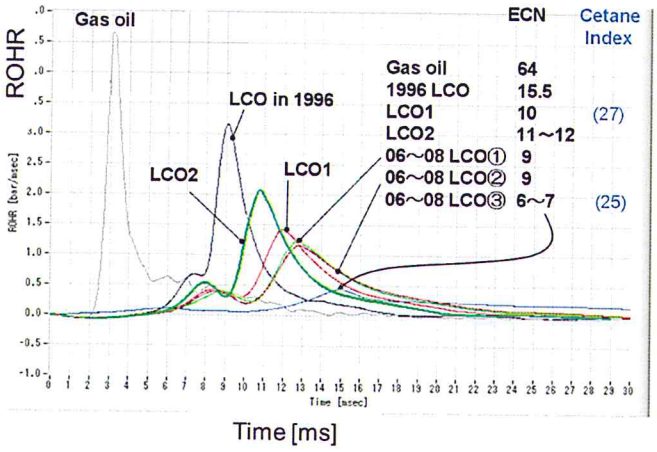
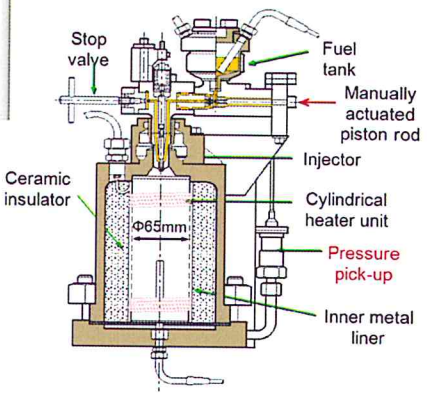
High aromaticity and low CN of LCOs in Japan





FIA Test Result (Reference)



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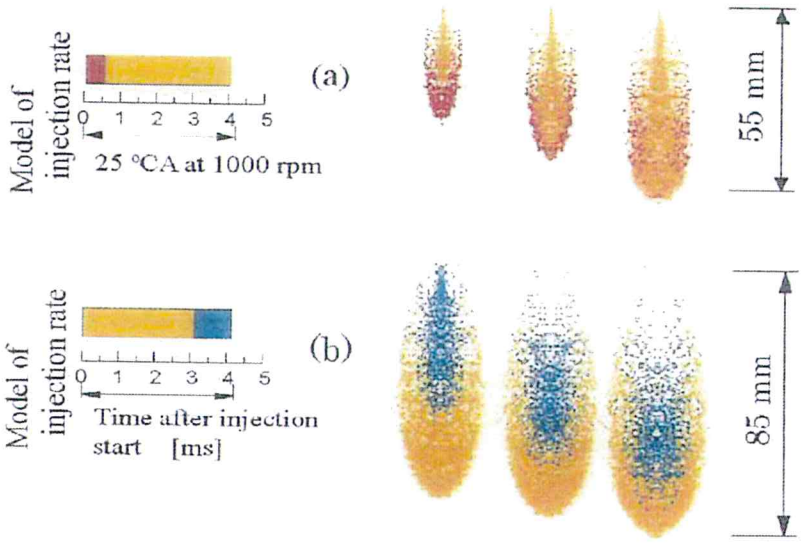
燃料噴霧のKIVA計算



出典：舶用重質油（バンカー油）の燃料特性とその改善〔九州大学　高崎講二〕

Best Mixed Utilization of Various Fuels
[New Concept Fuel Injection]

Aim: Compatibility of Economy and Environment

Stratified Injection System with Mutiple Fuels that meets Combustion-side Demands in each Stage of Combustion Period

Time	Fuel Properties requested by Combustion	Concrete Fuel
Initial stage of combustion	Fuel with better ignitable characteristi	High cetane number fuel(GTL and so on)
Middle stage of combustion	Fuel with low combustion temperature | Fuel with water addition	Fuel-Water Emulsion Stratified Fuel/Water Injection Methanol and so on
Final stage of combustion	Fuel with low smoky characteristic & Fuel with high momentum	Fuel with no aromatic compound(GTL and so on)

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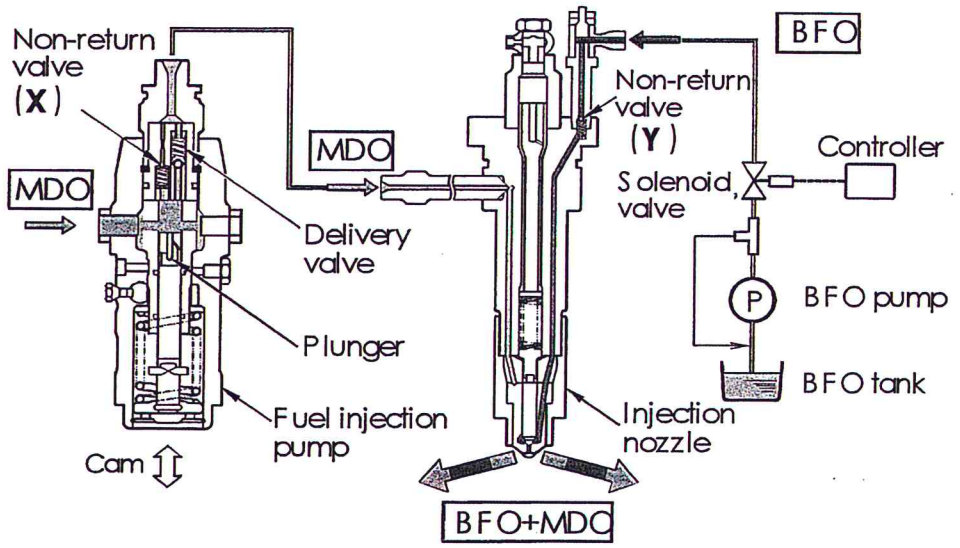

Stratified fuel injection system

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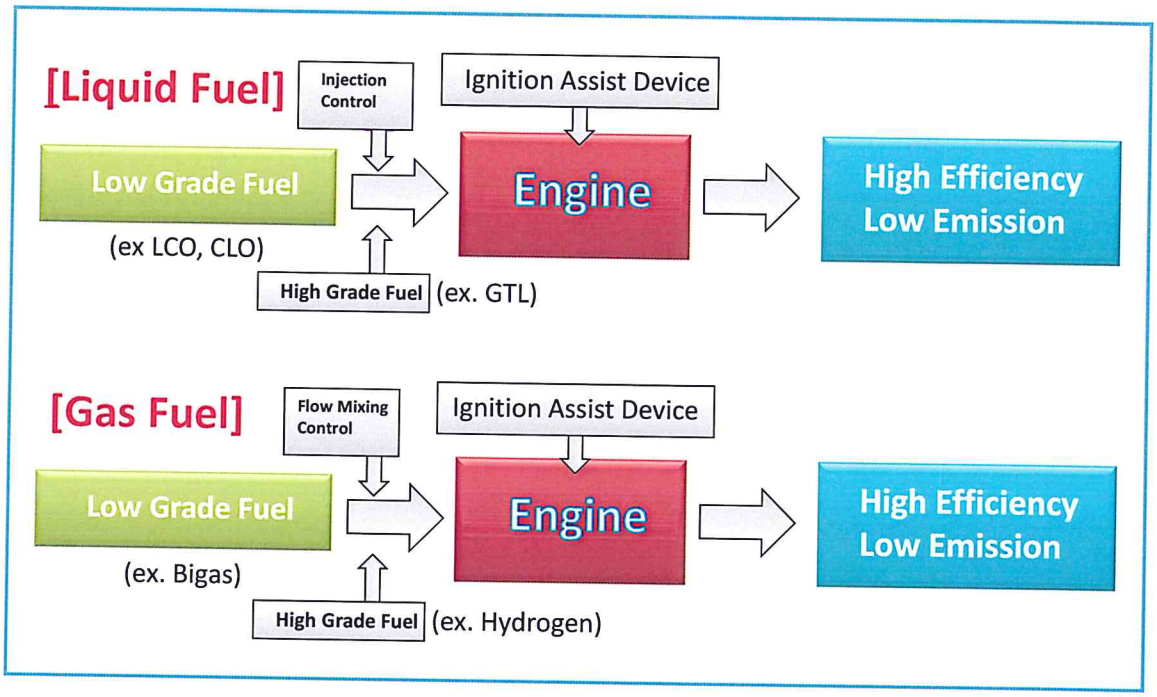
Combination of low grade fuels and high grade fuels



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Quality and Superiority of GTL as marine engine fuel (1)

【Features and technological problems for its marine application】

1. Environmental friendly : Adaptable without major modifications on conventional marine engines

1) **Zero-sulfur emission ⇒ Zero-SOx emission**

2) **Zero-aromatic particles ⇒ Improvement of after-burning characteristics**
⇒Decrease of smoke and PM Improvement of fuel oil consumption rate

3) **High cetane number, small theoretical combustion air volume**
⇒Capable of reducing NOx by 50% and improving fuel efficiency by 10% through optimizing combustion, injection and exhaust T/C specificationos

2. Reliability and Durability : Fuel additives and lubricity-improvement additives are required to the level of practical use

No problems have been noted about fuel additives and lubricity-improvement additives through conducting basic experiments and others

Quality and Superiority of GTL as marine engine fuel (2)

3. Advantages in terms of handling, safety, transportation, and storage
No particular problems are noted.

Existing logistics and storage systems can be used as they are.

1) GTL is superior to HFO (Heavy Fuel Oil) in terms of cleanness and handling
2) GTL can do away with on-board facility investment compared with LNG (Expensive & large volumetric dedicated fuel tank is not required)

⇒**GTL has an advantage in existing ship modifications and retrofit.**

New port facilities including fuel supply infrastructure are not required.

【GTL's life cycle cost】

In spite of no apparent difference among GTL, HFO, MGO (Marine Gas Oil), and LNG in terms of price, **GTL has the potentials to have cost advantages for operations and maintenance of a marine diesel engine**
(Advantageous storage, handling, and others)

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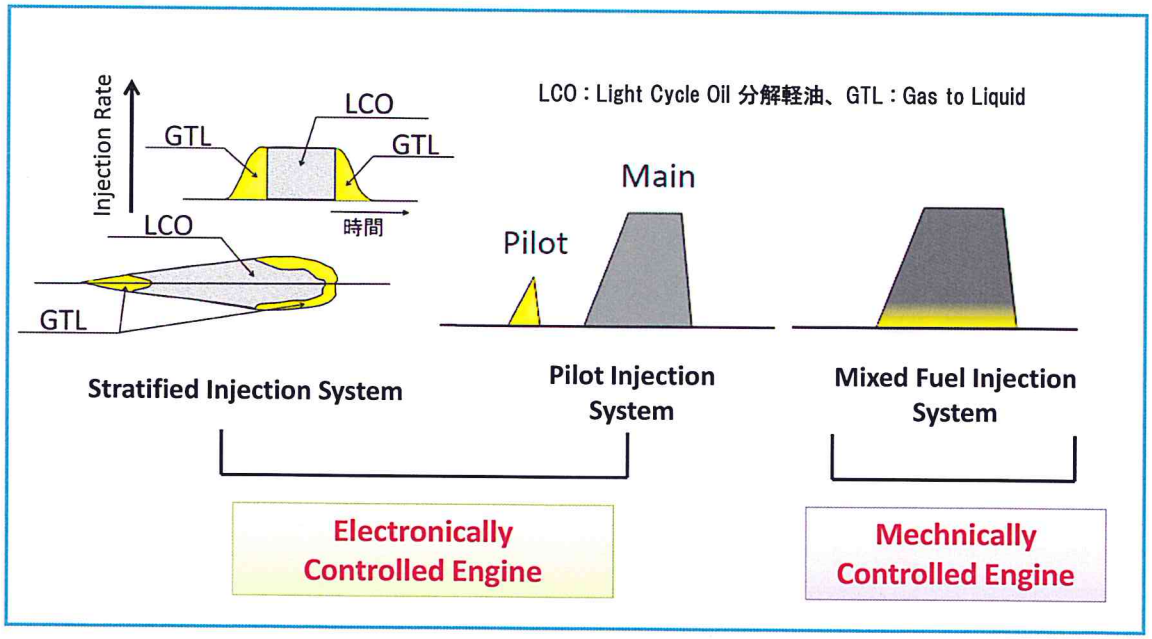
Best Mixed Utilization of Various Fuels Injection Rat



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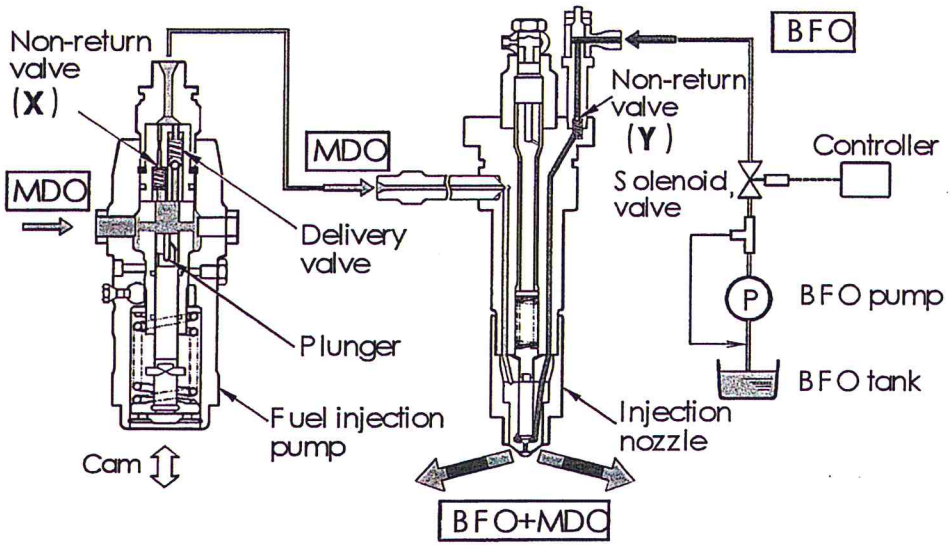

Stratified fuel injection system

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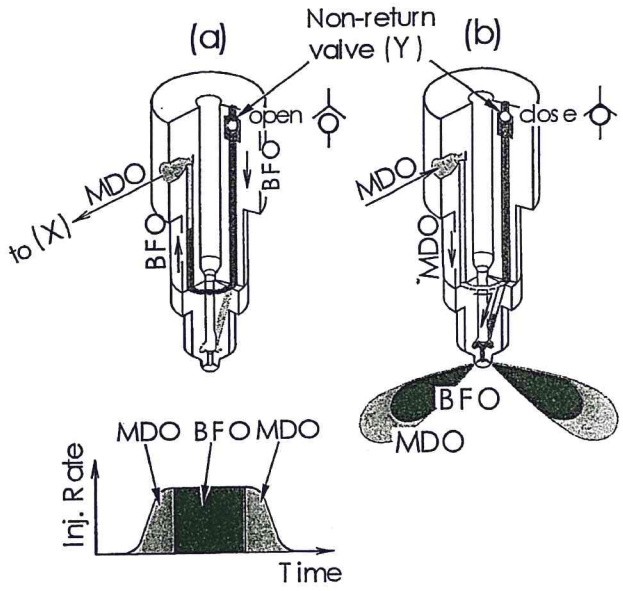
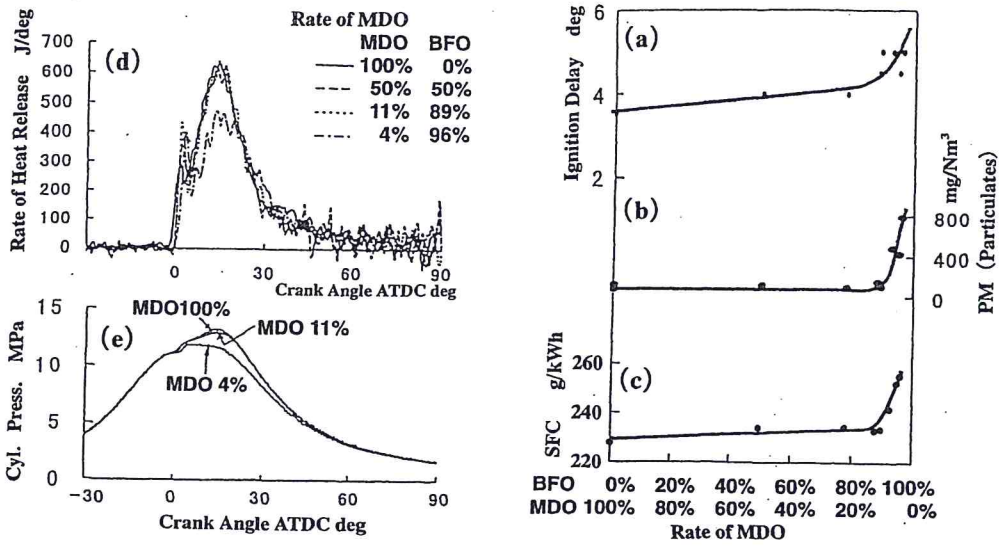
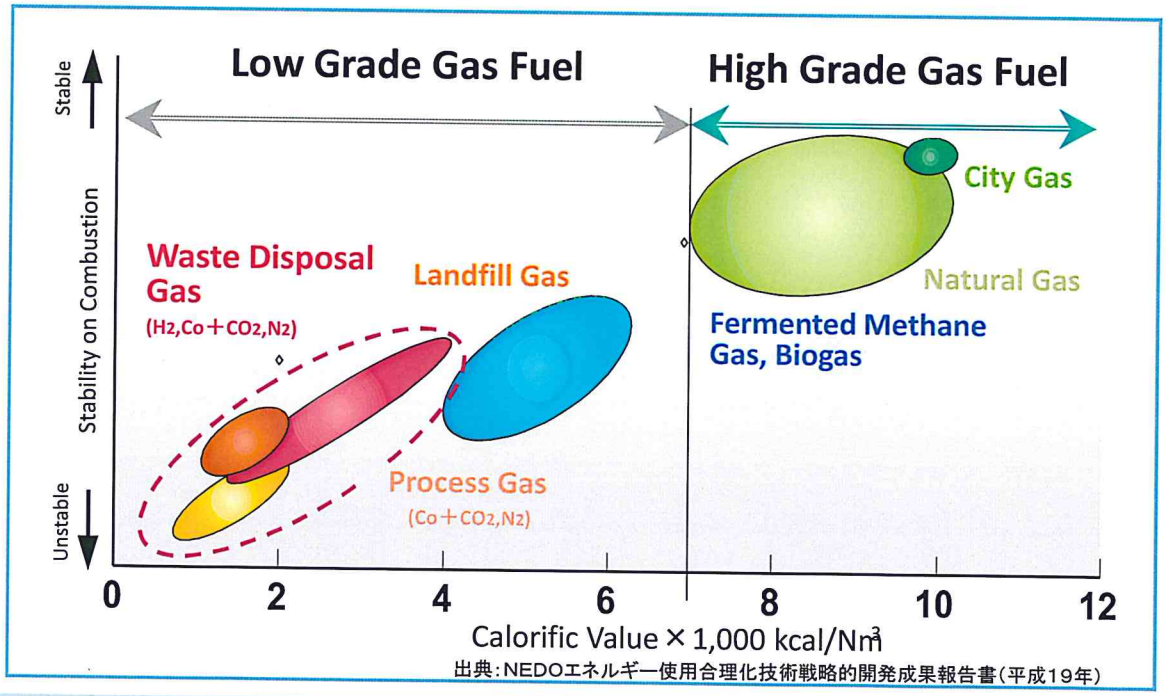


Stratified fuel injection system



Effects of stratified fuel injection system

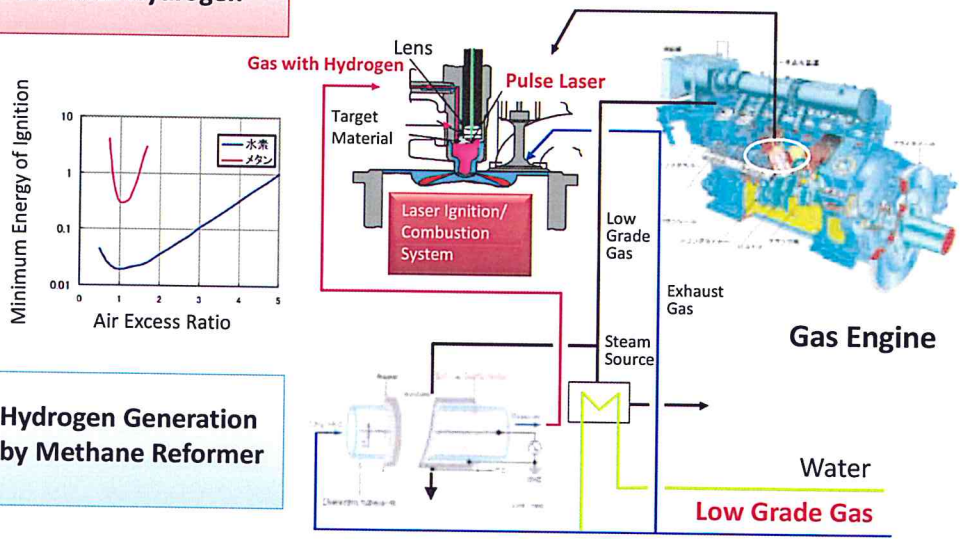
Calorific Value and Stability on Combustion of Various Gas



出典:NEDOエネルギー使用合理化技術戦略的開発成果報告書(平成19年)

Full Picture of New Concept Combustion System

Laser Ignition on Gas with Hydrogen



Hydrogen Generation by Methane Reformer

出典:NEDOエネルギー使用合理化技術戦略的開発成果報告書(平成19年)

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Summary

- In ECAs the application of exhaust gas cleaning systems or the use of LNG may be effective options.

・Shortages of low-sulfur distillates are likely.
・Scrubbing technology seems the better strategy.

・LNG fueled ships aimed at inland and coastal shipping are likely.

- The prospects for alternative fuels or sustainable energy ?

・New viewpoint to solve the marine fuel issues :
Best mixed utilization of various fuels

⇒ LCO＋GTL or CLO+GTL

Diversification of fuel / energy source for marine propulsion

Eco friendly Ship Propulsion 2030 ???

TUHH
Hamburg University of Technology
Energy Systems and Marine Engineering

出典：ハンブルク工科大学Rulfs教授講演資料

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Thank you very much
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