Gerard Vittecoq, Group President Power system Changing world: Megatrends

• Developed to Developing Markets
• Diesel to Gas & renewable Fuels
• Mechanical to Electrical
• Hardware to Software
• Products to Solutions
0.1% Sulfur Limits in ECA effective 2015

Key Drivers for Dual Fuel

- Low Sulphur (0.1%) fuel regulations in ECA regions as of 2015
- High fuel cost delta of MDO vs. LNG
- Amortization time of DF Retrofit by fuel cost savings?
- Increasing focus on "Green Image"?
Emissions – Differ with the fuel used

HFO / MDO with Additional engine technology & After treatment!
ECA Zones - Area of Operation

Logistics
- Area of Operation
- Percentage, Routing & Distance
- LNG infrastructure
- Refuel cycle
- Vessel charter time
- Retail
Meeting the Emissions regulations With Operational Efficiency

Technical Requirements
Emissions Solutions

Low sulfur Fuel
Operating cost+

Heavy fuel
Engine Complexity+
After treatment

LNG
Engine Design?
Cargo space?
Availability?
Operational cost – Choice of solution

First Cost (%) vs. Operational Cost (%)

- LSF
- SCR
- EGR
- Base
- HFO
- SCR+SCB
- Otto
- Gas
- Otto DF

2011 Zeebrugge LNG price Incl. transport

MPPD
Marine and Petroleum Power Division
LNG – Running on GAS

Dual Fuel

Spark Ignited

If Yes Then ?

Mechanical

Diesel Electric
Where is Caterpillar in all of this?

Dual Fuel?  Spark Ignited?
Marine Gas Genset – Caterpillar Gas History

1932: Lab work initiated to convert gasoline engines to natural gas

1940

D13000/D17000 converted to spark-ignited natural gas

1960

Intensified gas engine research due to increasingly available gas sources

1980

Pioneering work in high output, high speed, turbocharged engine development

2000

G3516C engine introduced

Spark-Ignited Engine Business Unit formed, development programs accelerated

3500 Gas engine introduced

MPPD
Marine and Petroleum Power Division
Caterpillar Gas Engine Product Range

- **Current Gas Engine Range**
  - G3300, G3400, G3500, G3600, & GCM34 platforms
  - MWM brand
  - 67 – 6100kW

- **First 3500 Gas engine produced late 80’s**

- **Markets**
  - Electric power & gas compression
  - Future Marine & Petroleum

- **Engines Shipped**
  - 18’000+ G3500 Sold
  - 4’000+ G3600 Sold
3500 Marine Gas Genset

- Marinization of an existing Gas Generator Set
- Technical feasibility study completed
- Technical review conducted with multiple Marine Classification Societies
- Gas Technology Demonstration Project ready for technology validation

![Graph showing G3516C IM 80-100% load step]

Capable to meet MCS requirements at 20% block load
Dual Fuel vs. Spark Ignited - Considerations

Gas Only (Spark Ignited):
- Expected to Meet IMO III / EPA Tier 4 without After-treatment
- Biggest Fuel Cost Savings
- Simple and well proven Engine / Control System
- Durability Better Than Diesel
  - Slower Response than Diesel
  - Requires Regular Access to Gas Supply
Dual Fuel MaK M46DF

- Shares engine platform with M43C
- 460mm bore
- Conventional diesel system
- Common rail pilot injection system
- HFO / MDO / LNG capable
- Running in test bed since Q3 2011
Dual Fuel vs. Spark Ignited - Considerations

**Dual Fuel:**
- Transient Response & Acceleration Similar to Diesel
- Fuel Flexibility – Diesel, Gas, HFO or Mix
  Requires more Sophisticated Controls
  Fuel Cost Savings Limited by Need for Diesel Pilot
- Durability expected to be similar to Diesel
Future of Dual Fuel

Year

World Fleet Development, GW

0 100 200 300 400 500 600 700 800 900

2010 2015 2020 2025 2030

Rest of Fleet  Fleet of New DF Vessels  Fleet of DF Retrofits

Caterpillar Confidential: Yellow

MPPD
Marine and Petroleum Power Division
LNG engine strategy

- Future Tendency towards larger SI engines based on: Infrastructure, operational risk and technology.
Summary

• New emission regulations are coming!

• Future fuel price/availability is an uncertain factor

• LNG is a good option, but not the only one
Thank you!