Fuels for Tomorrow

Future Availability and Acceptability of World Energy Resources Suitable for Marine, Power Generation and Locomotive Applications Covered by CIMAC

CIMAC Collin Trust Lecture

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AVL List GmbH

24th May 2007

Agenda

- What is Driving the Fuel Situation?
- Which Fuels Options do We Have?
- Engine Technology for Future Fuels
- Reviewing the Key Issues
- Conclusions

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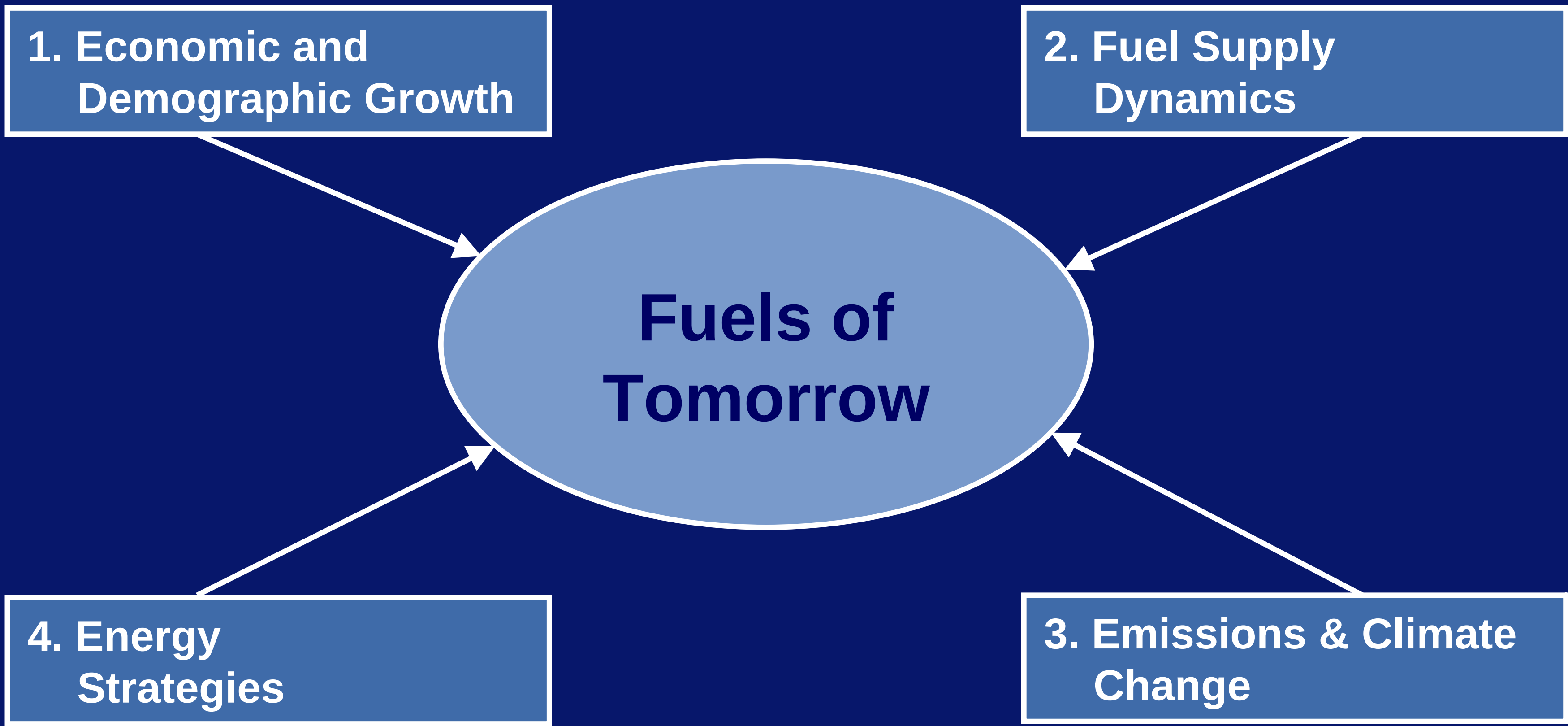
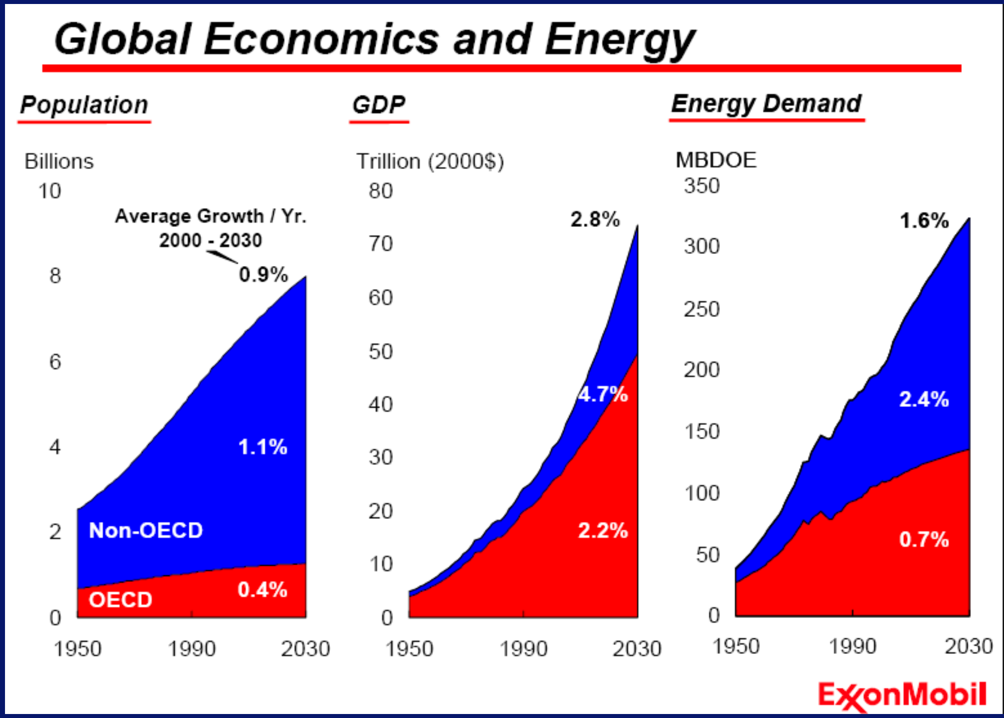
Main Drivers of the Fuel Situation



Driver 1: Economic and Demographic Growth 2007 - 2030

- World Population Growing by 25% towards 8 bn.
- GDP Increasing 80%
- Energy Consumption Increasing by 35%. Surpassing in Non OECD Countries Western Countries

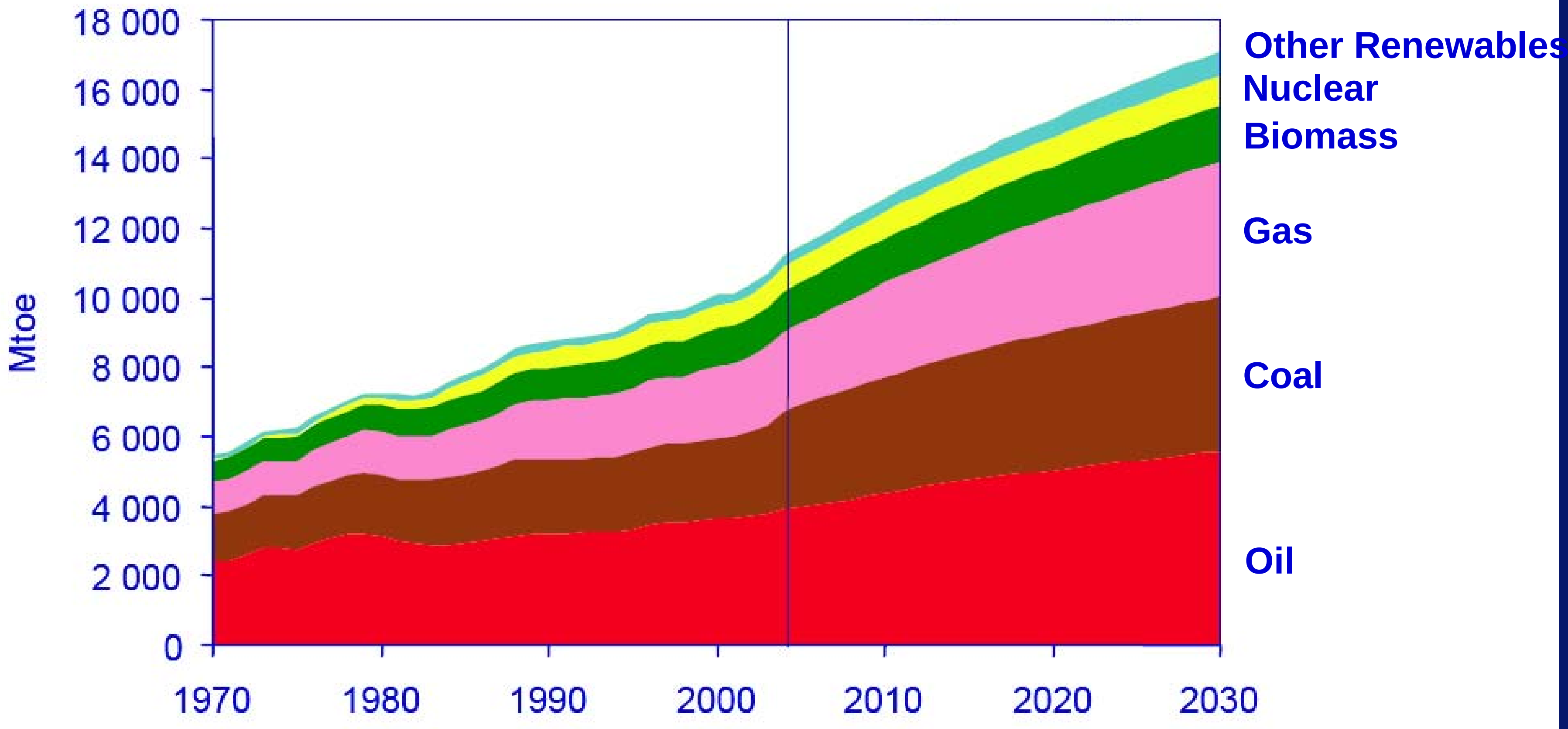


Source: Exxon Mobil

Driver 2: Fuel Supply Dynamics

- Current Oil Resource/ Production Ratio (R/P): 40 Years
  - Middle East Oil Reserves 62% of Total
  - Access to Most of Oil Reserves is Restricted
  - Geopolitical Instability in the Areas of the Largest Oil Reserves
  - It Seems to have Settled that the Level of Cost of Crude Oil Remains Above $ 60/Barrel
- Gas R/P Ratio: 70 Years
  - Largest Gas Reserves Eurasia, Middle East (75% of Total)
  - Gas Supply Crisis 2006 Uncovered Vulnerability of Safe Gas Supply
- Coal is Taking an Important Share in the Energy Supply

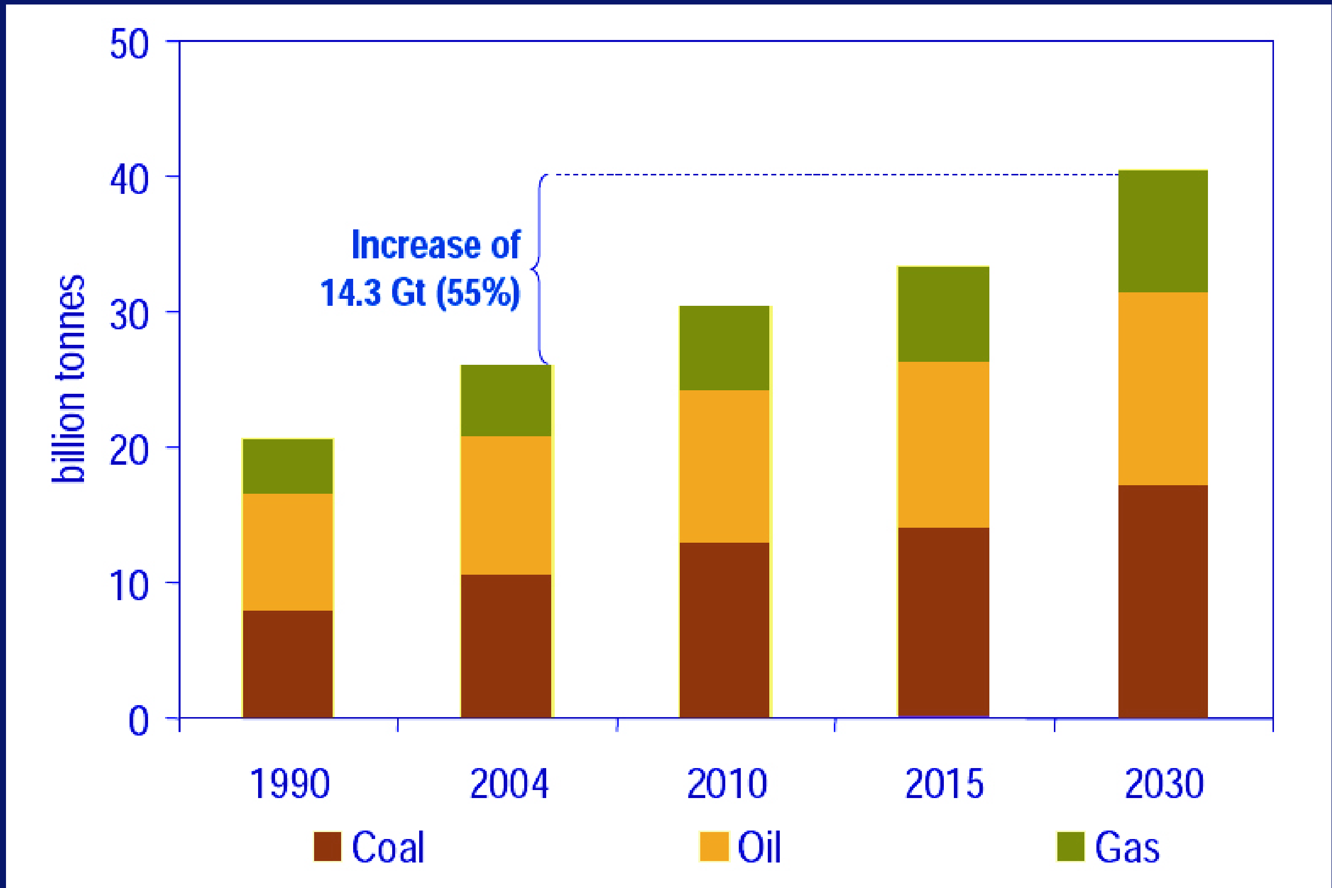
World Primary Energy Demand Forecast Until 2030



Source: OECD/IEA
World Energy Outlook 2006

Driver 3: Emissions & Impact on Climate Change

- **Greenhouse Effect (CO2 Emissions +55% Until 2030)**



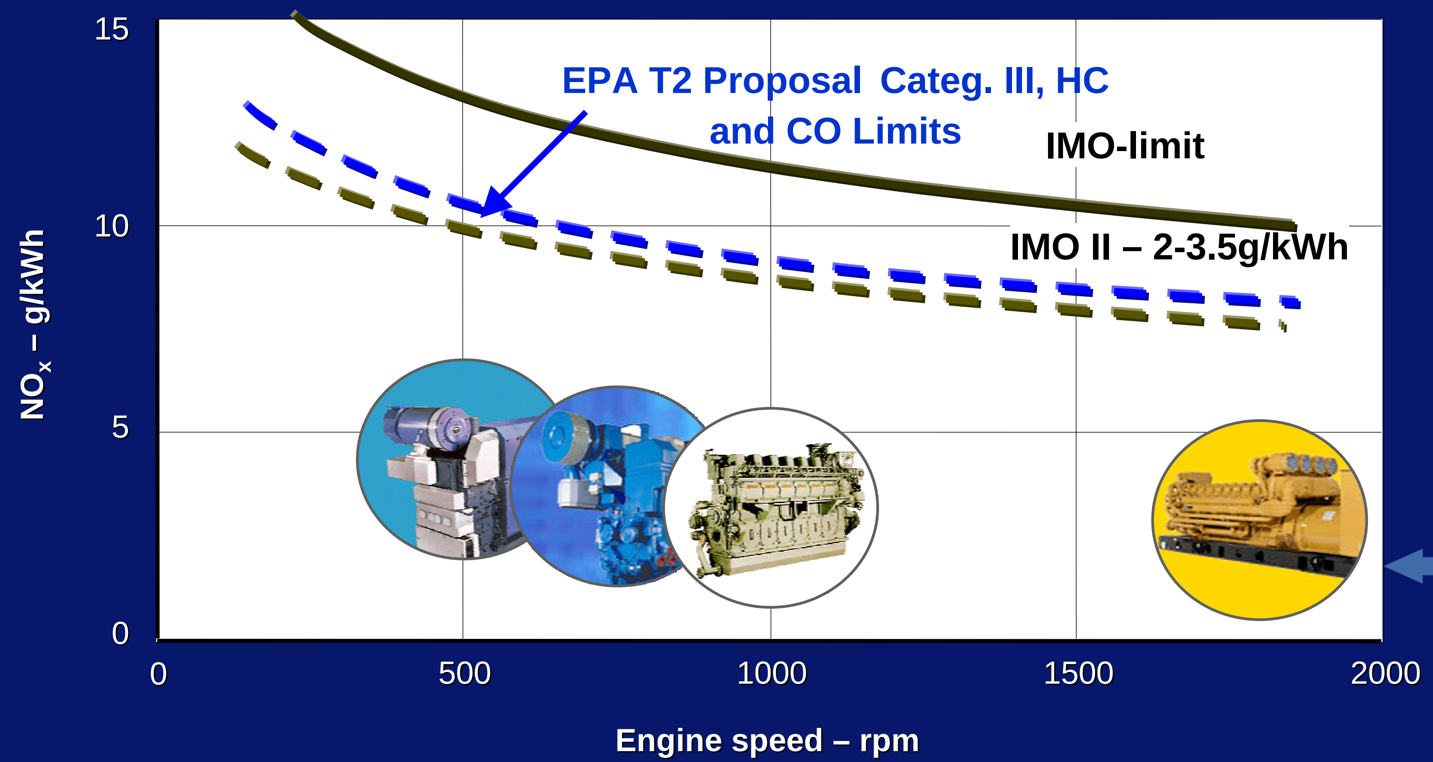
Source: OECD/IEA
World Energy Outlook 2006

Driver 3: Emissions & Impact on Climate Change

- **China Overtakes US in 2010 in Pollutant Emissions Per Capita**
- **Transportation is Taking the Major Share of Emissions (1.8% P/A Increase)**
- **Ships Major Pollutant Contributors Unless Drastic Change Implemented**
  - **Estimated Percentage of Ships' Contribution to Pollution in the US 2030:**
    NO_x 28% / PM 25% / SO_x 80%
    (Source: US 48 States Inventories Incl. Nonroad)

Source: OECD/IEA
World Energy Outlook 2006

Emission Limits for Marine Engines



EPA T4 Proposals for 2016 and <30 L/Cyl.

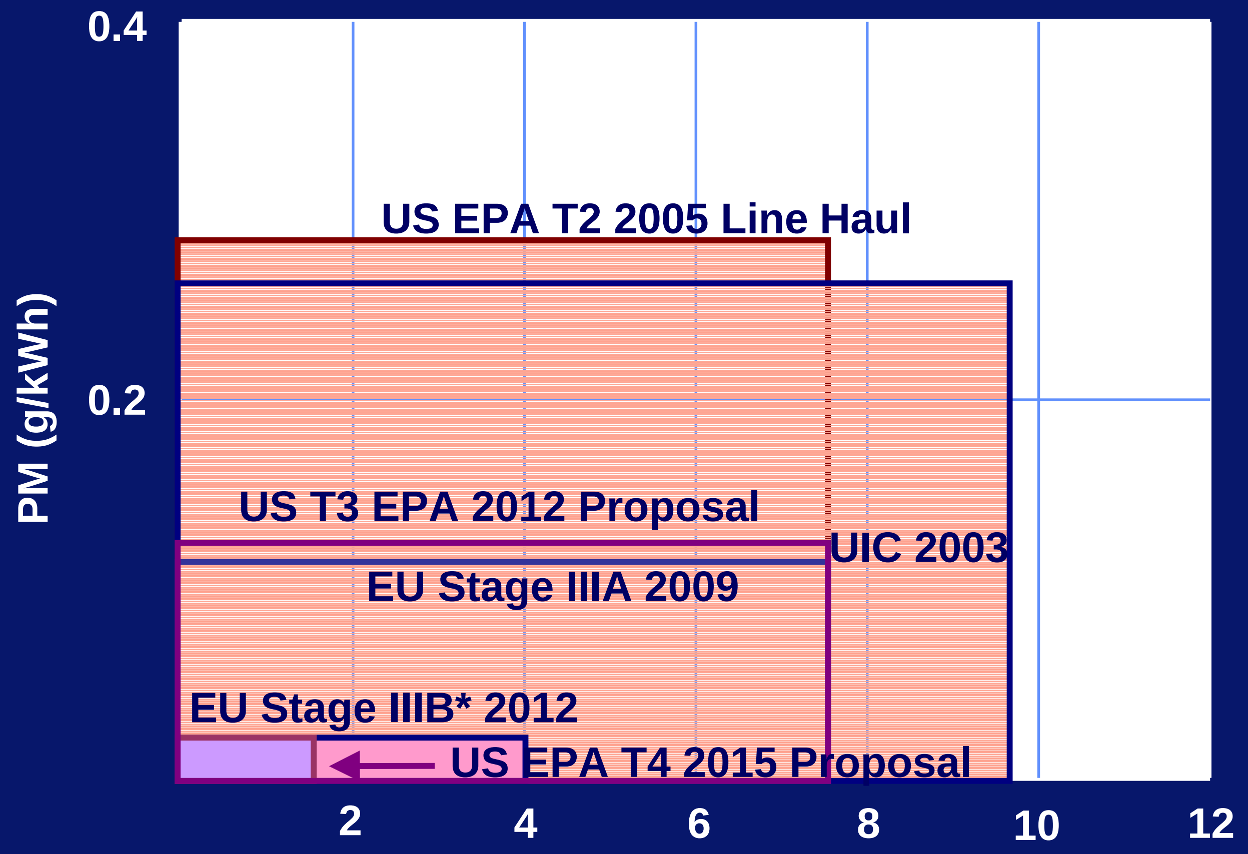
NOx< 1.8 g/kWh

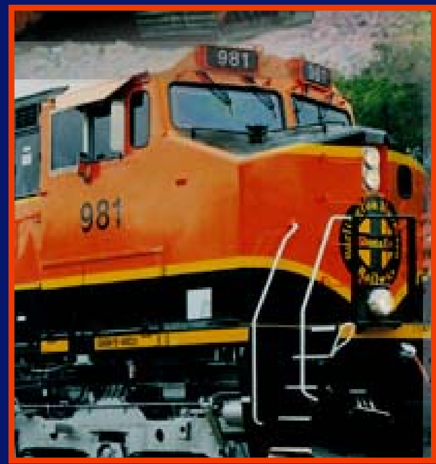
PM <0.04-0.08 g/kWh

- IMO Tier II: ~30% NOx Reduction Expected for 2011
- IMO Tier III in 2015, Best Available Technologies with Aftertreatment
- US: EPA Tier 2 and Proposed Tier 3 and Tier 4 80-85% NOx Reduction
- Low Sulphur Caps in Implementation or Under Evaluation

Source: EPA, Int. Maritime Org.

Emission Limits Locomotive with Focus on PM and NOx



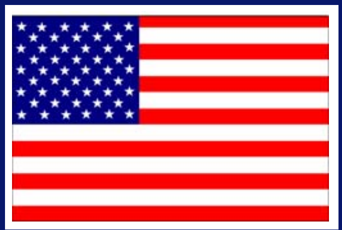


*) HC+NOx

Source: EPA

Driver 4: National and Regional Energy Strategies

- EU: Energy Review 2007
  - 5.75% Share of Biofuels in 2012
  - Reduce Green House Gas by 20% Until 2020 (Base: 1990)
  - Increase Portion of Renewable Energy to 20%



- US &Canada :
  - US Energy Policy Act 2005
  - DOE Financial Assistance
  - Province of Ontario: 5%v Ethanol Obligation by 2007

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Fuels Options for Marine, Electric Power and Locomotive Engines

Fossil Fuels	Biofuels	Derivate Fuels

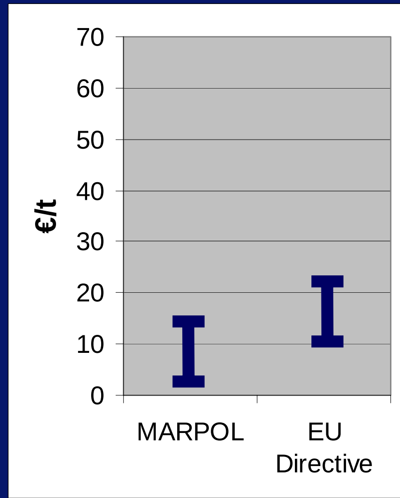
▪ HFO
▪ Distillate
▪ Natural Gas
  ▪ LNG
  ▪ LPG
	▪ Biomass to Gas (BtG)
	▪ Biomass to Liquid (BtL)
	▪ Bio Hydrogen
	▪ Bio-DME*)
		▪ Hydrogen from Nat. Gas or Electrolysis
		▪ Coal to Liquid (CtL)
		▪ Other Synfuels

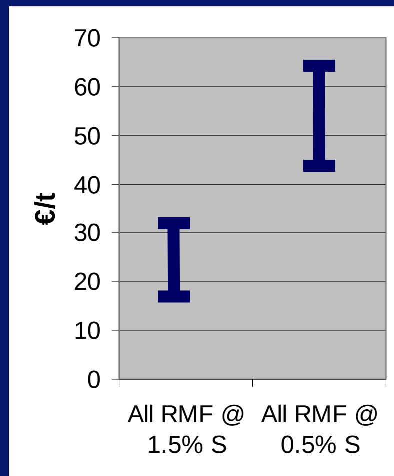
*) DME can be generated also from Fossil Fuels

Economic Ecologic Consequences of Low Sulphur Fuels

- **In Implementation**
  - **MARPOL/SECA Sulphur Caps 2007 1.5% for Baltic and North Sea**
  - **EU Directive 2005 For Ferries All EU Ports 1.5%**
- **IMO Evaluation**
  - **Sulphur Cap for HFO 1.5% in 2010 and 0.5% in 2015**
  - **Refinery New Investment Up to G€ 13**
  - **Incentive to Switch to Low Sulphur Fuel is Low**

The Option: HFO Ban?





Desulphurization Increases Cost of HFO > €62/Ton

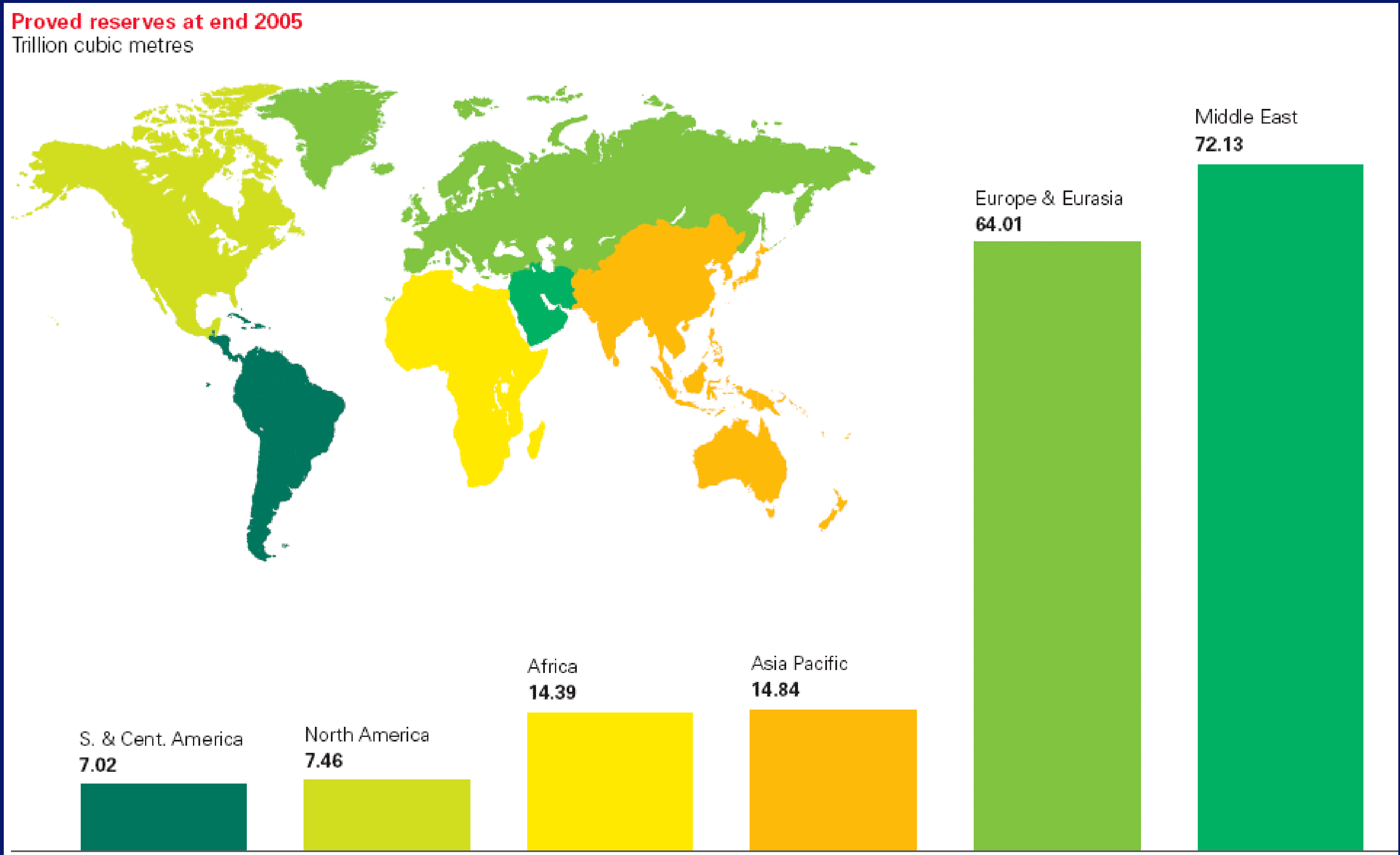
Source: CONCAWE

Fossil Fuels: Natural Gas

- Natural Gas Playing a Major Role in the Energy Supply (~25% of the W/W Primary Energy Consumption)

- Application: Power Generation, CHP but Also for Marine Engines (15% of Consumption in 2030 Transported as LNG/LPG)
- CO_2 Emissions Reduced by ~20%
- SOx ? 0%
- Potential for “Near Zero” NOx and PM Emissions

Proved Natural Gas Reserves at End 2005



Source: BP

Biofuels

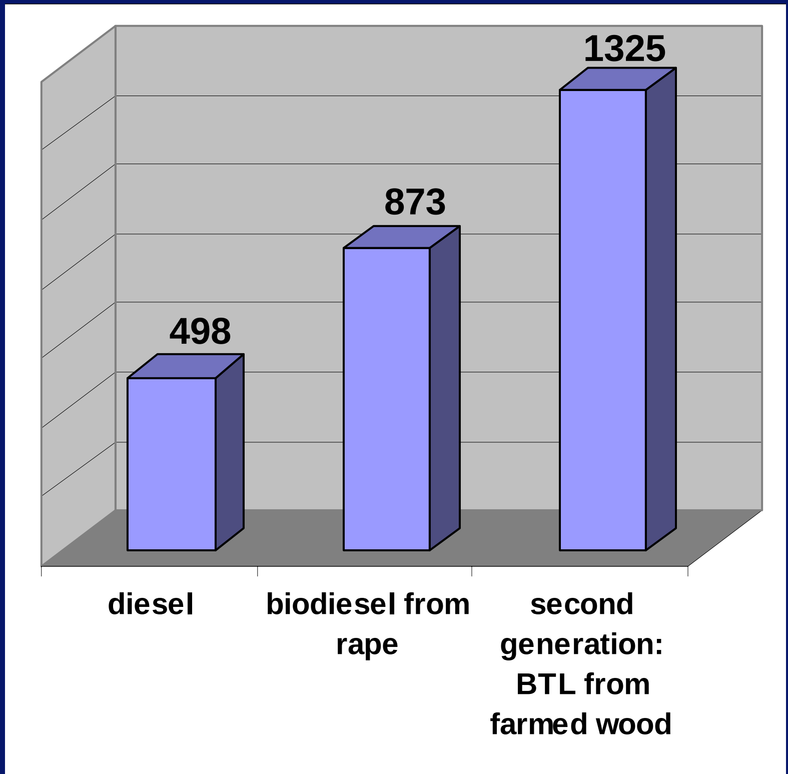
1) First Generation Biomass to Liquid Available Today:

- Vegetable Oil ? Biodiesel 100% or Blends with Diesel Oil (5 - 30%)
- Capacity to Reduce CO_2 Impact by Up to 50%
- Bioethanol Used in Gasoline Engines

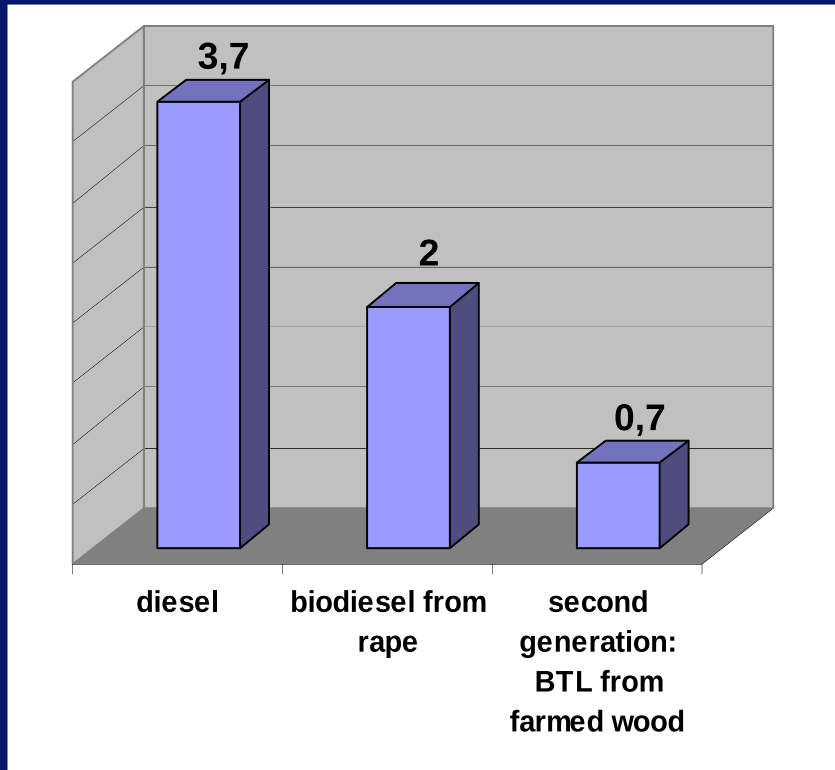
2) Second Generation Biomass to Liquid (BtL) Using Non Food Feed Stock:

- Fischer Tropsch Synthesis to Diesel
- CO_2 Impact Reduced by Up to 90%
- Industrial Production Still 10 Years Ahead

Biofuels: The Cost/Benefit Trade Off



Cost as Consumed in EU, €, assuming Oil @$ 60/Barrel in €-toe)



Green House Emissions tCO2 eq/toe

Source: Maria Fuentes EU Strategy for Biofuels (EU Commission)

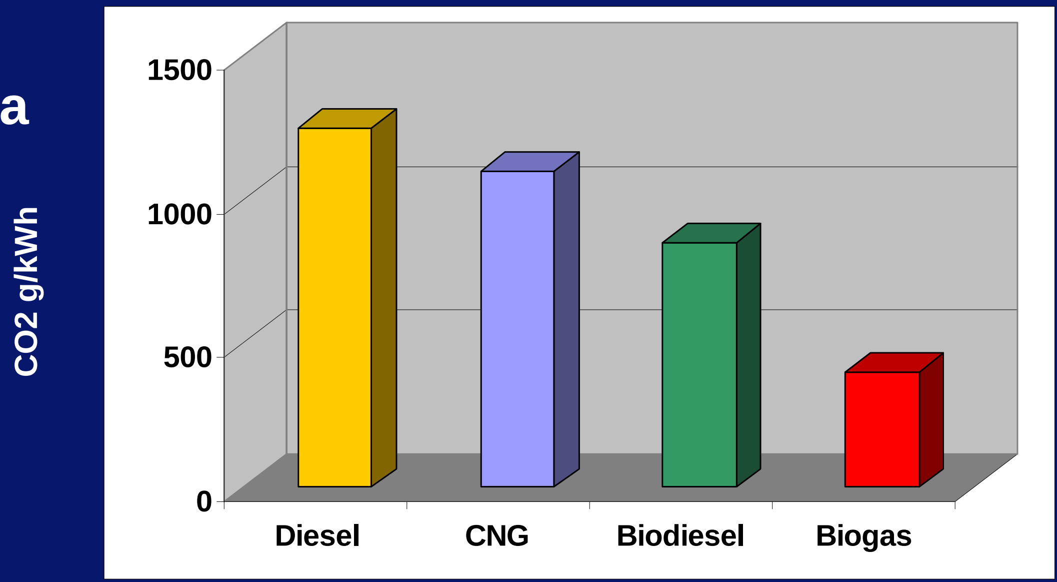
Gaseous Biofuels

2) Biomass to Gas

- Highest Energy Output / ha Cultivated Surface

- Low CO2 Impact

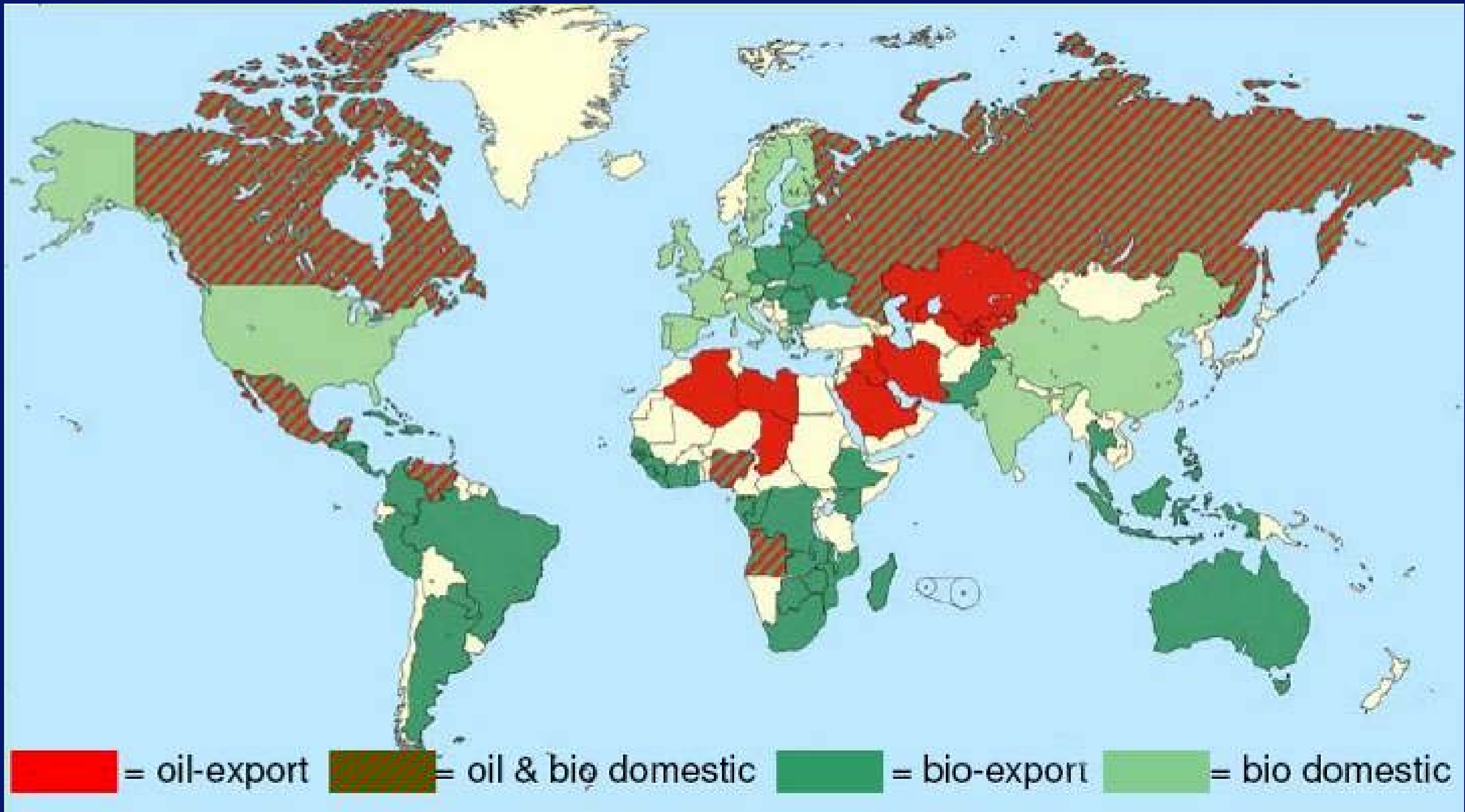
- Stationary Plants for Powergen and Cogen



Source: e-on / Ruhrgas

Production Potential of Biomass

Countries with potential in biomass production for fuels



Source: GTZ, Presentation Dr. Elke Foerster 2006 Kraftstoffe der Zukunft

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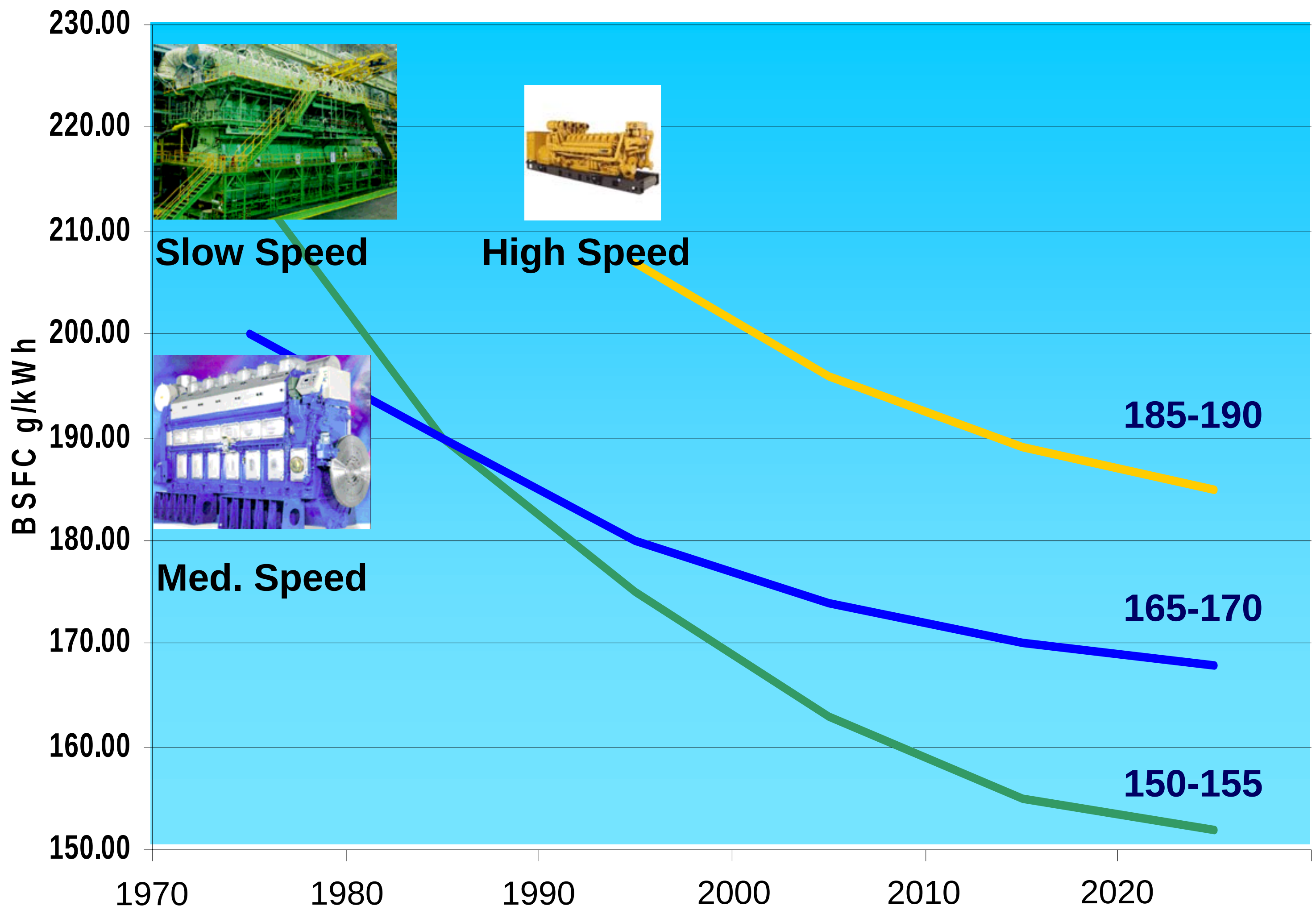
Fuels for Tomorrow: Possible Options by Application

Fuel	Slow Speed ➢ Marine ➢ Power Gen 	Medium Speed ➢ Marine ➢ Power Gen ➢ Locomotive 	High Speed ➢ Marine ➢ Power Gen, Industr. ➢ Locomotive 
Low Sulfur HFO	✓	✓	
Low Sulfur Distillate	✓	✓	✓
Natural Gas, LNG/LPG	✓	✓	✓
Blend HFO or Dist. w. Biof.	✓	✓	✓
1. Gen. Biomass to Liq. Or Gas		✓	✓
2. Gen. Biomass to Liq. Or Gas		✓	✓
Biogas		✓	✓
Bio Hydrogen or Other Source		✓	✓

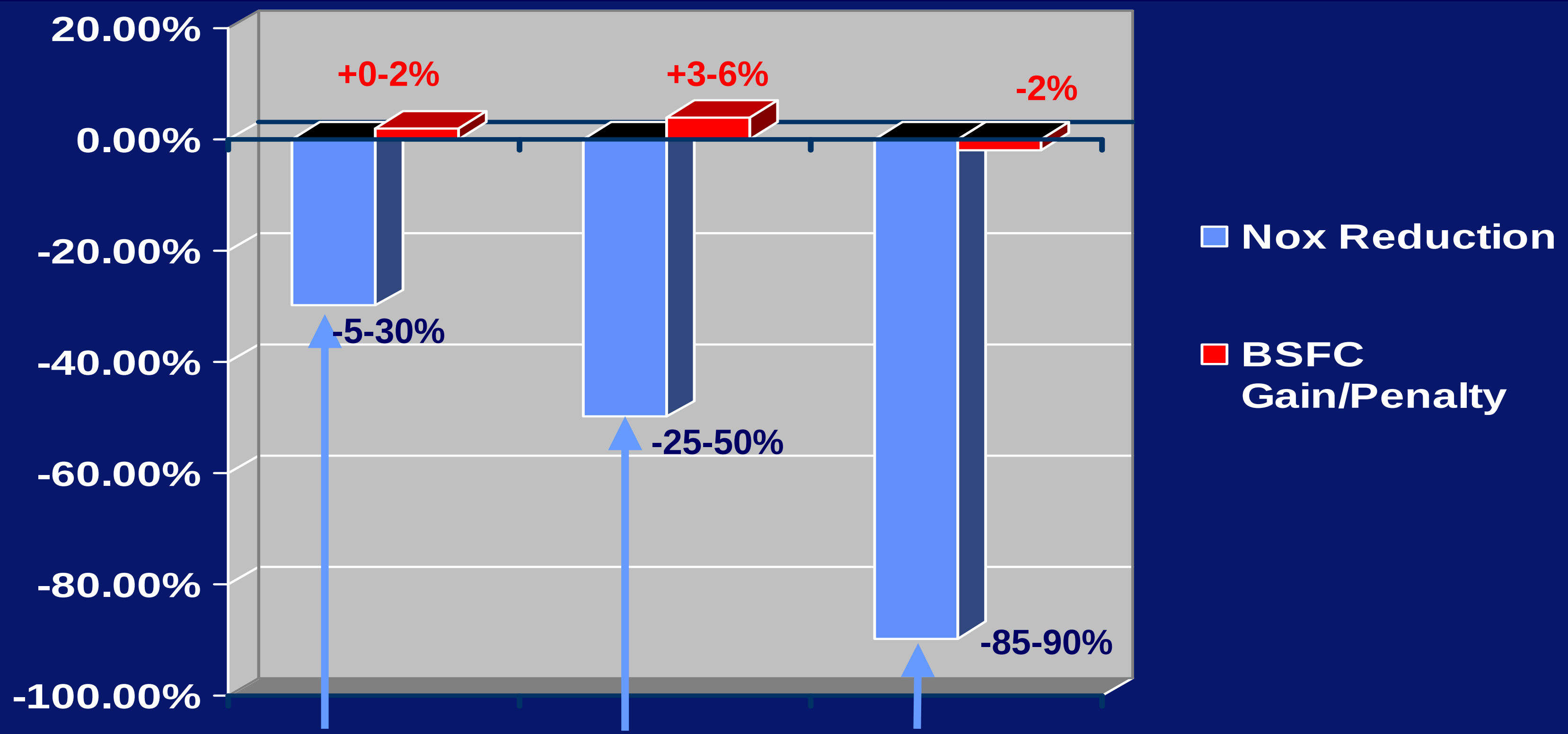
Technology Outlook for Engines Using HFO and Distillates

Focus		Direction		Potential Improvement
Reducing NOx / PM /Smoke	→	Combustion & Aftertreatment	→	95%
Reducing CO2 Impact	→	Fuel Efficiency	→	Up to 55-60% Mech. w. Waste Heat Recovery CHP ~80-85%
Control Low Sulfur Fuels Impact	→	Control Wear of Critical Components	→	Maintain & Improve Reliability

CO2 Reduction: Through Continuous Improvement of Fuel Efficiency



NOx Reduction: Making the Optimum Choice, From Low NOx Combustion to Aftertreatment



Low NOx Combustion

- Heat Release Rate
- Common Rail
- Miller and Var. Valve Timing

Wet Methods

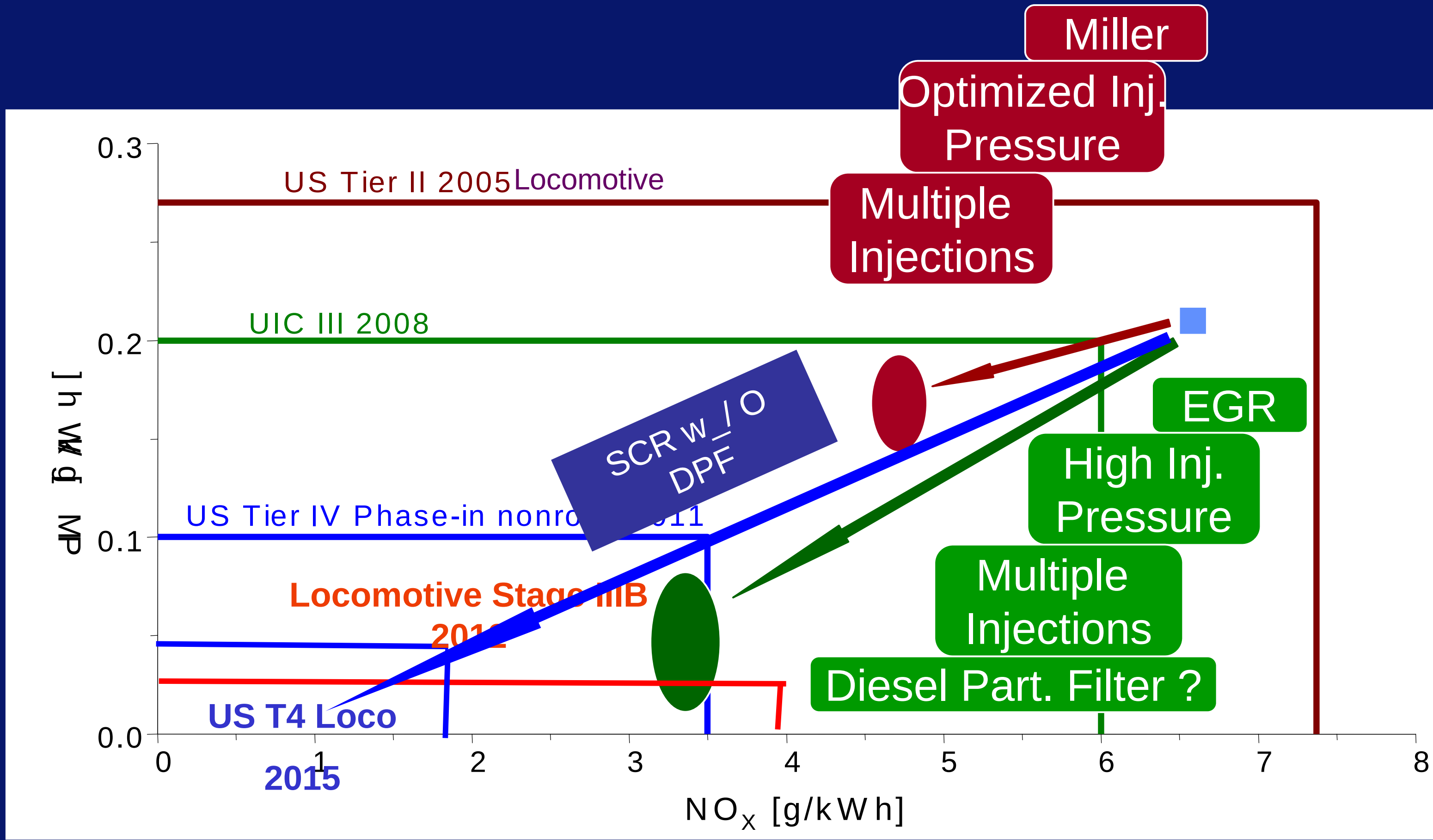
- Emulsion
- Dir Water Injection
- HAM

After-treatment

- SCR

The Issue: Trade-Off NOx Reduction vs. Cost

Combined NOx & PM Reduction Through System Integration of Key Technologies



Source: AVL Research

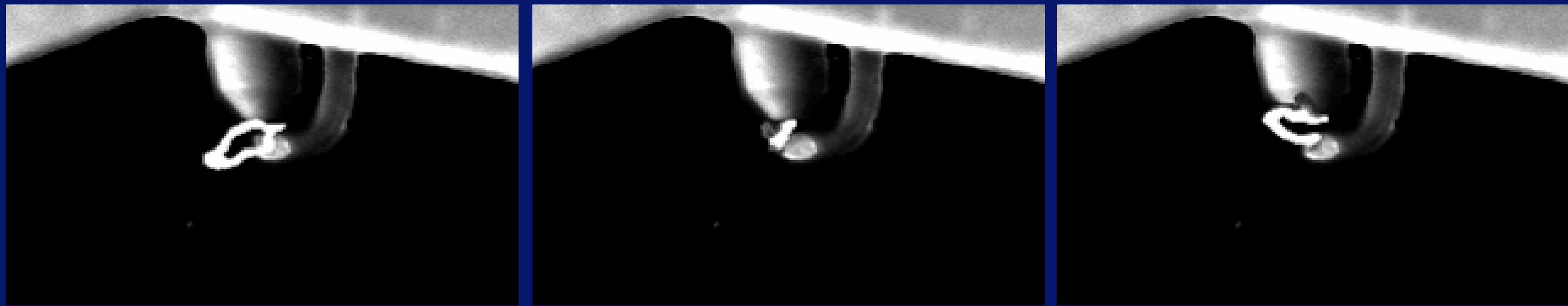
Technology Outlook for Engines Using Natural Gas

Focus	Direction	Potential Improvement
Reducing NOx / PM / HC and CO →	Combustion & Aftertreatment →	Reduction by 99%
Reducing CO2 Impact →	Fuel Efficiency →	Efficiency Up to 50% , With CHP ~80-85%
Reduce First Cost →	Raise Power Density to Diesel Level →	BMEP Towards 27 bar

Laser Ignition for Gas: Enabler for High Power Density

Conventional Spark Plug

2000 [rpm], WOT

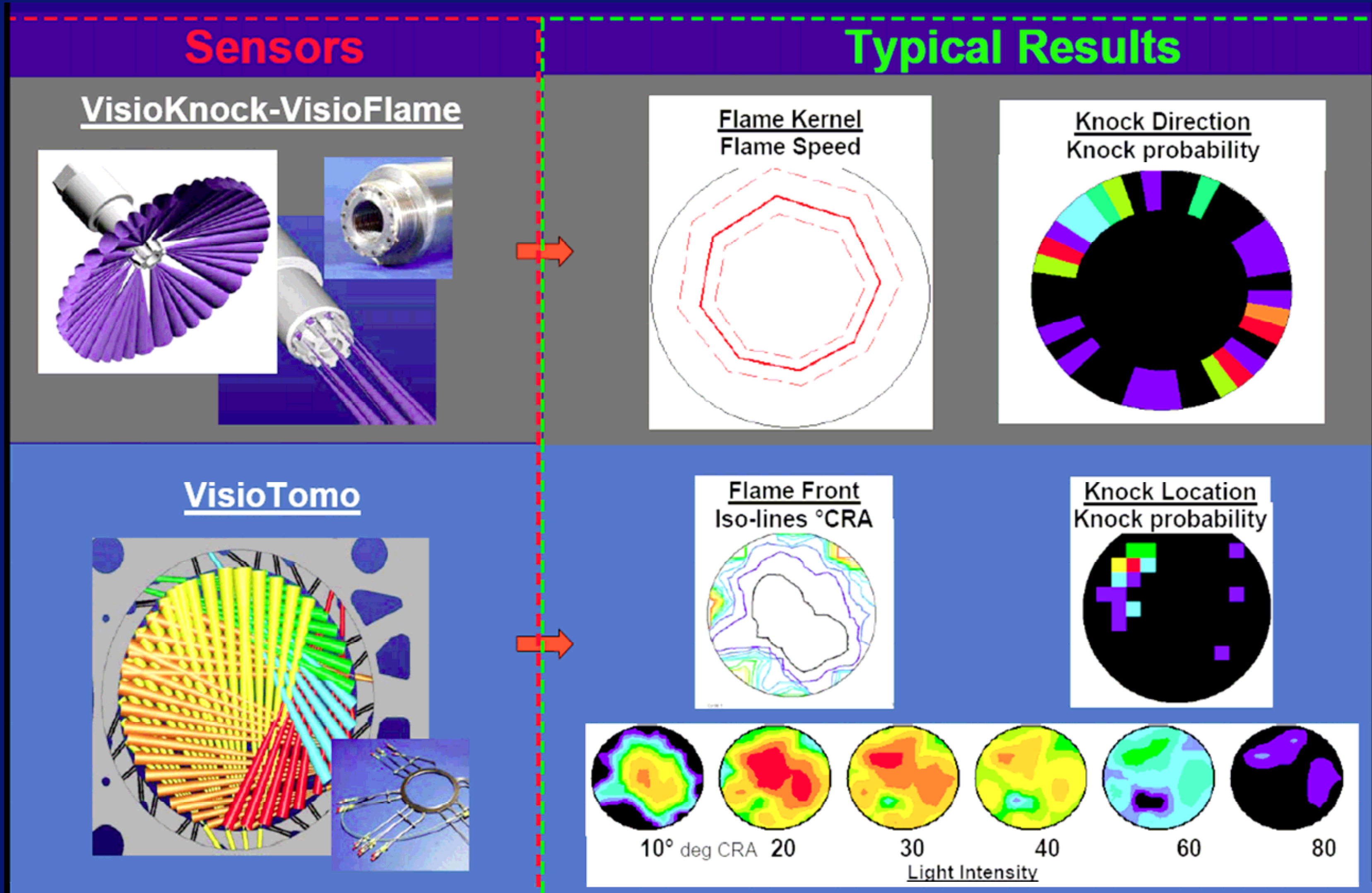


Ignition Laser

The local plasma formation process is independent from highly turbulent flow regimes.

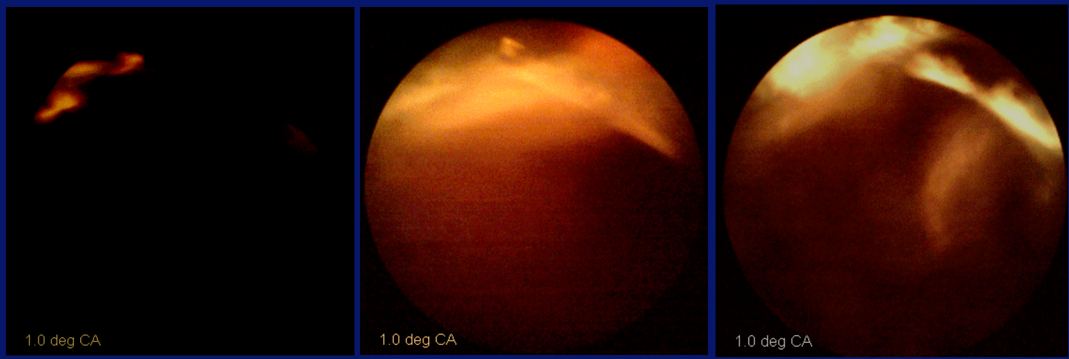
Source: AVL Research

Advanced Combustion Development Methods are Key



Source: AVL Research

Key Technologies for Burning Future Biofuels in Diesel Engines



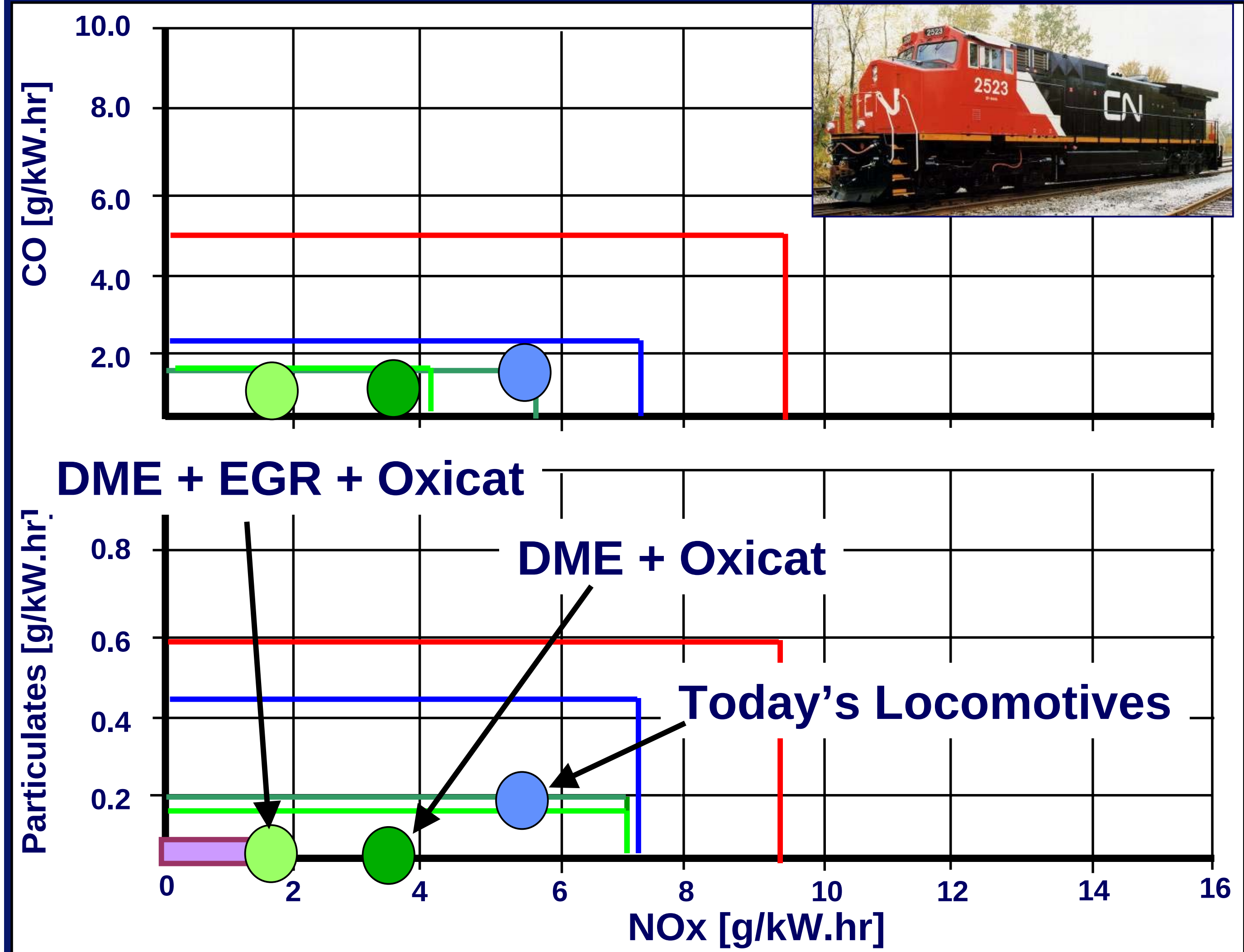
Source: NICE Project
AVL/FEV/DC/Volvo/
Renault/VW/CRF

Combustion System Must Be “Tailored” to Fuel Spec.

- **Fuel Injection strategy adapted to Fuel Spec.**
    - **Common Rail System Most Suitable**
- **Premixed Combustion at Part Load**
- **Closed Loop Combustion Control (AVL EmIQ)**
- **EGR**
- **Air System Matched to Fuel Specification**

Source: AVL Research

Synfuels, Opportunity to Meet Tighter Emission Limits: Dymethylether (DME)



- **Eliminates Need for DPF**
- **CO2 Red. By 80% if Produced From Biomass**
- **Competitive Cost**
- **Technology Challenge: Fuel System/Materials**

Source: AVL Research

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Sustainability Aspects of Future Fuels

Fossi Fuels	Biofuels	Derivate Fuels
• How Far Reaching Are the Worldwide Reserves of Crude Oil? • Are Low Sulphur Residues (HFO) Economically Sustainable?	• Impact of Biofuels on Farmland, Forest and Food Chain? • True Impact of Biofuels on CO_2 Emissions? • Further Cost Reduction? • Other Usage?	• Economics and Storage of Hydrogen Fuel? • True Impact on CO_2 Emissions?

Creating the Favorable Political and Economical Environment

- Taking a Multi- Stakeholder Approach: Producers / Industry and Trade / Public Sector / NGOs
- Creating the Right Political and Economical Environment: Taxes / Standards / Trade Rules
- CO_2 Credits
- Investing in R&D and New Infrastructures

Substitution Technologies: Fuel Cells

New Products and R&D Activities			
Improved Efficiency			Process Efficiency = 70% @ 2 MW
Additional Features for Customer Value	Hybrid Fuel Cell Battery Electric Solutions	H2-O2 PEMFC without Exhaust	
Reduced Emissions	Electric Traction in Mines w/o Battery	Quiet Power Generation APU in Harbor	Clean, Efficient, Competitive Distributed Power

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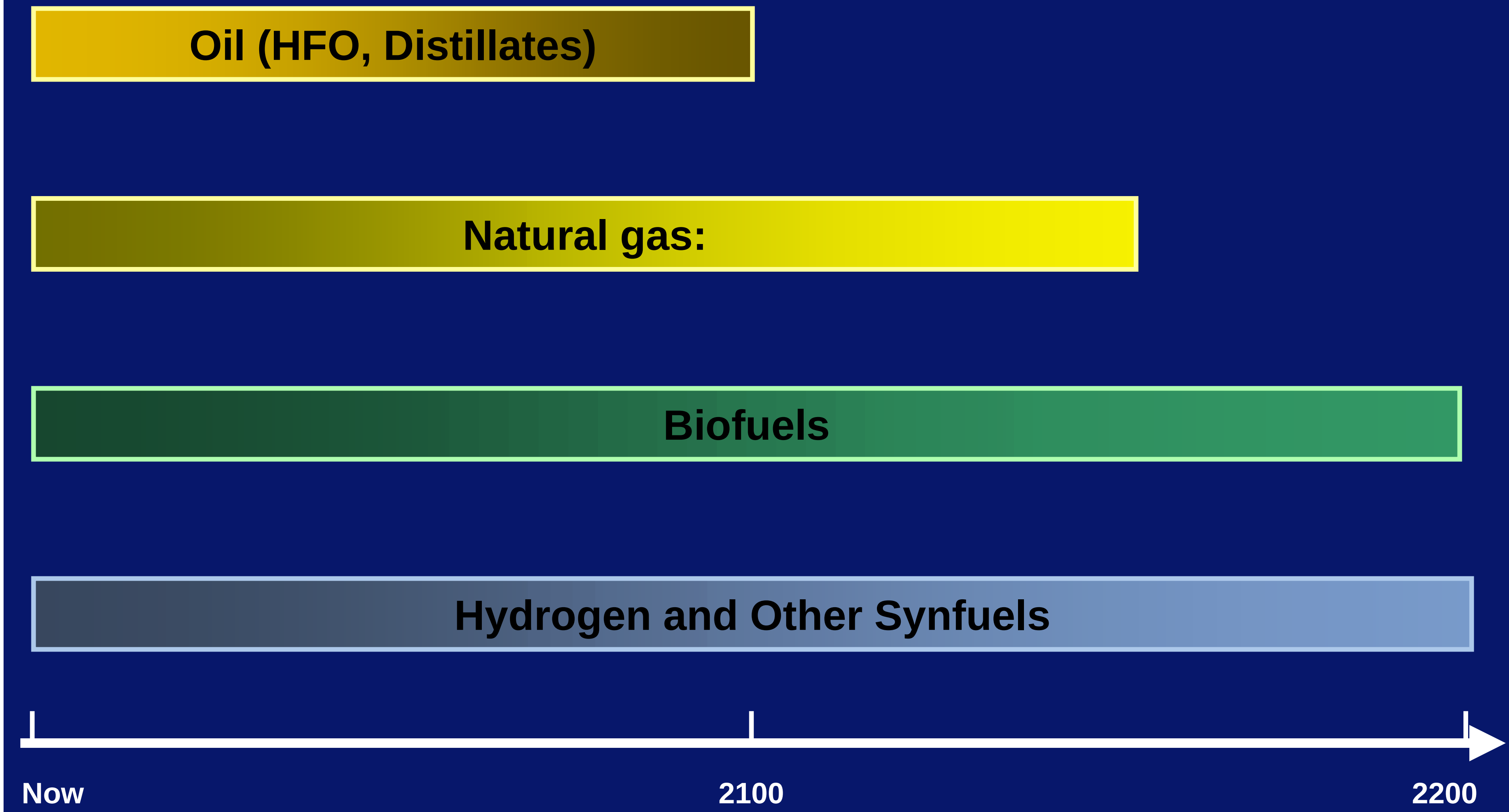
A Time Horizon for Future Fuels



Predominant Energy Sources By Application:

- Marine: Heavy Fuels and Distillates, LNG/LPG

- Power Generation: Gas and Biofuels (Liquid and Gas)

- Locomotives: Liquid Fuels (Fossils, Biofuels) and Syntethic Fuels

Conclusions

- **Energy Demand Increase: In 2030 60% Up From 2000**
- **Fossil Fuels Liquid and Gas Dominate But Stricter Emission Limits Impact**
- **Biofuels and Derivate Fuels: Complementary Resource**
- **Responsible Energy Utilization is Key**
- **The Right Investments in New Technologies and New Infrastructures**