The Drive for Energy Diversity and Sustainability:

The Impact on Transportation Fuels and Propulsion System Portfolios

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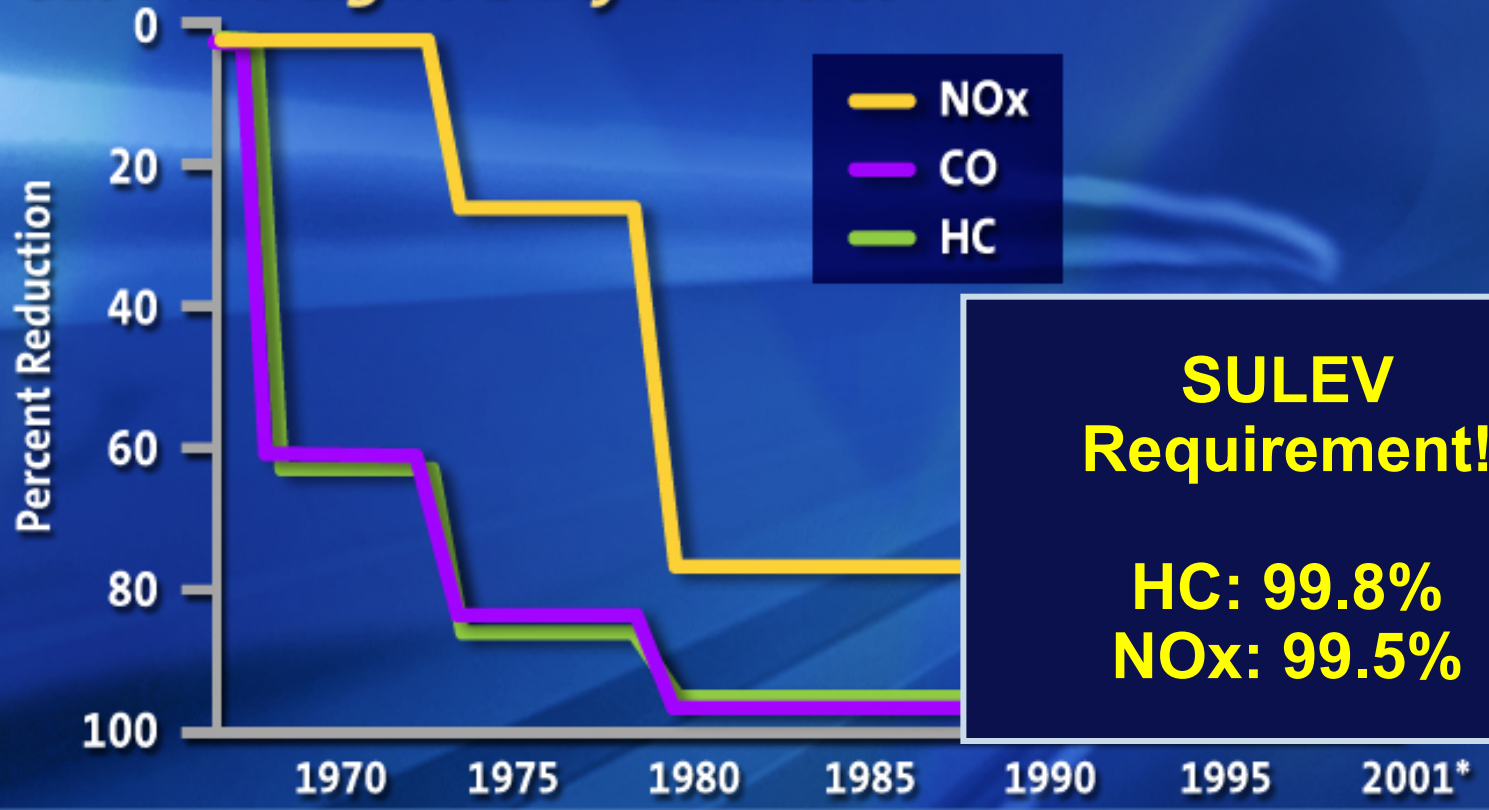
General Motors R&D and Strategic Planning,

Warren, MI, USA

13th Diesel Engine-Efficiency and Emissions Research (DEER) Conference, August 2007

U.S. Tailpipe Emissions

Gasoline Light-Duty Vehicles

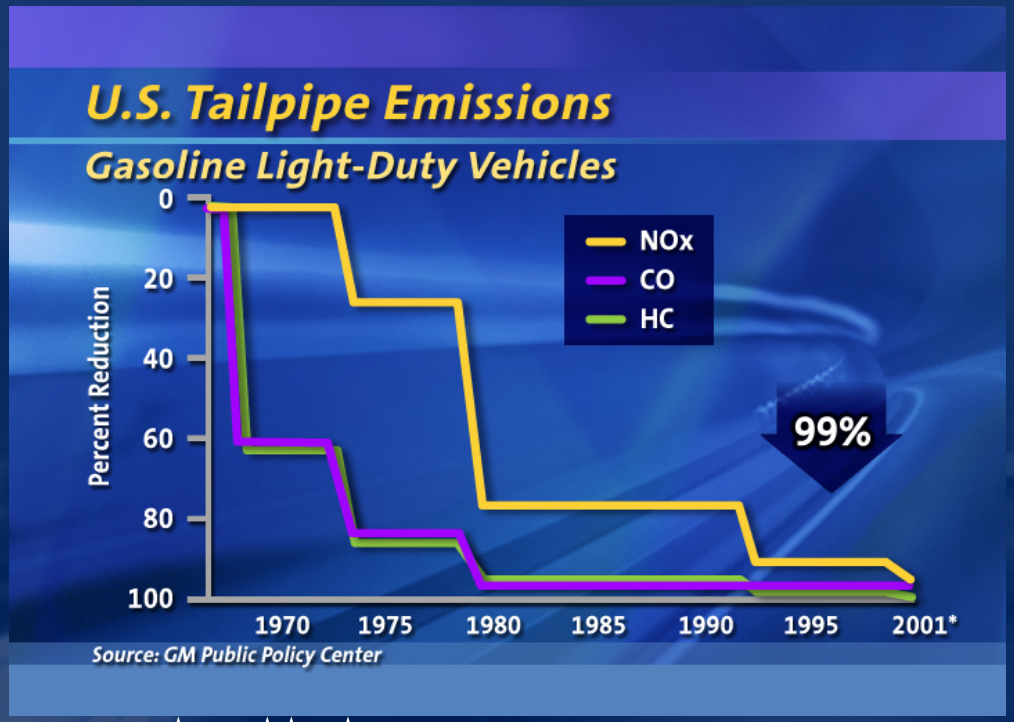


SULEV Requirement!

HC: 99.8%
NOx: 99.5%

Source: GM Public Policy Center

GM's leadership in enabling the Federal Clean Air Act



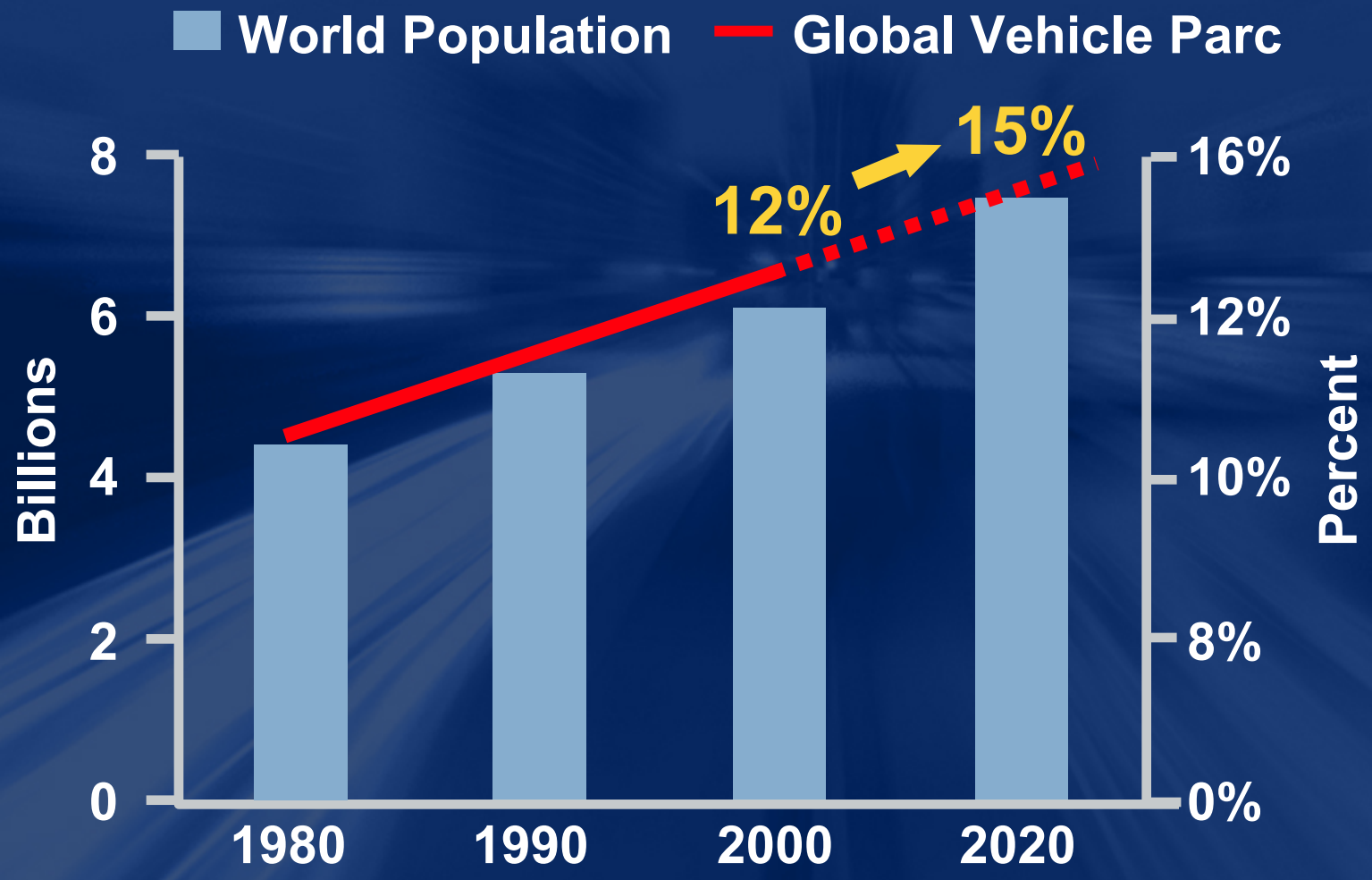
1960s Development of Catalytic Converter at GM

1970 Ed Cole announces emissions control program – driving unleaded gasoline nationwide in US

1970: GM introduces no lead tolerant engines on all 1971 models in US & Canada

1974: GM introduces the catalytic converter on all 1975 models sold in US and Canada

Transportation is a growth industry!



Sources: U.S. Census Bureau International Population Database, GM Global Market & Industry Ana

Automotive Growth Opportunity

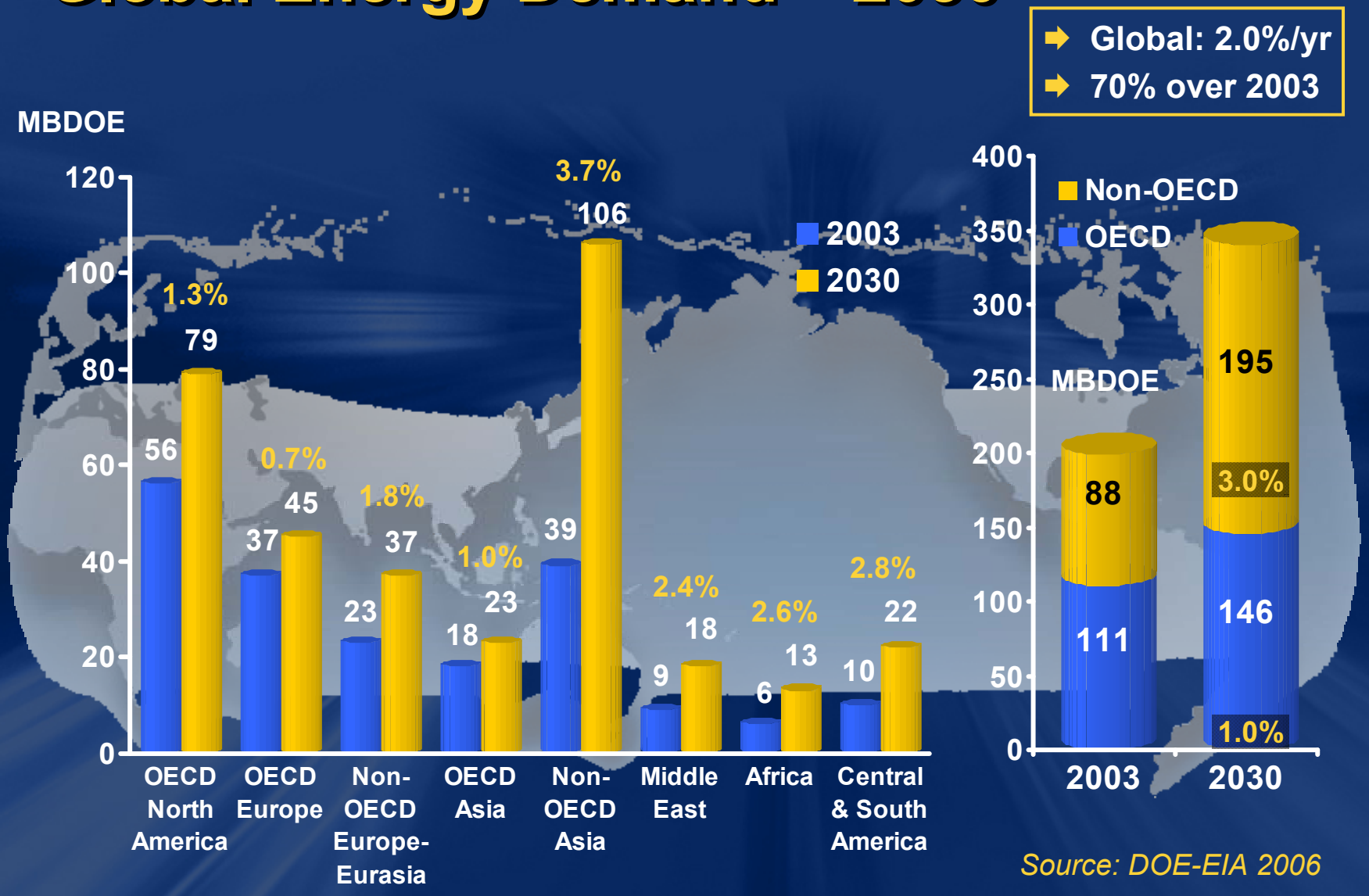
70%

of growth from *10* emerging markets

Industry Challenges

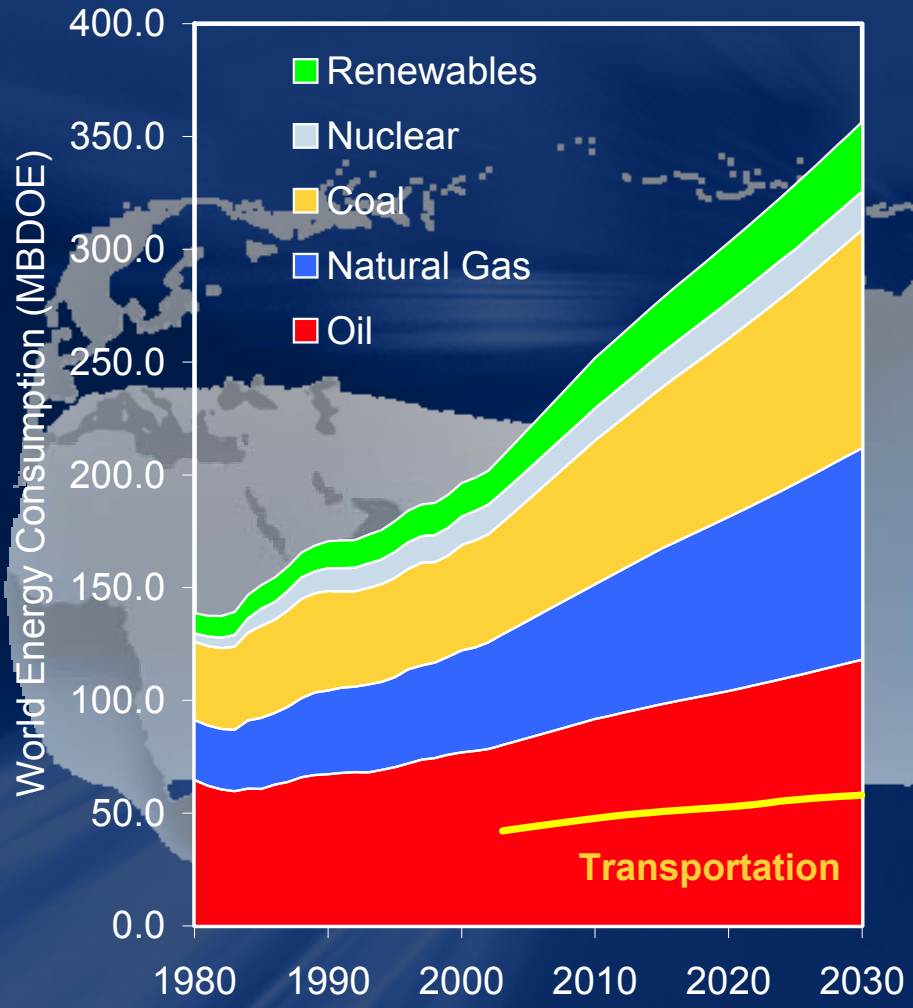
- Energy
- Environment
- Safety
- Congestion
- Affordability

Global Energy Demand – 2030



Source: DOE-EIA 2006

Global Energy Consumption to 2030

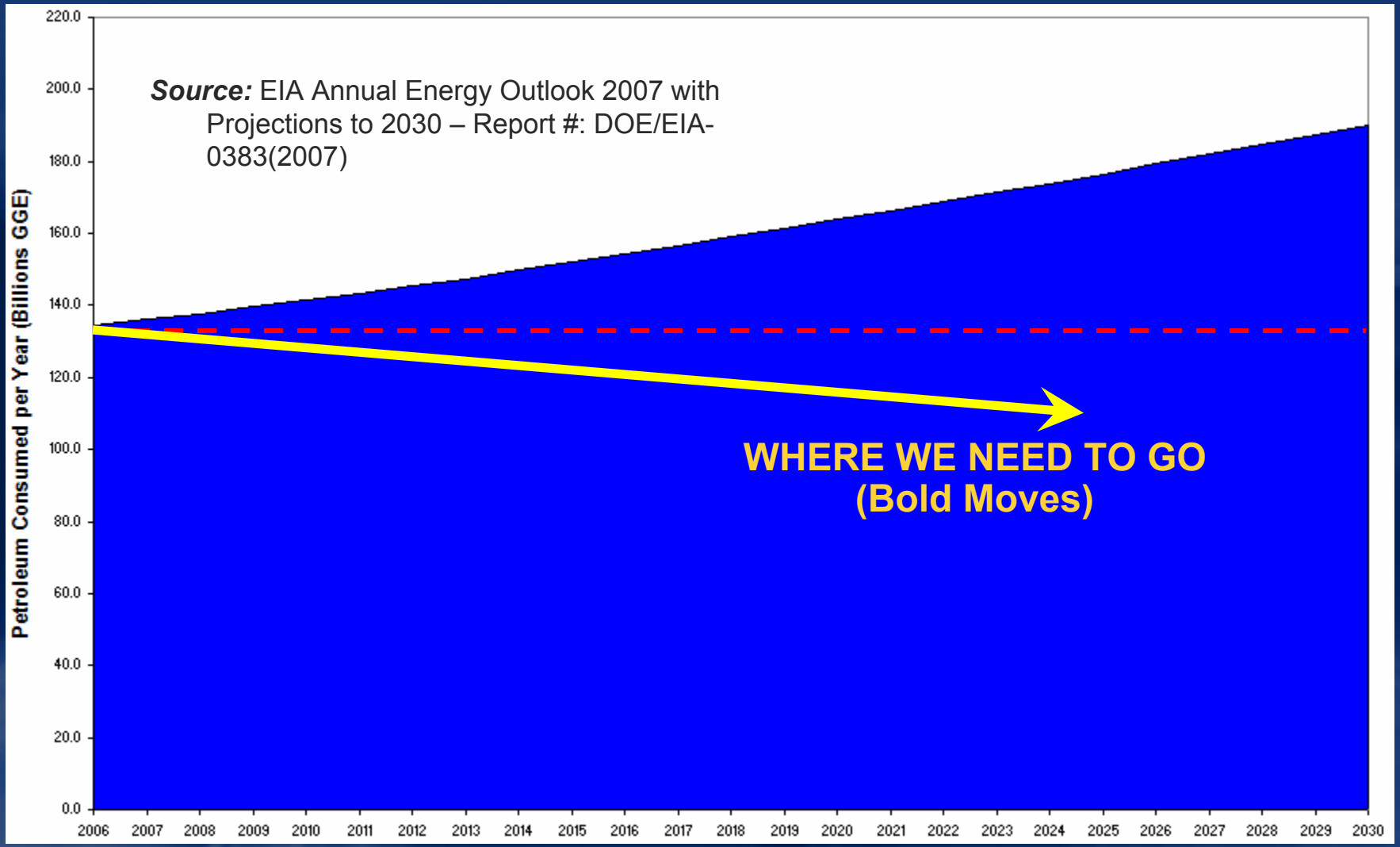


Source: DOE-EIA 2006

Oil

- 2006: 85MBD
  1,000 barrels/second !
- 2030: 120 MBD projected
- 50% used for transportation
- Transportation is 98% dependent on petroleum

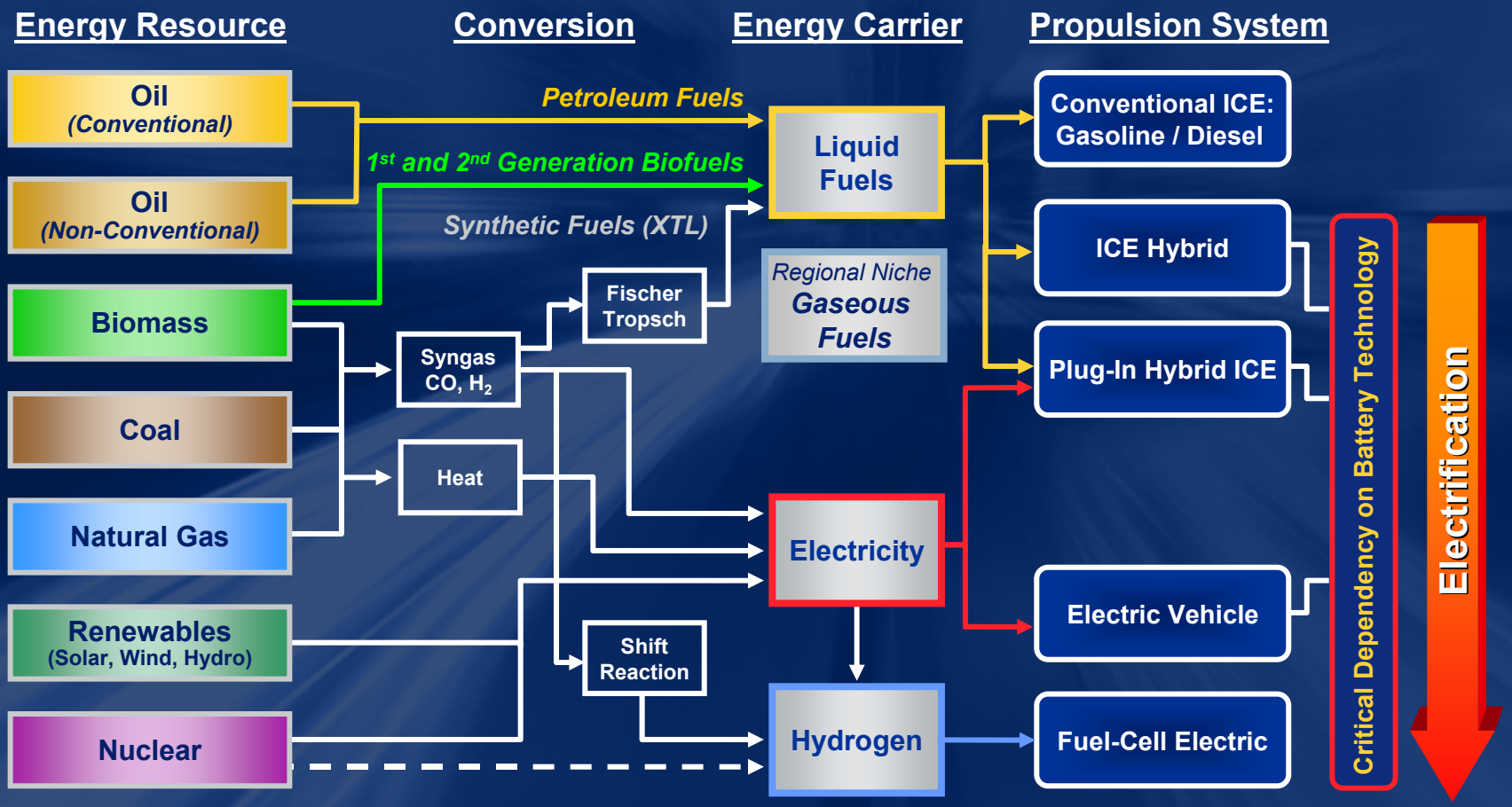
U.S. Petroleum Consumption by Automobiles




GM Strategy: Energy DIVERSITY
to Displace Petroleum

Alternate Resources – A Blending Strategy

Liquid Fuels / Electricity / Hydrogen as the In-Vehicle Energy Carriers



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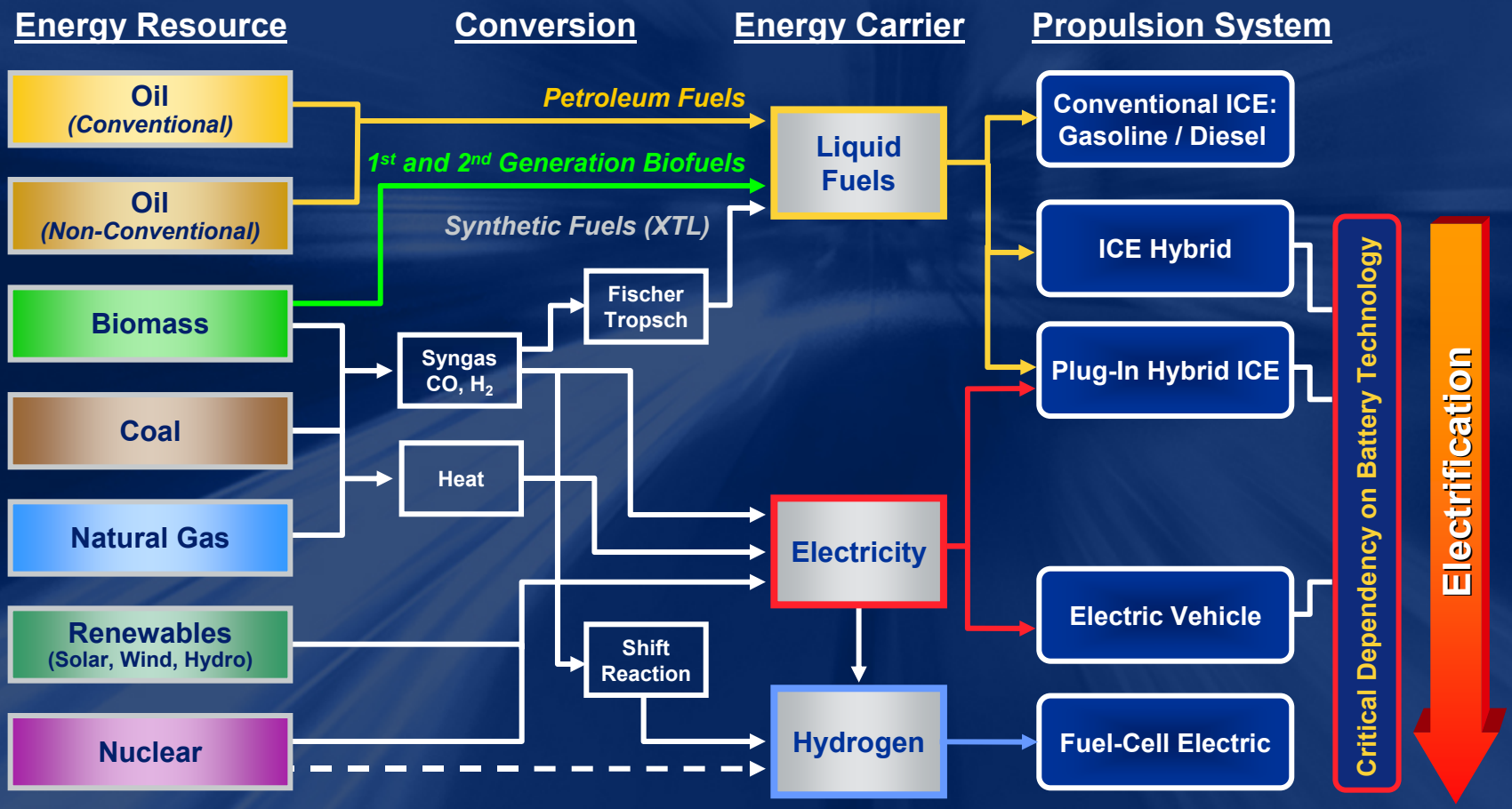


EXTRA-HEAVY OIL/OIL SANDS

Location: Venezuela/Canada

Quantity: Venezuela - 1.36 Tbbl resource, 270 Bbbl recoverable

Canada - 2.5 Tbbl resource, 315 Bbbl recoverable

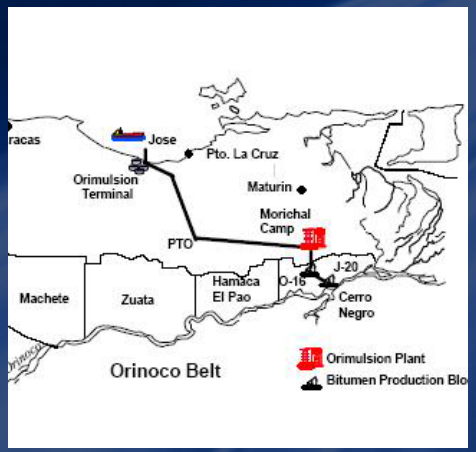
Source: AEO2006 EIA

(Note: Saudi Arabia - 270Bbbl recoverable)

Production: 5.3 - 8.5 Mbbl/day by 2030, depending on crude price

source: AEO2006 EIA

1.2 Mbbl/day in 2005 *Geological Survey of Canada 2005*



Issues:

Investment requires <u>sustained</u> high crude prices (> $30/bbl), inherently more expensive than Middle East crude

Water/process energy availability, GHG emissions

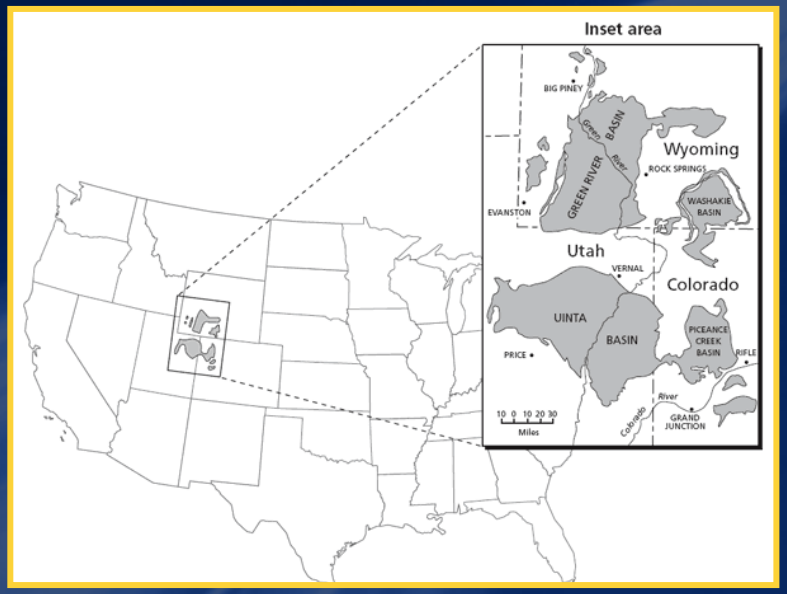
Can slow, not eliminate, falloff in world crude production

SHALE OIL

Location: Worldwide (U.S. resource - Utah, Wyoming, Colorado)

Quantity: Worldwide - 2.9 Tbbl recoverable
U.S. West - 750 Bbbl recoverable
source: AEO2006 EIA

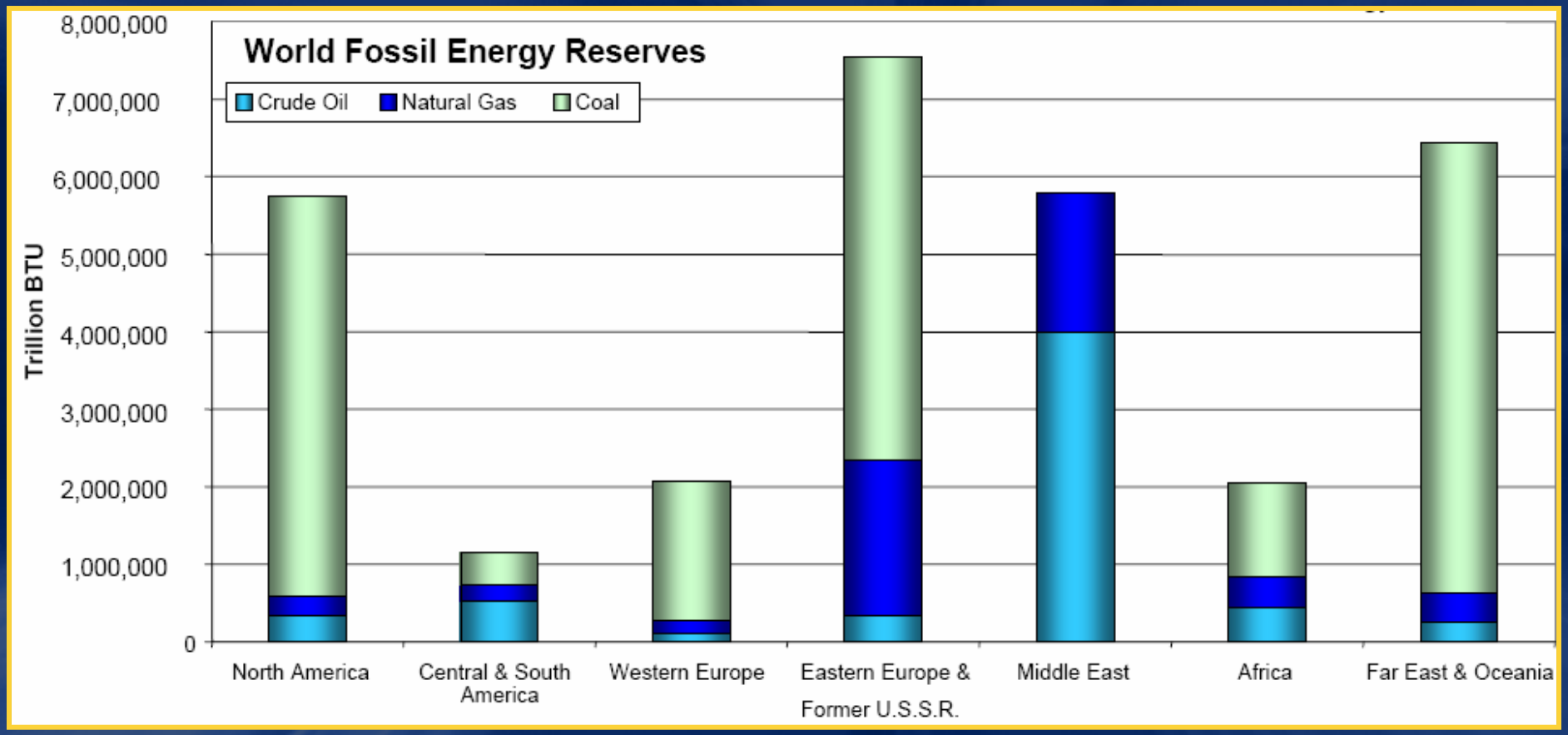
Production: 0.43 Mbbl/day by 2030, depending on crude price
source: AEO2006 EIA



Issues:
Investment requires sustained very high crude prices ($55-$70 bbl conventional mining, estimated $35-$48 bbl by 2030)

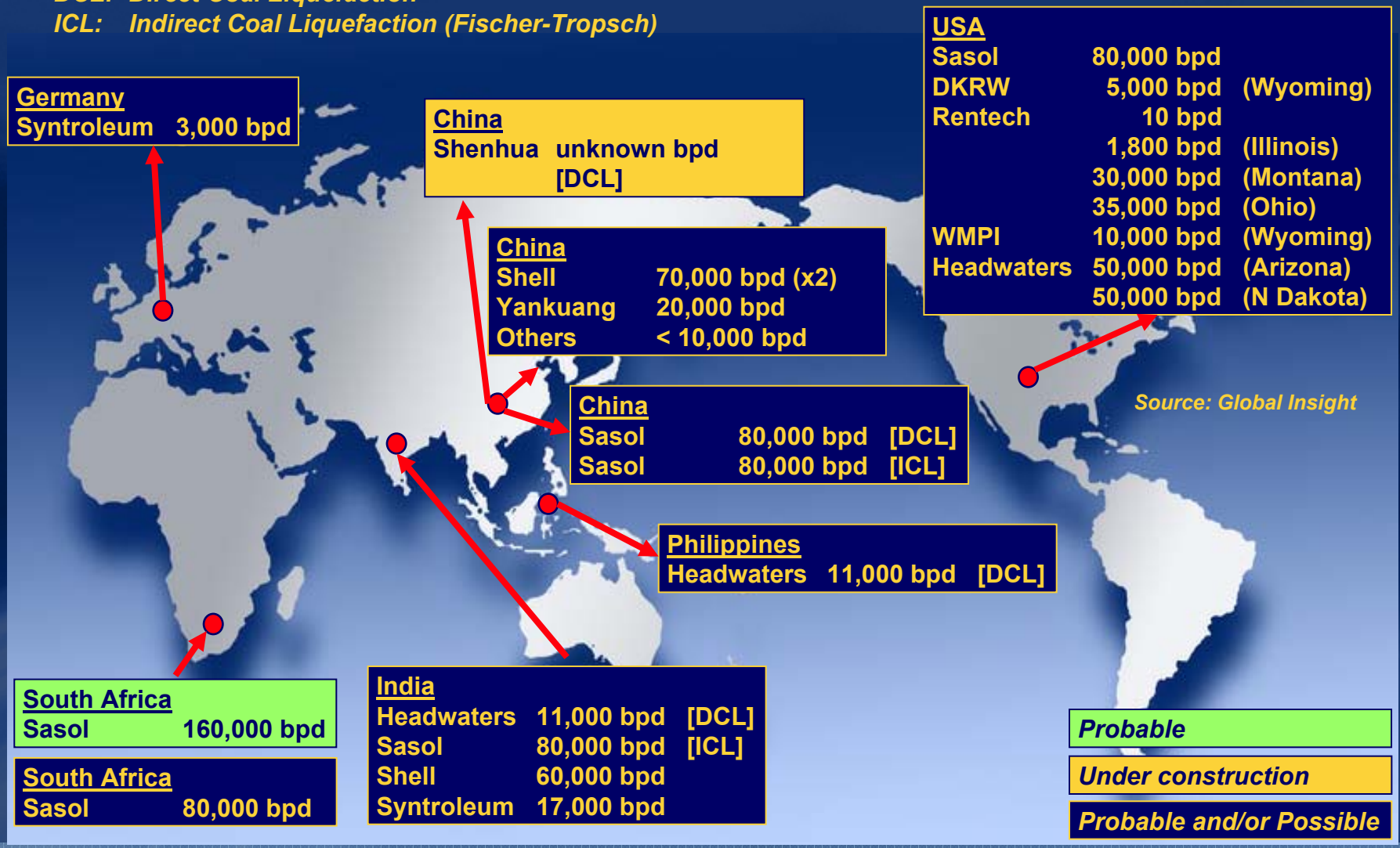
Water/process energy availability, GHG emissions

World Fossil Energy Reserves



Coal-to-Liquids (CTL) Growth

DCL: Direct Coal Liquefaction
ICL: Indirect Coal Liquefaction (Fischer-Tropsch)



Germany
Syntroleum 3,000 bpd

China
Shenhua unknown bpd [DCL]

China
Shell 70,000 bpd (x2)
Yankuang 20,000 bpd
Others < 10,000 bpd

China
Sasol 80,000 bpd [DCL]
Sasol 80,000 bpd [ICL]

USA

Sasol	80,000 bpd	
DKRW	5,000 bpd	(Wyoming)
Rentech	10 bpd	
	1,800 bpd	(Illinois)
	30,000 bpd	(Montana)
	35,000 bpd	(Ohio)
WMPI	10,000 bpd	(Wyoming)
Headwaters	50,000 bpd	(Arizona)
	50,000 bpd	(N Dakota)

Source: Global Insight

Philippines
Headwaters 11,000 bpd [DCL]

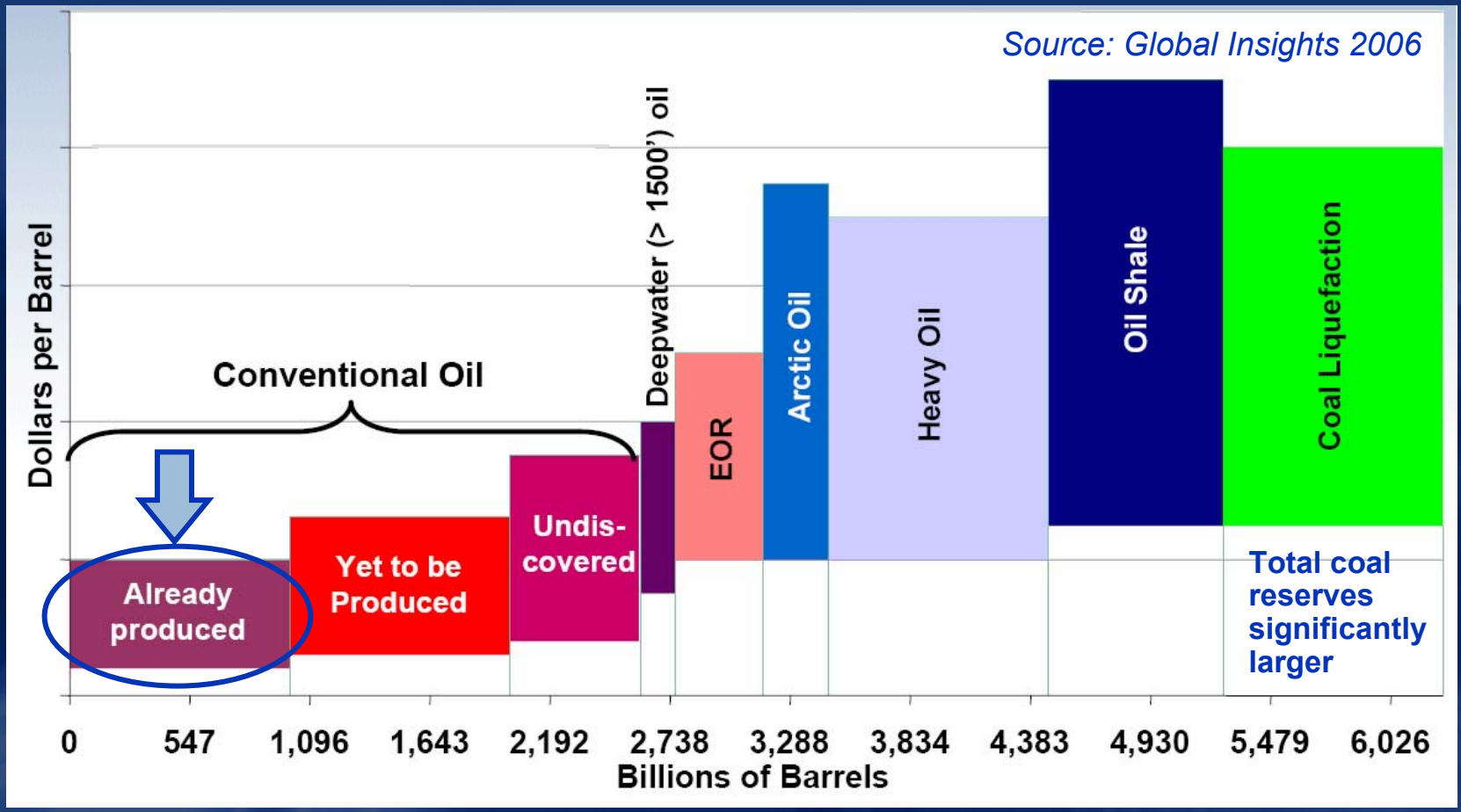
South Africa
Sasol 160,000 bpd

South Africa
Sasol 80,000 bpd

India
Headwaters 11,000 bpd [DCL]
Sasol 80,000 bpd [ICL]
Shell 60,000 bpd
Syntroleum 17,000 bpd

Probable
Under construction
Probable and/or Possible

Alternate fossil fuel resources

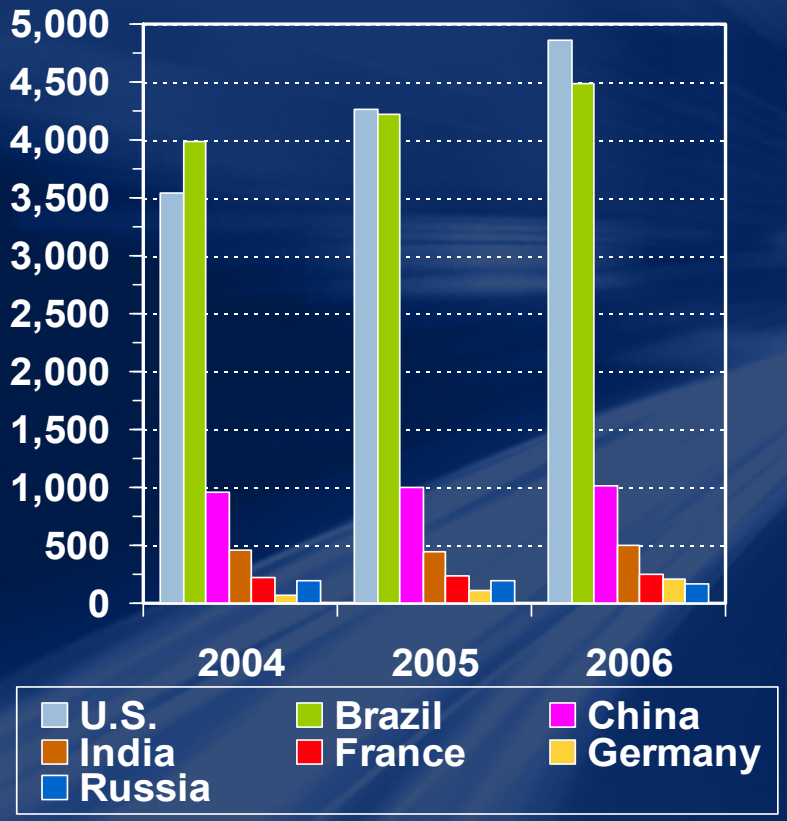


- Very large reserves to produce liquid fuel from unconventional oil & coal
- Issues: Cost, CO_2 emissions and large energy required to extract

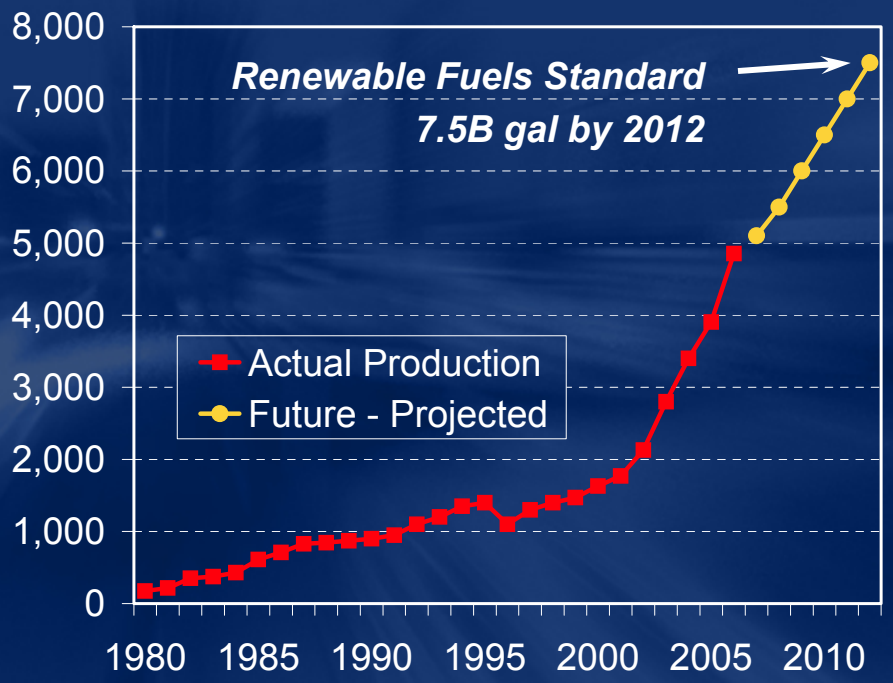
BIOFUELS

Biomass Production and Potential

Global Production



US Production

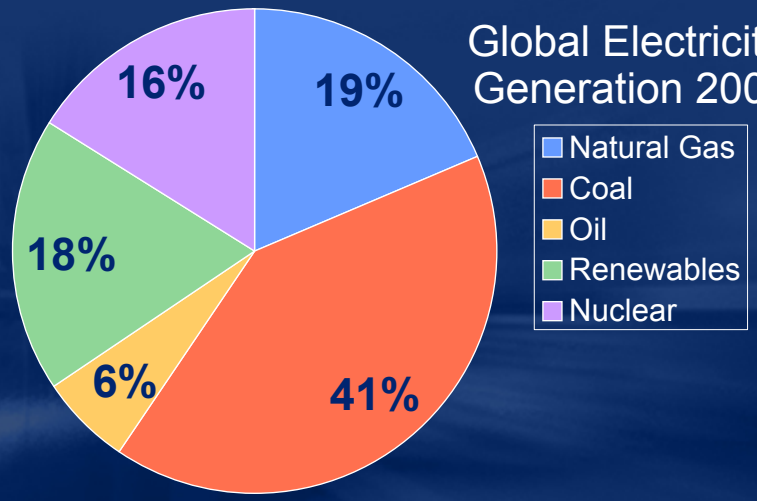


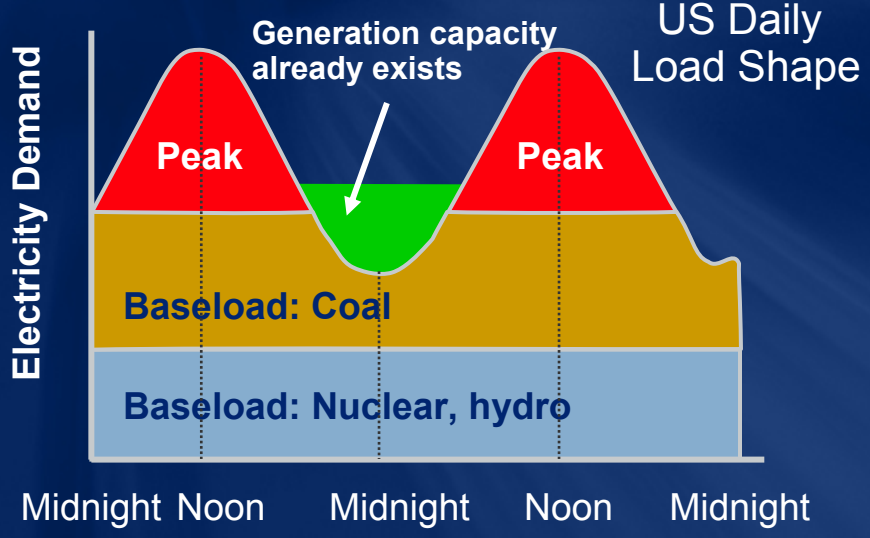
US Biomass Potential:
1.3B Tons Per Year by 2030 (DOE)
= ~100B gallons ethanol
(~65B gallons gas equivalent)
= 46% of actual usage in 2006
= 34% of projected usage in 2030

Electricity: Energy Diversity Exemplified

- Diverse energy sources are used for electricity generation – based on local resources
- Existing, global infrastructure with clearly-defined standards
- Efficient transmission system
- Spare generation capacity exists: US “valley filling” up to 43% of light-duty fleet *
- Energy from Renewables (17%)
  - High growth (~52%) but just keeping up with overall demand growth
  - Hydropower already maximized

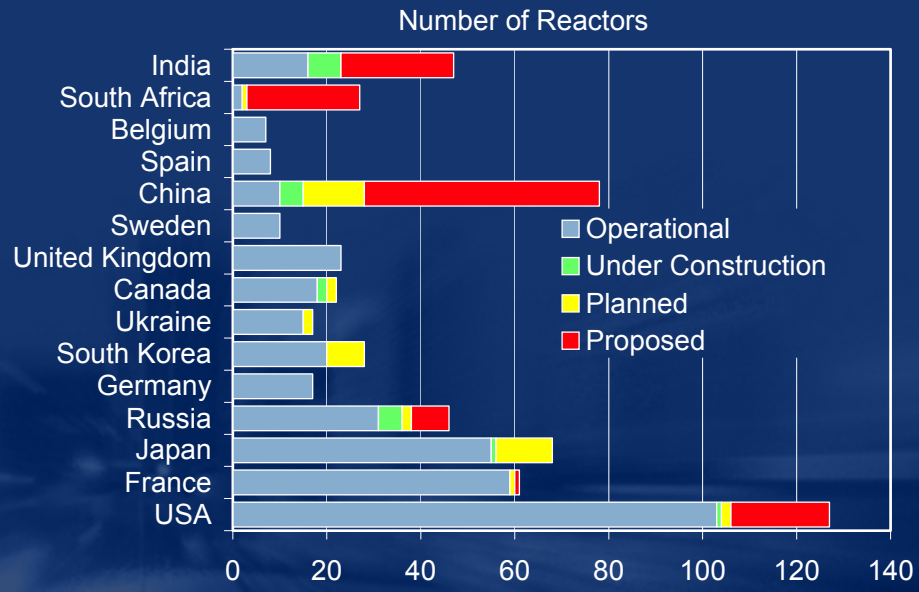
** PNNL Report 2007; 33miles/day commute*

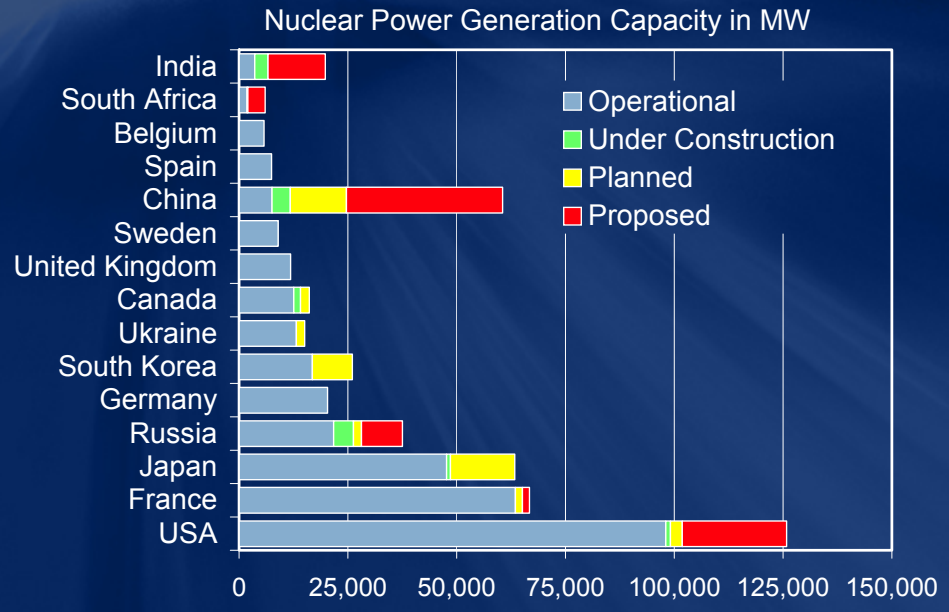




Nuclear Energy

- 16% of global electricity generated (2005; 16 trillion kWh)
  - 442 reactors
  - 370 GW capacity
- Current projections indicate significant additional capacity approved / being constructed
  - 80 reactors
  - 80 GW capacity
- Proposed capacity additions:
  - 152 reactors
  - 107 GW capacity
- China has 10 reactors, with 18 under construction / approved and 50 more proposed





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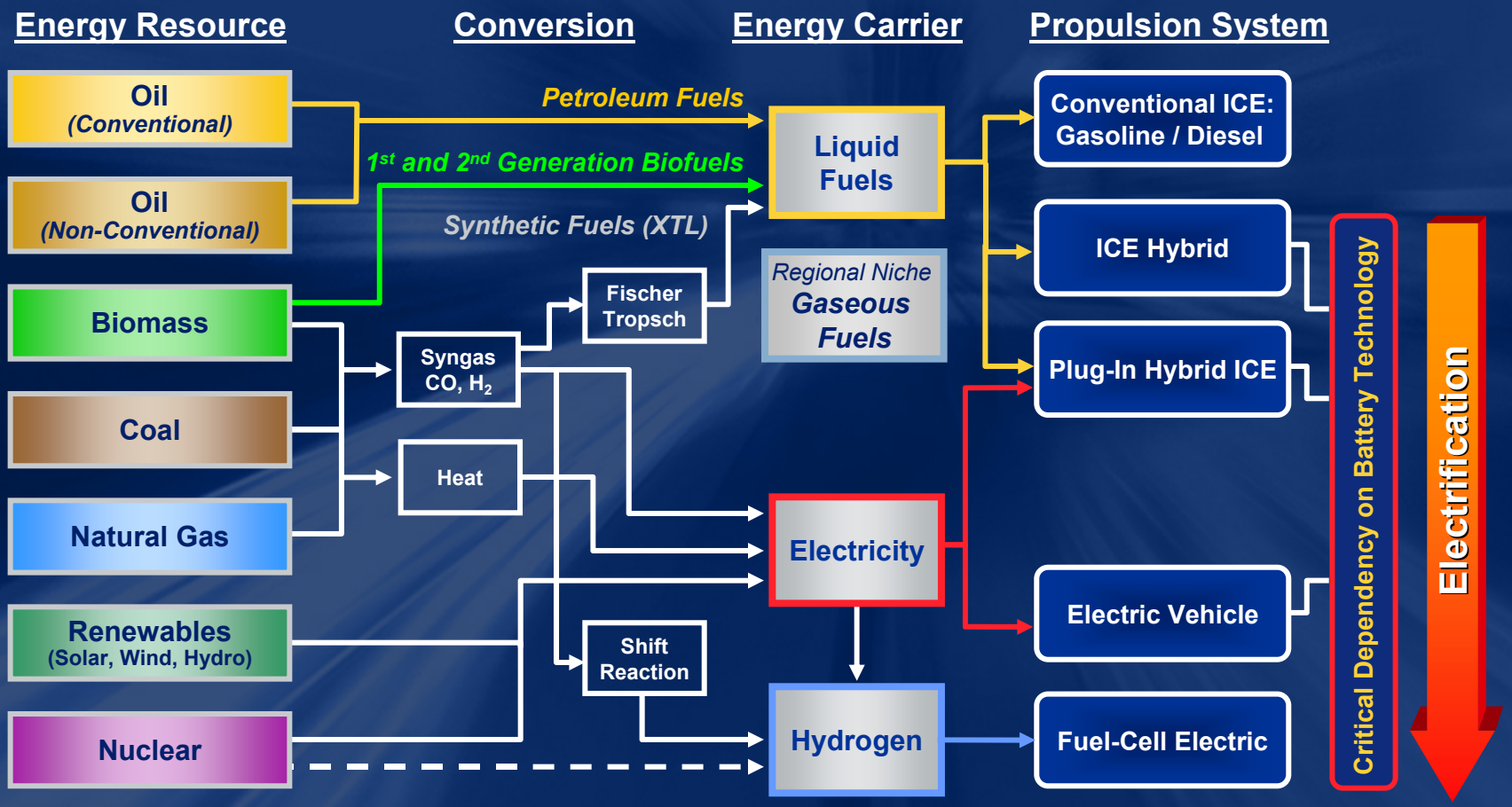
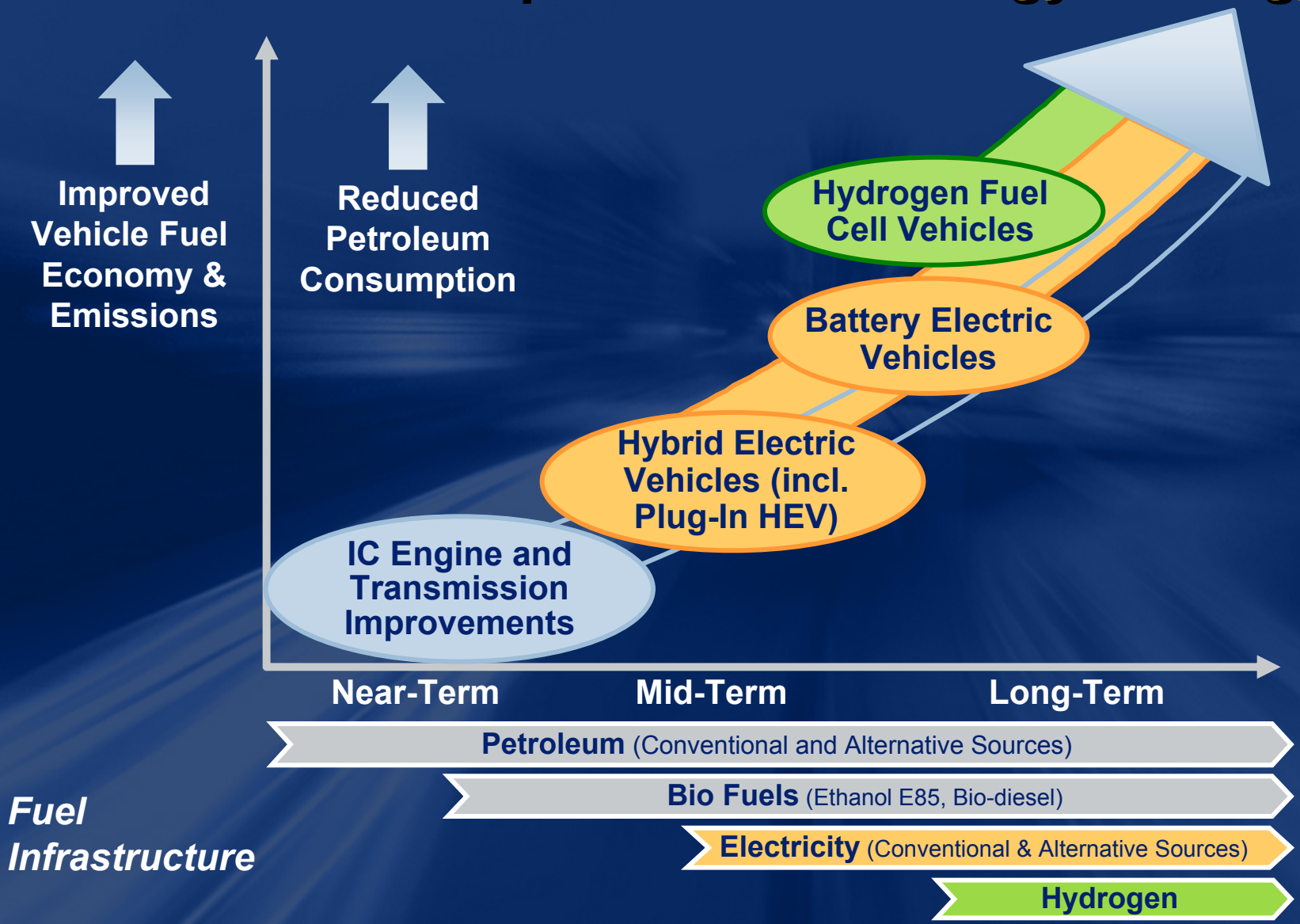


GM Advanced Propulsion Technology Strategy



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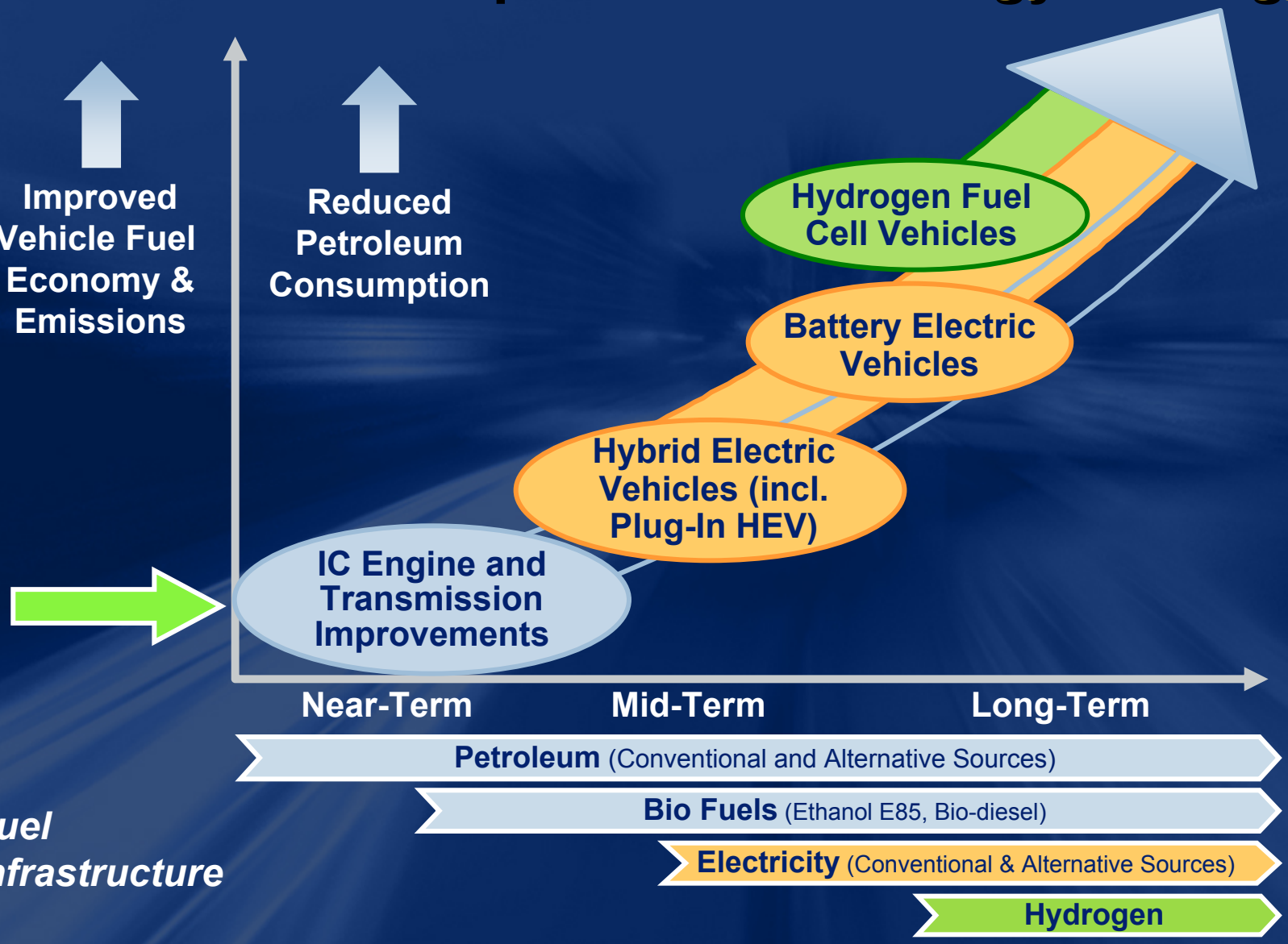
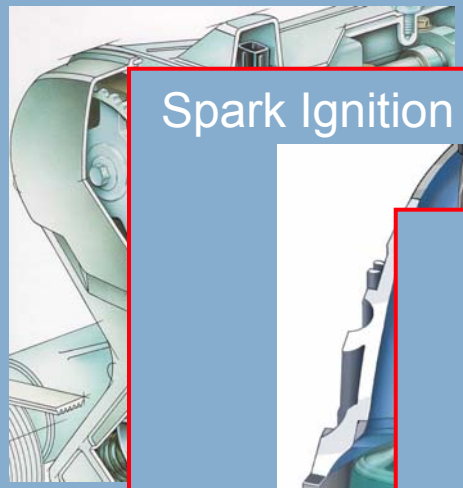
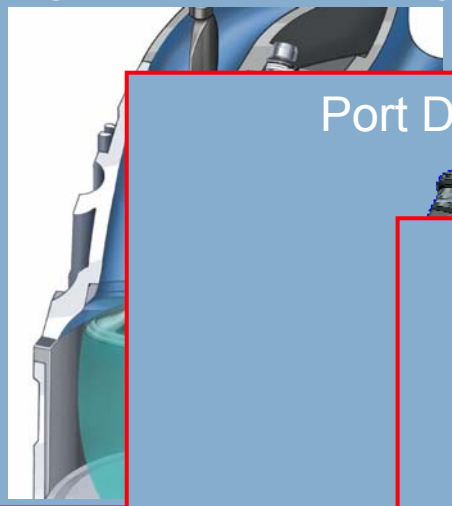


Achieving the Upper Potential of Gasoline Engines

Cam Phasing



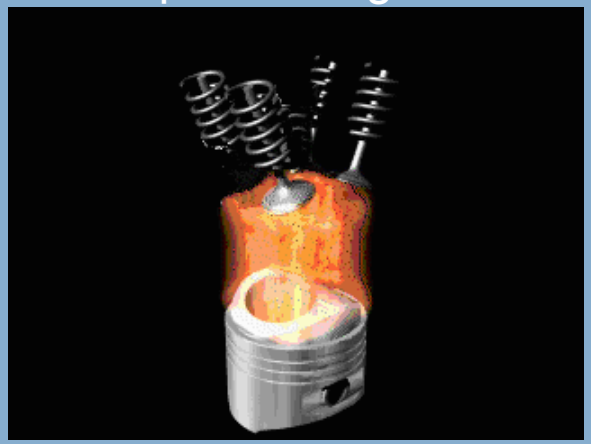
Spark Ignition Direction Injection



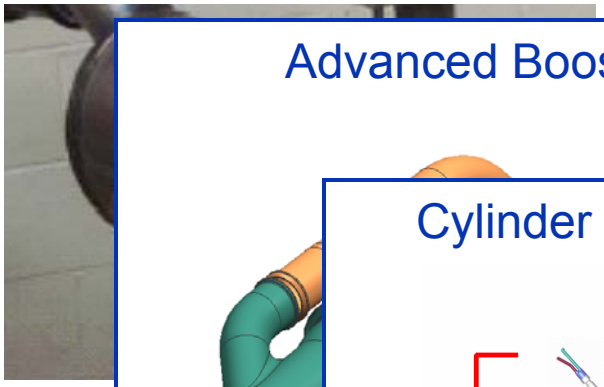
Port Deactivation

2-Step VVA

Homogenous Charge Compression Ignition

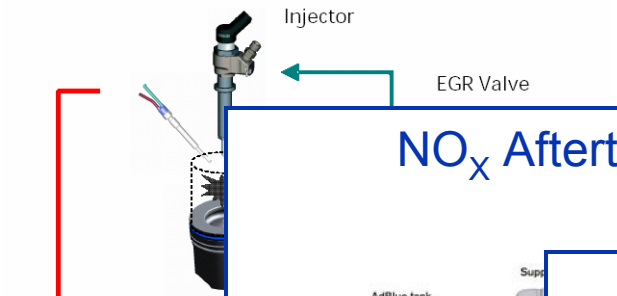


Diesel Particulate Filter

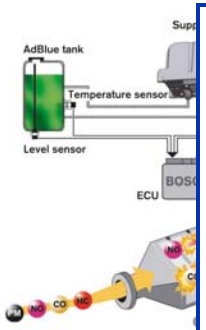


Advanced Boosting

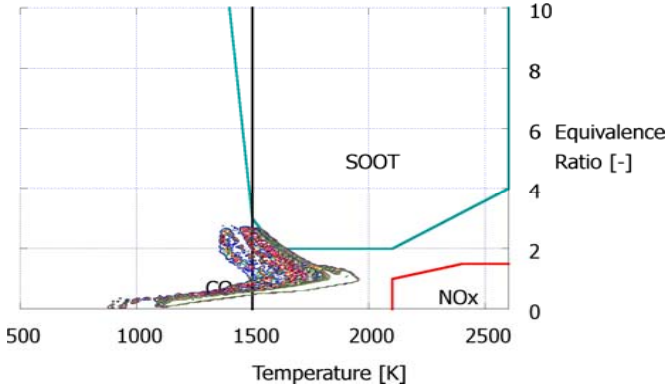
Cylinder Pressure Sensing



NO_X Aftertreatment



PCCI Combustion



Enhanced EGR Cooling

PCCI Pre-Mixed Charge Comb.

HCCI Homogeneous Combustion

GMPT Global Portfolio Diesel Engines

1.3L I-4 CDTi
90 hp / 200 Nm (148 lb-ft)

1.7L I-4 CDTi
125 hp / 280 Nm (207 lb ft)

1.9L I-4 CDTi
150 hp / 320 Nm (236 lb ft)

2.0L I-4
150 hp / 310 Nm (229 lb ft)

NEW IN 2009 – Europe

2.9L V-6
250 hp / 550 Nm (406 lb ft)

3.0L V-6 CDTi
180 hp / 420 Nm (310 lb ft)

NEW IN 2009

Duramax 4.5L V-8
310 hp / 704 Nm (520 lb ft)

Duramax 6.6L V-8
365 hp / 895 Nm (660 lb ft)

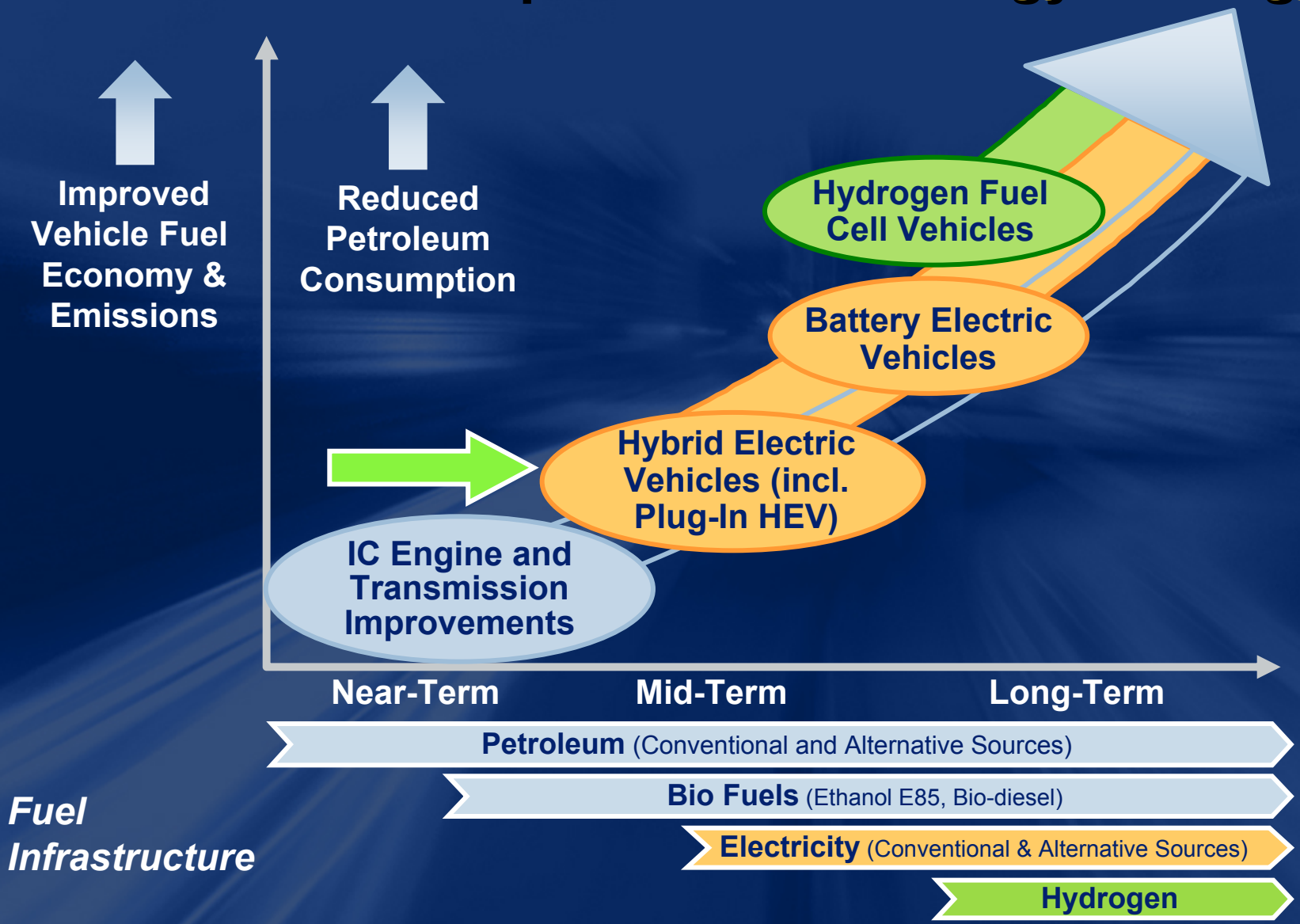
Global Renewable Fuels

In U.S., GM has over 2 million FlexFuel E85-capable vehicles on the road. Building >400,000 more every year.

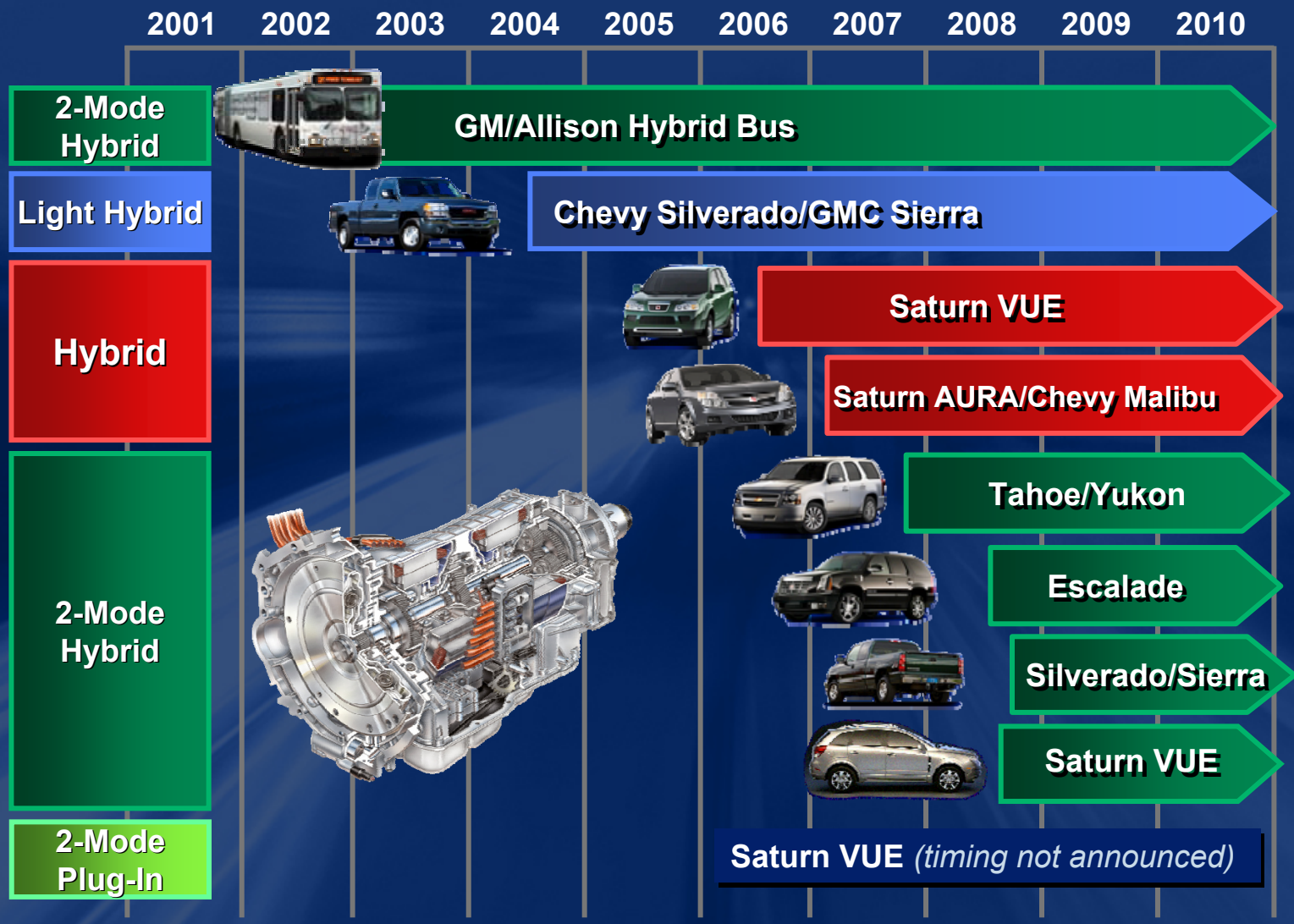
In Brazil, FlexPower is now available in every passenger car model. FlexPower models account for 90% of sales.

In Sweden, Saab leads the environment-friendly car segment with 9-5 BioPower, accounting for 85% of Saab 9-5 sales.

GM Advanced Propulsion Technology Strategy

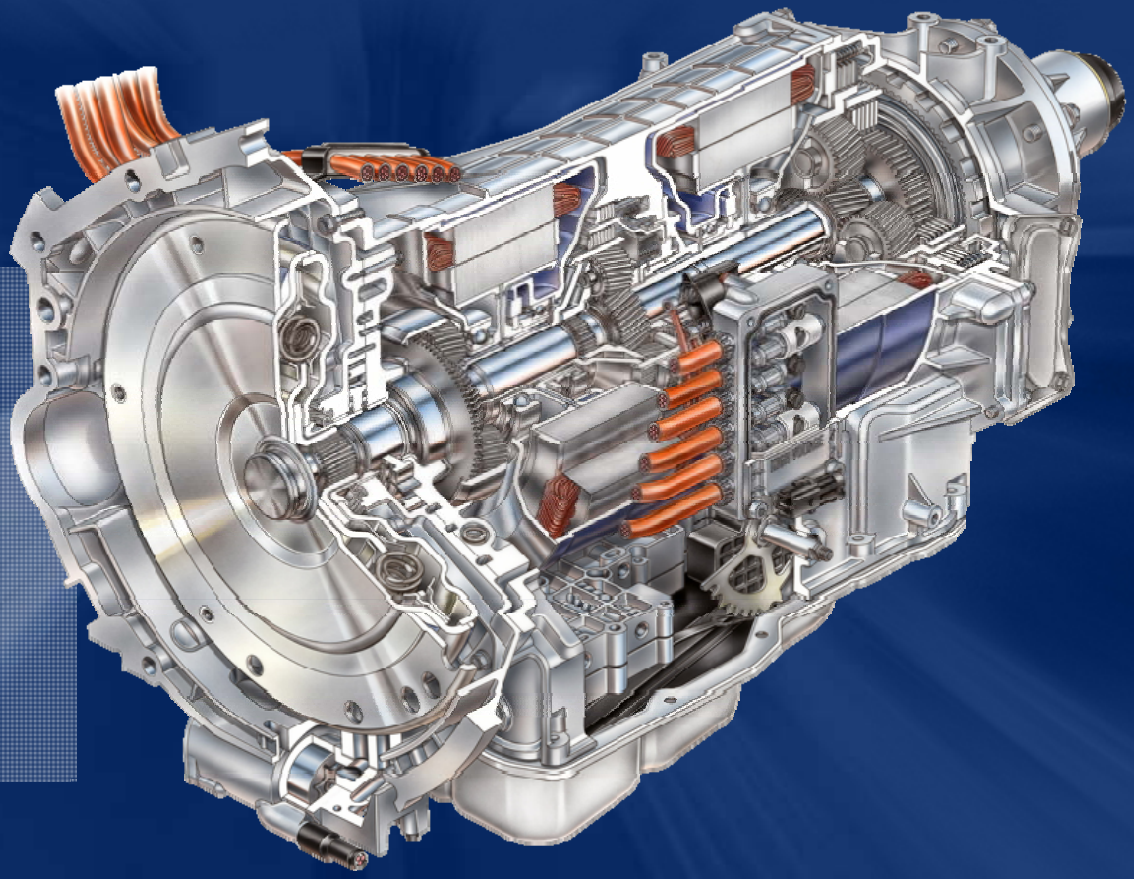


GM Hybrid Portfolio



HYBRID 2MODE

- 288V NiMH Battery
- 2-Mode Operation
- 2 X 60KW Motor/generators




TAHOE
HYBRID
2 MODE
GM

2-Mode Hybrid - Joining Hybrid Forces

GM-DC MoU, 13.12.2004

USA TODAY

BMW joins DaimlerChrysler, GM in hybrid car project

FRANKFURT (Reuters) — German luxury carmaker BMW has joined DaimlerChrysler (DCX) and General Motors (GM) in an alliance to develop hybrid vehicle technology, DaimlerChrysler and GM said Wednesday.

Bloomberg.com

BMW Joins GM, DaimlerChrysler to Develop Gas-Electric Engines

washingtonpost.com

BMW joins DaimlerChrysler/GM hybrid project

By Michael Shields, European Automotive Correspondent
Reuters
Wednesday, September 7, 2005; 9:04 AM

sueddeutsche.de

BMW schließt sich Hybrid-Allianz von GM und DaimlerChrysler an

DC-GM-BMW MoU, 12.09.2005

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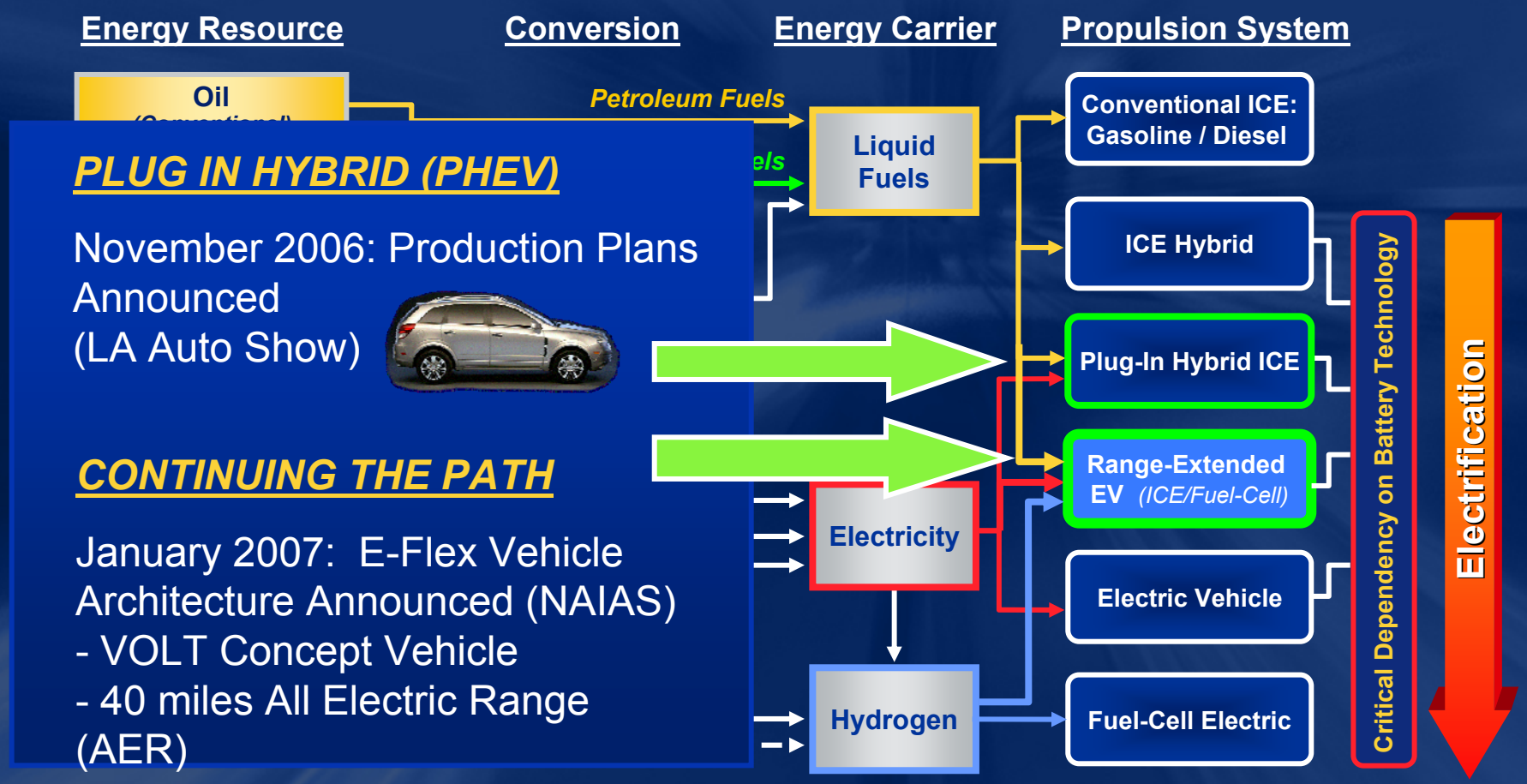
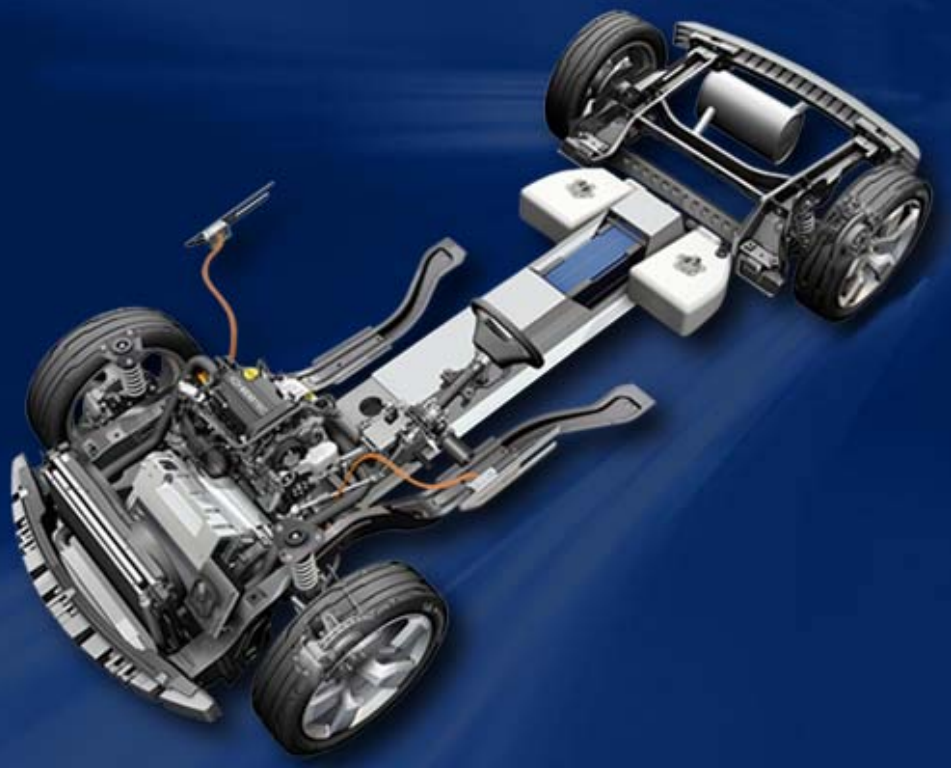



VOLT
E FLEX

Chevy Volt Concept



Electric Drive Motor

- 120 kW / 320Nm (peak)

Li Ion Battery Pack

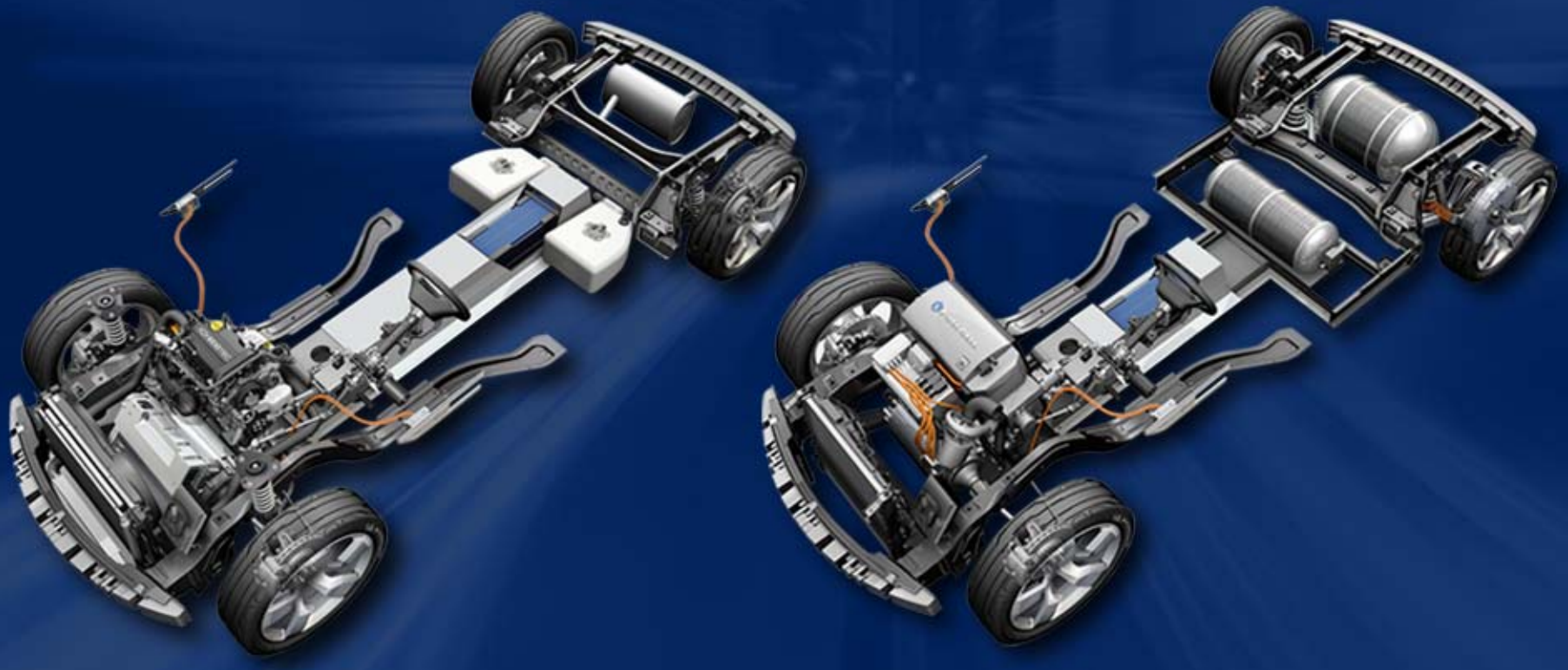
- 136 kW peak power
- 16 kWh energy

53 kW Generator

- Internal Combustion Engine
- 1.0L 3-cylinder turbo

Range-Extended EV

FUEL CELL



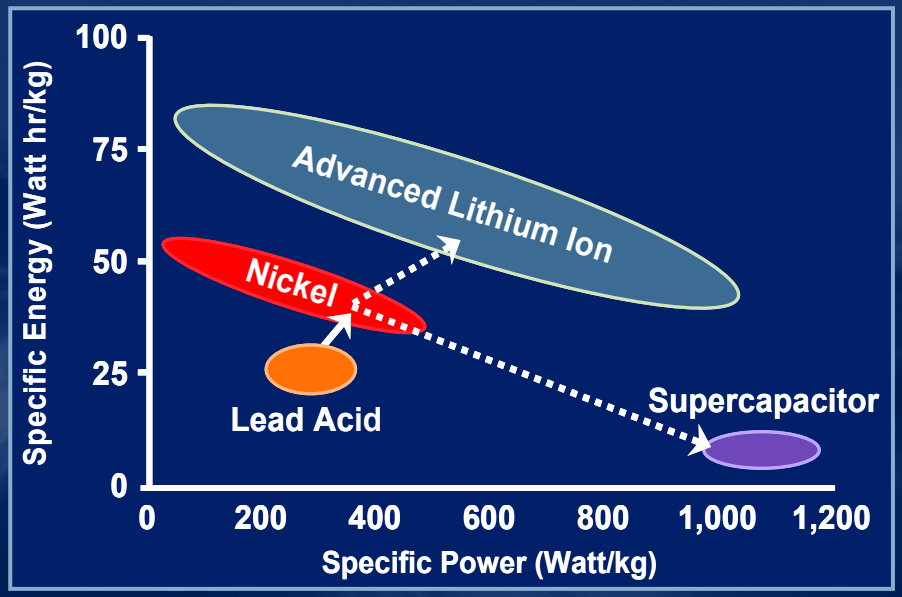
Range-Extended EV

FUEL CELL

Advanced Battery Technology

Much improvement over time

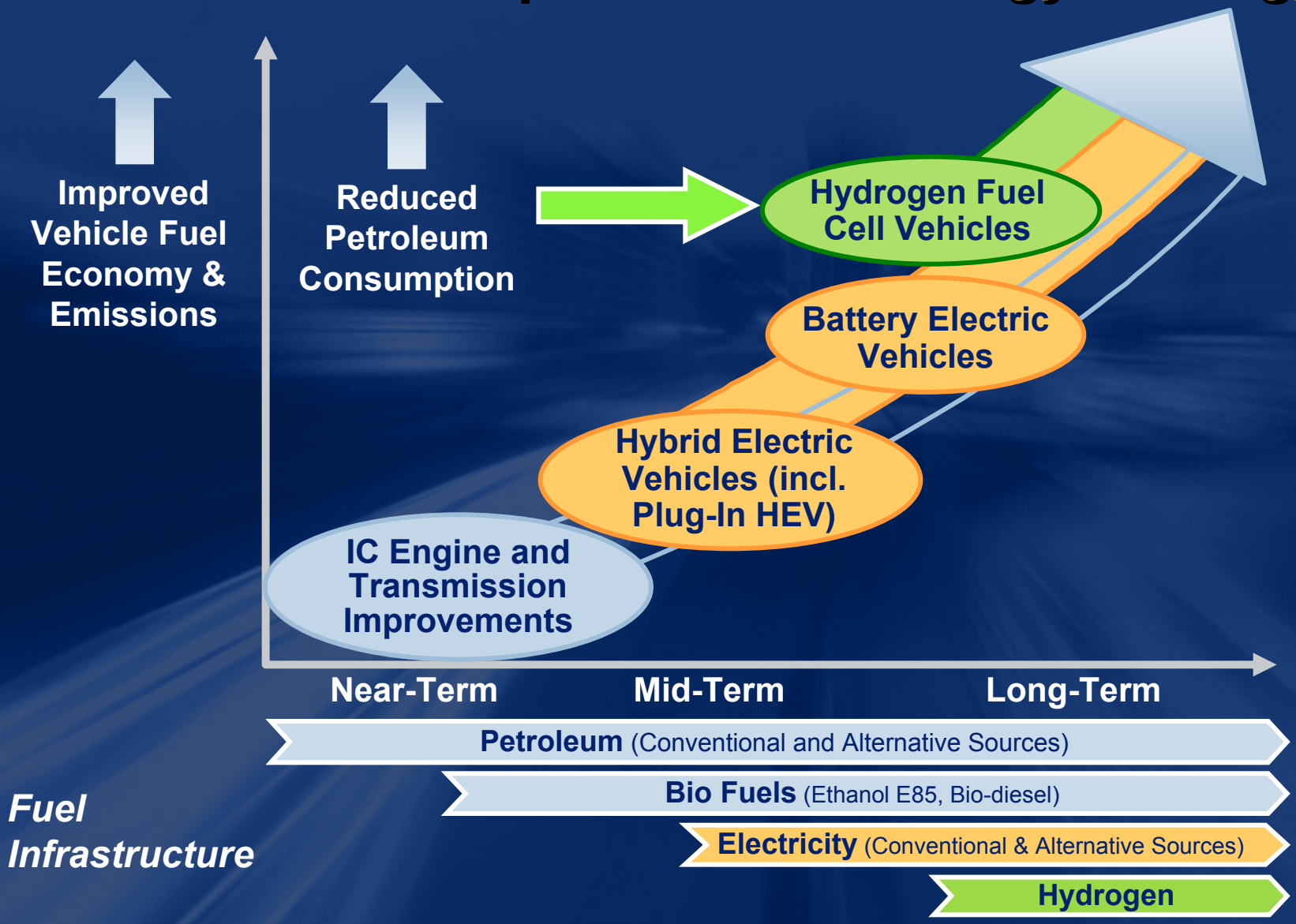
- Focused on “power” for hybrids, NOT “energy” for plug-ins and pure electric vehicles
- Lithium-ion chemistry can provide both power and energy



Greatest hurdle: Develop large, high-volume lithium-ion battery packs

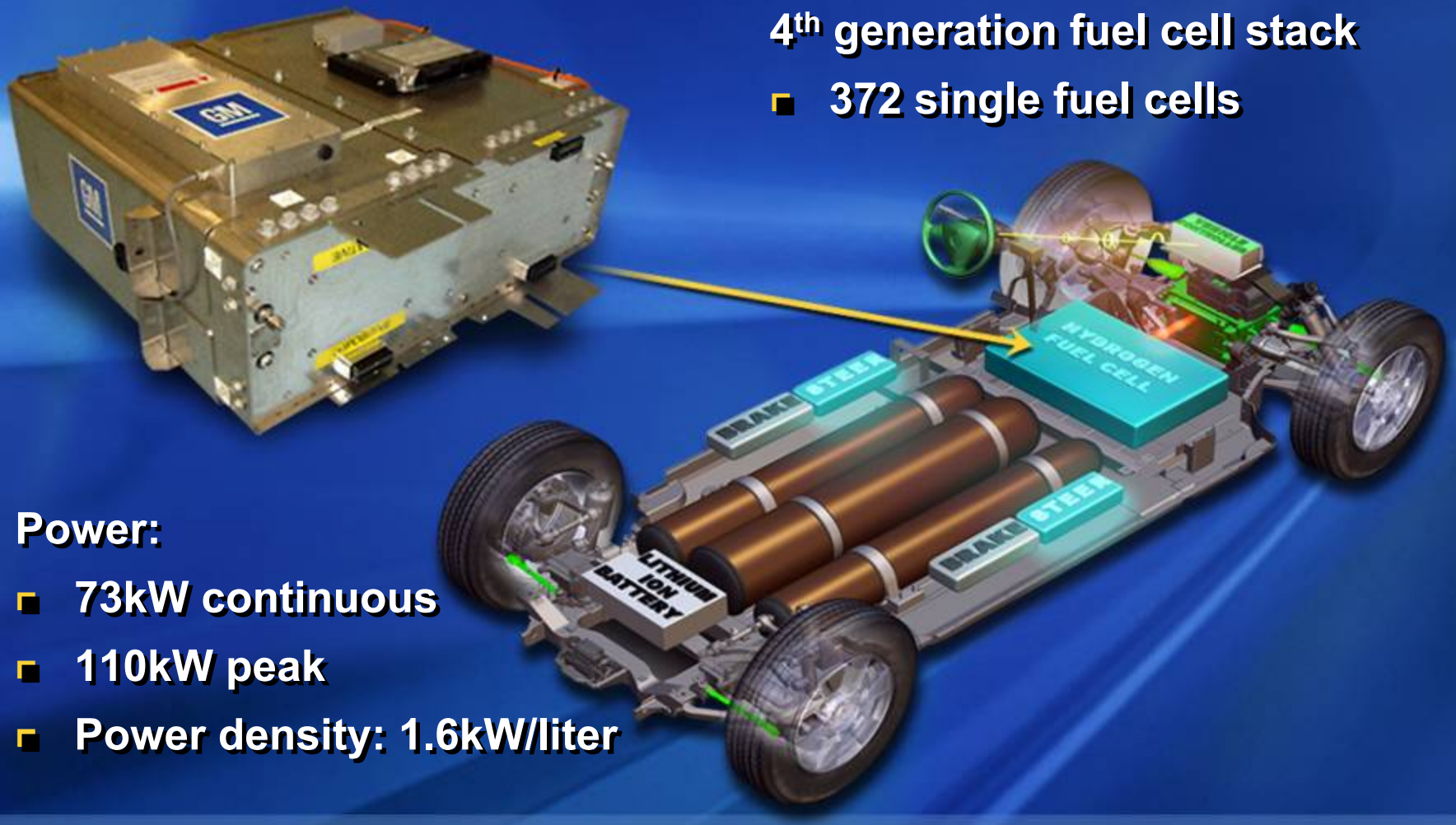
- Individual cells that meet requirements exist
- Cost ($/kWh)
- Requires intensive development with battery sources

GM Advanced Propulsion Technology Strategy




HYDROGEN3
HY◆WIRE
HYDROGEN3
SEQUEL
AUTONOMY

GM's Newest Fuel Cell Stack



- 4th generation fuel cell stack
- 372 single fuel cells

Power:

- 73kW continuous
- 110kW peak
- Power density: 1.6kW/liter

Project Driveway - 100 Vehicle Fleet

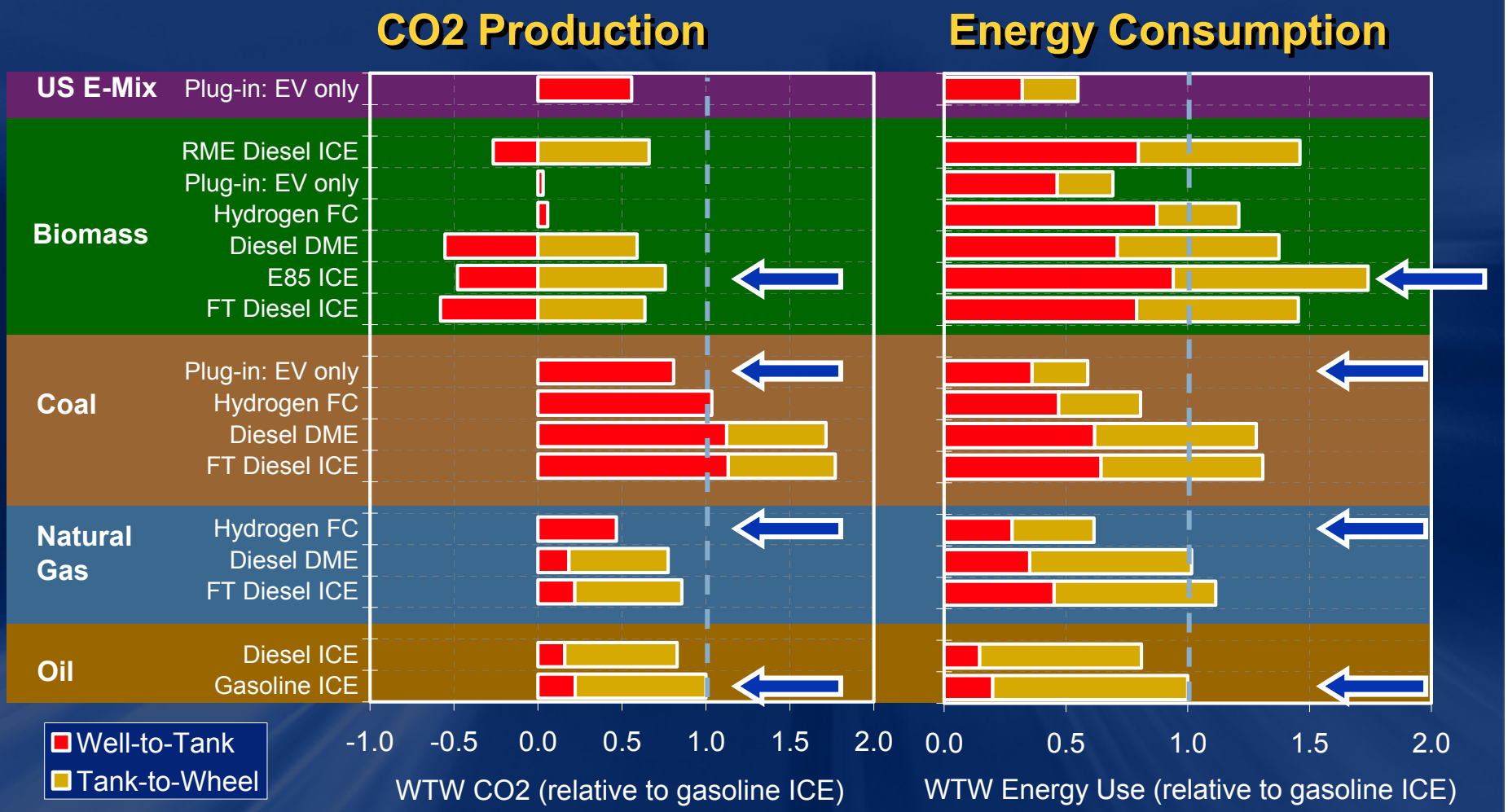
- World's largest fuel cell vehicle fleet
- With customers later this year
- 4th-generation fuel cell propulsion
- Engineered for 50,000 miles of life
- Able to start and operate in sub-freezing temperatures.

Well-to-Wheels Analysis

Well-to-Tank

Tank-to-Wheels

Energy Pathways – Well-to-Wheels



Based on 2006 EUCAR/CONCAWE and GM 2005 WTW

In Summary

Demand

- 85MBD = 1,000 barrels / second!
- 70% growth through 2030
- US petroleum usage:
  140B gallons growing to 190B gallons (2030)

Supply

- Energy diversification required (reduce petroleum)
- Blending energy carrier strategy:
  coexistence of liquid fuels, electricity & hydrogen
  as the on-vehicle fuels

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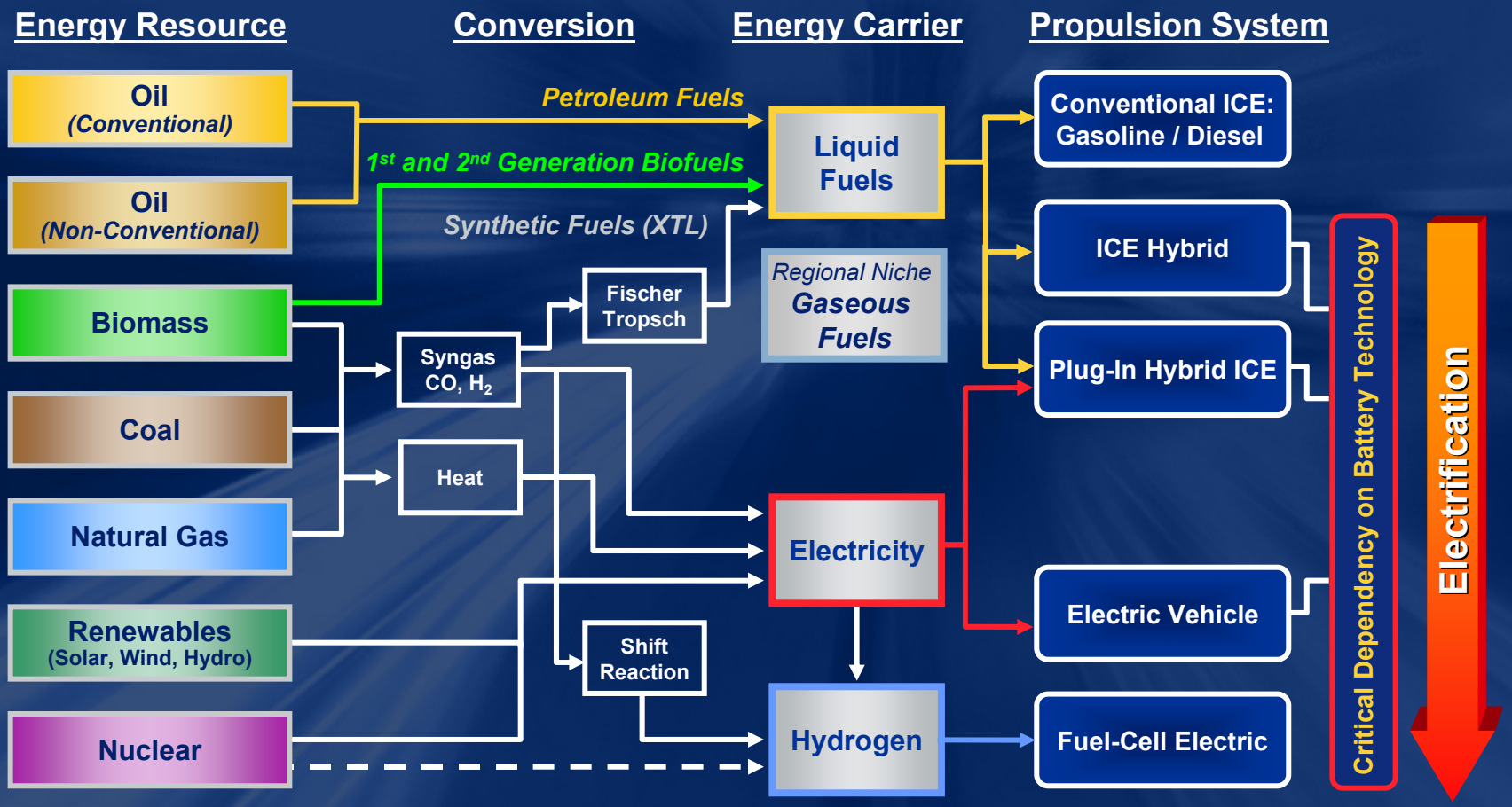

GM's Commitment

Promote & execute a "Blending Energy Carrier Strategy"

- ***Efficiency***: Implement Advanced Propulsion Technologies to optimize fuel efficiency and minimize emissions
- ***Biomass***: Accelerate the utilization of biomass with E85 and Bio Diesel capable propulsion systems
- ***Electrification***: Drive the electrification of the vehicle
  - Hybrid vehicles & plug in hybrids
  - State of the art "Electric Drive" systems
- ***Hydrogen***: Reinvent the automobile through the design, development and validation of a production viable automotive fuel cell system

March to Zero: Removing the Automobile from the Environmental Debate

Noxious Emissions:

Key Enabler : Catalytic Converter

Tailpipe CO2:

Key Enablers : Efficiency Improvements

Alternative Fuels

Electrification of the Vehicle

LEADERSHIP AND COLABORATION
Auto Industry
Energy Industry
Governments


GM
Thank You for your Attention.

Most Affordable Hybrid SUV on Market

- Delivers 20% improved fuel economy
- Best highway fuel economy
- Priced less than $23,000

Saturn VUE Green Line

GM

GM Hybrid System for Saturn VUE Green Line

Hybrid Version in 2007

Saturn Aura

Chevrolet Malibu

The GM U.S. "FlexFuel Club"

17 models for 2007 MY!

GMC Savana

GMC Sierra

Chevy Impala

Chevy Silverado

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GMC Yukon & Yukon XL

Chevy Monte Carlo

Chevy Uplander

Chevy Avalanche , Suburban & Tahoe

Powertrain Technology Global Highlights
2007 MY

- Active Fuel Management: 9 engine variants in 15 models available
- Variable Valve Timing: 26 engine variants in 66 car and truck models
- SIDI: Globally, 2 engine variants in 9 models
- Port De-Activation: 6 engine variants in 16 models
- Turbocharged Gasoline Engines: 14 engine variants in 18 models
- Six-speed Transmissions
  - AT: 7 new variants in 41 global models
  - MT: 7 variants in 21 global models
- Diesel Engines
  - 17 engine variants available in 45 vehicle lines
  - More than one million diesel engines annually

A Healthy New Pipeline of CTL Projects are in Planning Stages Worldwide and in China

Source: Industry Reports, Booz Allen Analysis