

Snowmass, CO
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Technological Change to Address Climate Risks

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Energy Investment Perspective

Twin challenges

- Meeting significant increase in energy demand and improving access to energy
- Responding to GHG risks

Context (IEA):

2B People without access to commercial energy
\$22T Investment (through 2030) energy supply and distribution
\$45T Investment (through 2050) to manage climate risks

Accelerated development and deployment of advanced technology will be essential to meet aspirations and manage risks at affordable costs

Deployment will occur globally in thousands of multi-billion dollar investment projects for currently non-commercial technologies

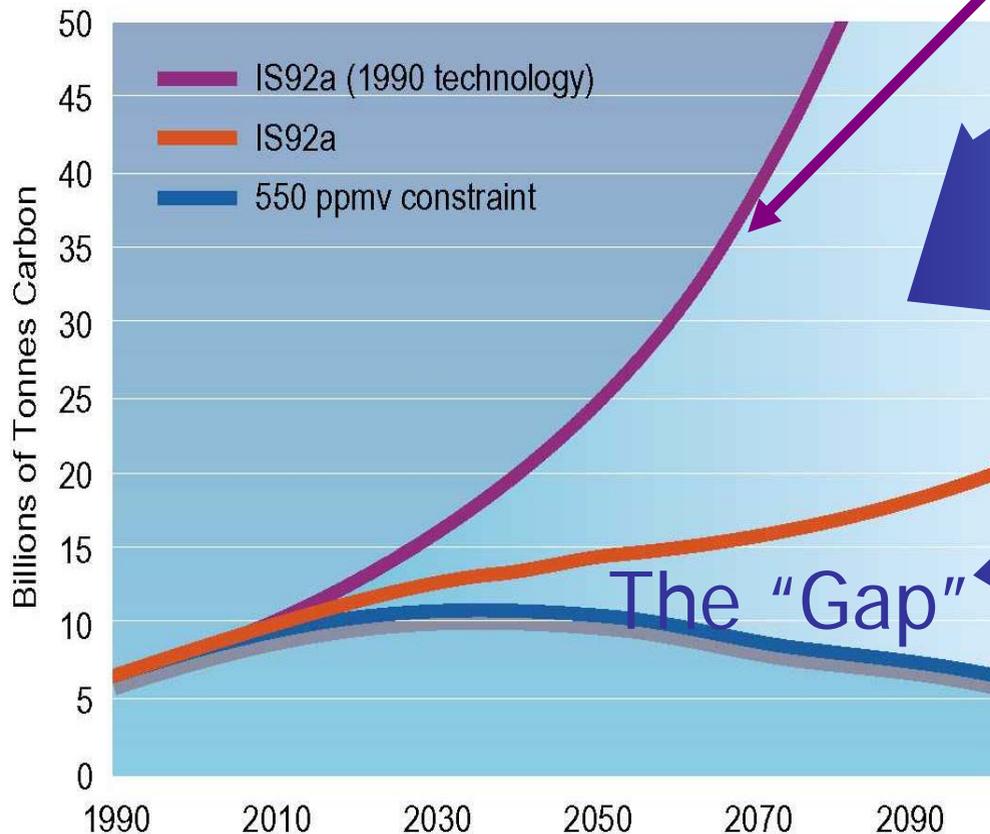
**An investment decision-making perspective may inform
Issues for IAM formulation and climate policy**

The Need for Innovative Technology

Technology frozen at 1990 efficiency levels

Source: J. Edmonds
PNNL

Carbon Emissions



Assumed Advances In:

- Fossil Fuels
- Energy intensity
- Nuclear
- Renewables

Gap Technologies:

- Carbon capture and storage
- Nuclear
- H₂ and advanced transportation
- Bio-technologies
- Solar

Mitigation cost estimates depend sensitively on assumptions about the cost, performance and public acceptance of advanced technologies

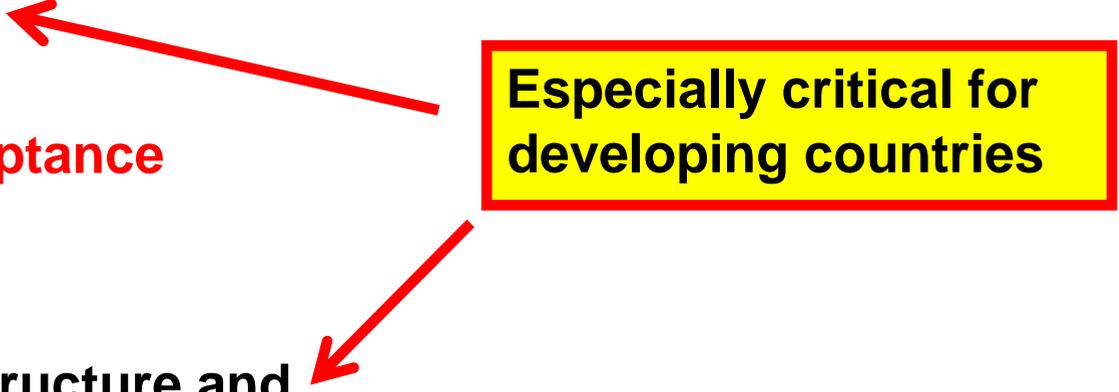
Technology Objectives

- **Promote more widespread use now of existing efficient technology in developed and developing countries**
- **Encourage earlier retirement of less efficient but still productive technology**
- **Stimulate research and development to create innovative, affordable, lower GHG technologies sooner**

Criteria for Technology Evaluation

- **Performance**
- **Cost**
- **Consumer acceptance**
- **Safety**
- **Enabling infrastructure and capacity**
- **Regulatory compliance**
- **Environmental and social impacts at large scale**

Especially critical for developing countries



Weakest link paradigm: failure in any dimension will prevent widespread commercialization

Why Do Large Scale Infrastructure Changes Take So Long?

- **Development of key enabling technologies**
- **Capital investment / market penetration**

Historically, public concerns generally were not a major factor in setting time scale for energy technology. . . this has changed:

- **Siting wind or solar**
- **Gas/ CO₂ pipeline & terminal access / permits**
- **Safety and long-term integrity of CO₂ sequestration**
- **H₂ production / supply / storage**
- **Impacts at large-scale deployment**
- **...**

Considerations Regarding Potential Solutions

- **Major technology systems that contribute to mitigation *in models* are challenged by significant interest groups**
 - Nuclear
 - Carbon Capture and Storage
 - Biofuels
- **Open questions in deployment will affect costs, availability**
 - Public acceptance
 - Regulatory frameworks for siting, operation, monitoring
 - Timely creation of required infra-structure
 - Liability
- **How might investments be affected by market and policy uncertainty and associated price volatility?**
- **More ambitious stabilization targets imply an enormous increase in the pace of capital-intense energy investment; bottlenecks affecting scarce inputs will increase costs, slow investments**

Many of these issues are institutional and political, not economic

Carbon Management: Key Challenges

- **Entry to market when competing against steady improvement in base technologies**
- **Expanding from niche applications to widespread use**
- **Delivering improved performance at competitive price**
- **Competition for R&D funding with other**
 - **promising means to address global climate change (efficiency, other GHGs, adaptation)**
 - **societal priorities**
- **For more aggressive policy intervention, lack of critical capacity, bottlenecks in R&D and Deployment**
 - **University research and laboratories**
 - **Regulatory frameworks and permitting**
 - **Large-scale, capital-intense project inputs from design through specialized equipment and materials**

Roles in Technology Innovation

Activity	Fundamental & pre-commercial research	Applied research	Pilot and demonstration projects	Commercialization	Technology diffusion
Outcomes	Lead Generation	Commercial feasibility	System integration, costs, reliability	Operations, costs, market acceptance	Operations, costs, market competition

Firms

Academia

Government Laboratories

Regulators

Markets

Not a one-way pipeline, interactions occur in all directions

Private Sector Role

- **Profitable multi-national companies with strategic emphasis on R&D play an essential role in research, development and global deployment of advanced technologies: products, processes, services**
- **Research**
 - **Aimed both at near-term deliverables and long-term breakthroughs**
 - **Involving internal R&D and collaborations with academia, national programs, other companies**
- **Commercial opportunities typically derive from a combination of technology and effective management systems (proprietary positions and know how)**

Production control	Market strategies
Financial controls	Operations integrity
Energy management	Environmental Compliance
Maintenance	...

Requires a corporate culture of promoting, utilizing and gaining competitive advantage from technological innovation

Government Role

- **Establish stable policy/regulatory environment**
- **Build societal capacity**
 - **Education/training especially in science and engineering**
 - **Fundamental Research**
 - **Infrastructure**
- **Create enabling frameworks**
 - **Investment**
 - **Technology deployment**
 - **Technology transfer**
- **National circumstances affect policy choices: ability of nations, firms, citizens to respond to an economic signal depends on: structure of economy, national circumstances, institutions, ...**

Enabling Frameworks for Business Contribution

To fulfill its potential most effectively, business requires a proper enabling framework that includes:

- Rule of law and good governance
- Transparent, uniformly enforced regulations
- Protection of intellectual property
- Honoring of contracts
- Free, open markets
- Safe and stable communities
- Partnership and multilateral cooperation
- Vibrant society: education, communication ...



International Chamber of Commerce

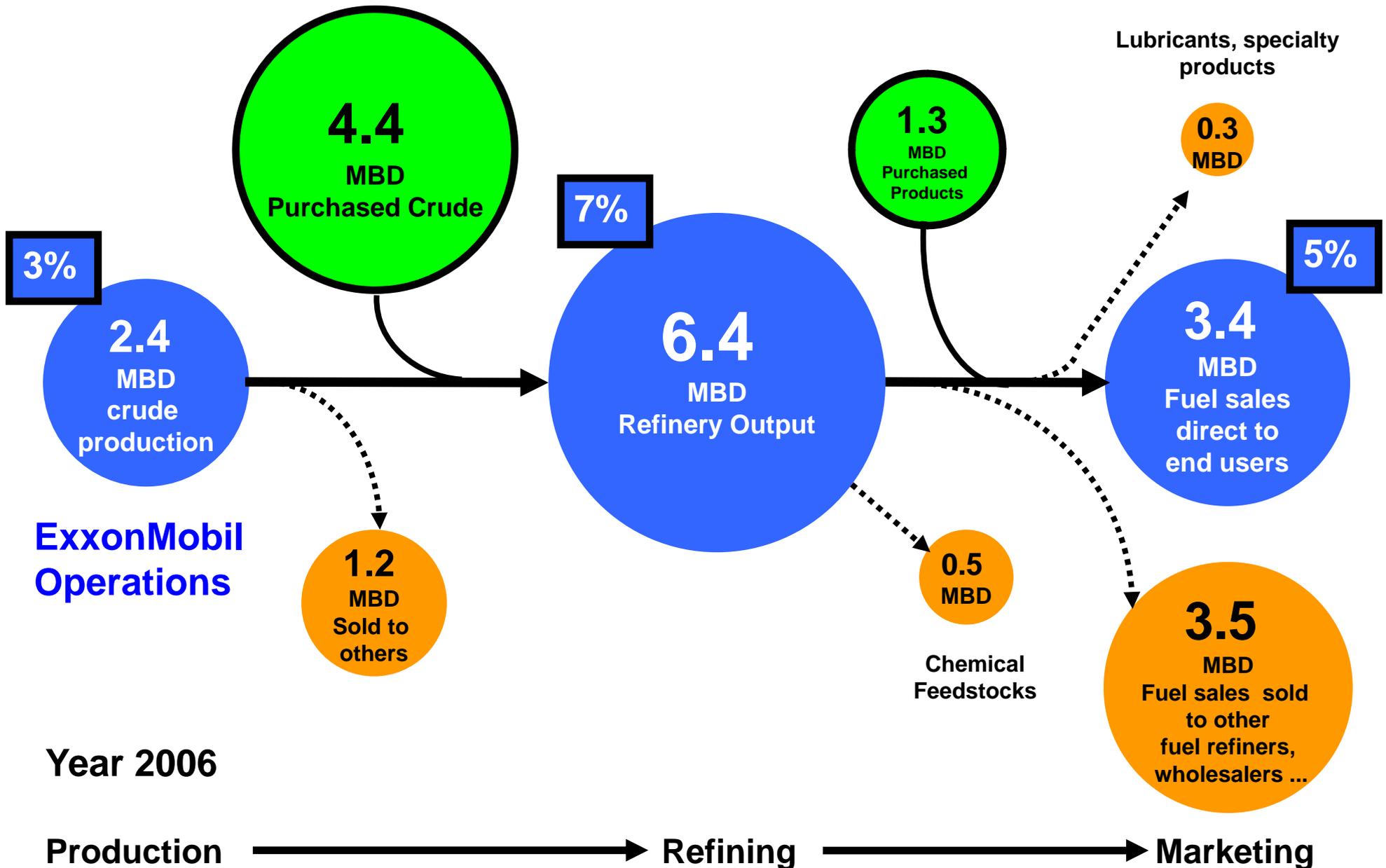
The world business organization

Innovation in Integrated Assessment

- **Representing technological change (in the real world, not just assumed behavior to successfully lower costs, accelerate innovation)**
 - AEEI
 - R&D
 - Induced technological change
 - Experience curves
- **Representing policy to affect innovation**
- **R&D and rates of induced technological change**
 - A response to long-term price signal
 - A purpose built activity
- **Path dependence in technology deployment**
 - Timing of “breakthrough” or public acceptance
 - Regional policy choices
- **Need for up-to-date case studies**

Thank You

ExxonMobil Global Petroleum Supply Chain



ExxonMobil Technology Efforts

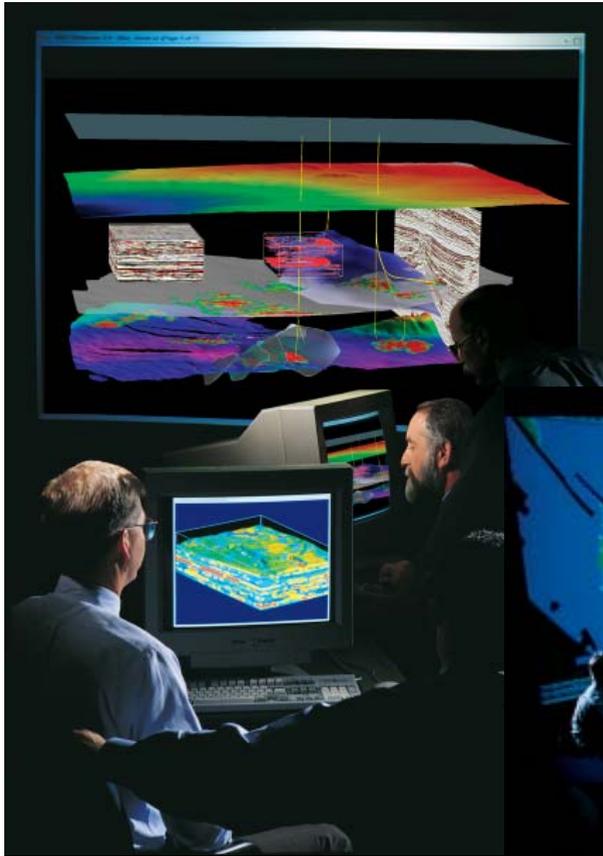
ExxonMobil Operations and Products

- Operations (efficiency, flaring) 13 %
- Products (vehicle fuels) 87 %

Broad-based societal emissions

- Carbon Capture and Storage (CCS)
- Global Climate and Energy Project

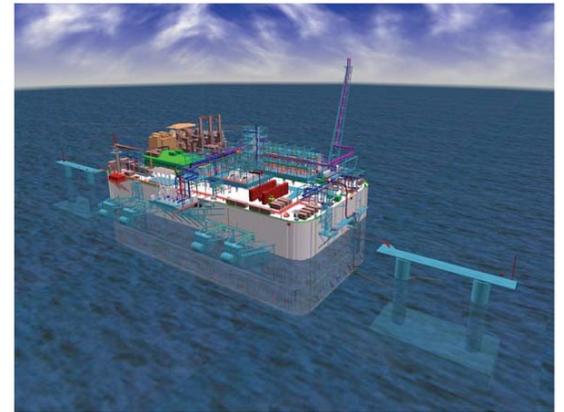
Technology in Action: 3D Seismic



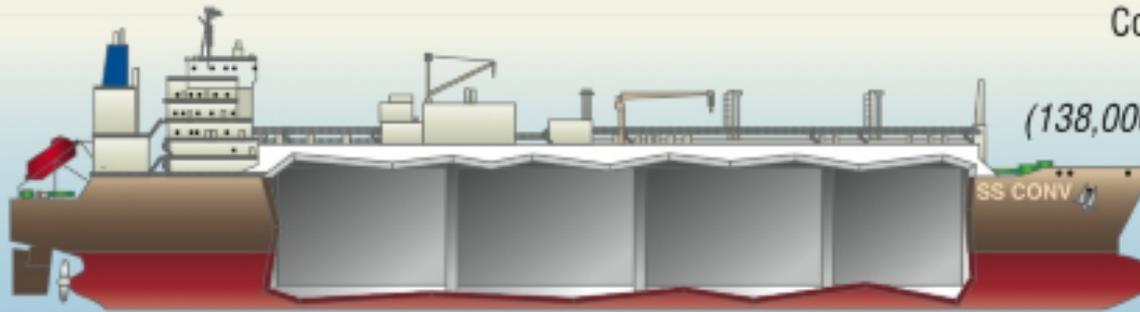
**On Sakhalin Island in Russia,
we are drilling horizontally
from an onshore location to
access oil supplies six miles
out beneath the ocean floor.**



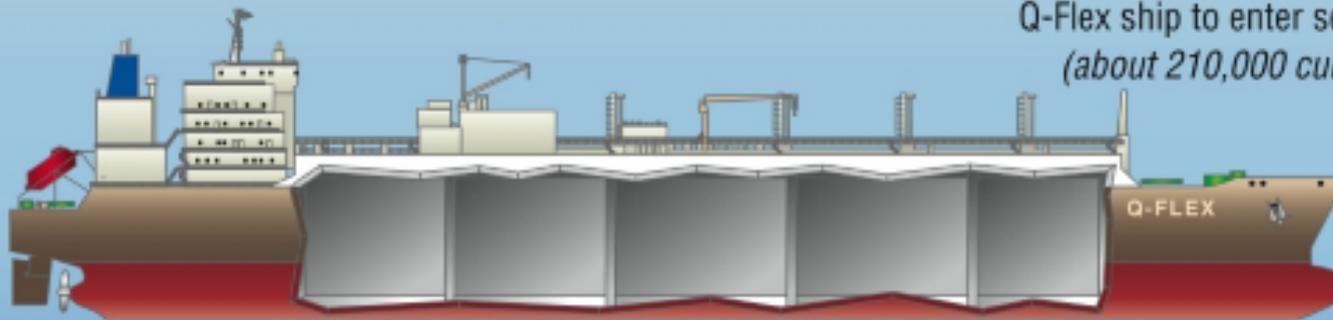
Technology in Action: LNG



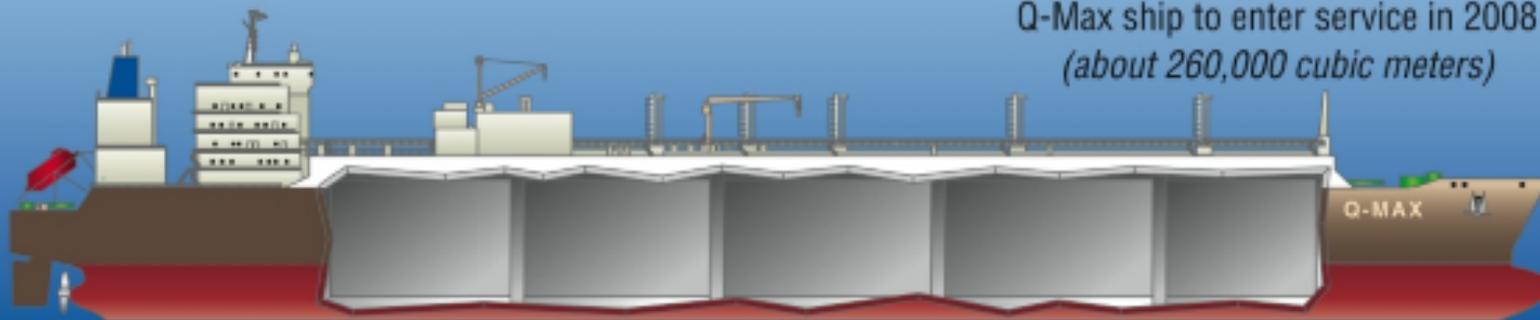
LARGER, MORE EFFICIENT LNG SHIPS



Conventional LNG ship
in service today
(138,000 to 145,000 cubic meters)



Q-Flex ship to enter service in 2007
(about 210,000 cubic meters)



Q-Max ship to enter service in 2008
(about 260,000 cubic meters)

ExxonMobil's proprietary *EMpact* technology is enabling a new generation of LNG ships significantly larger than today.

Global Energy Management System (GEMS)



A technician at Fawley Refinery monitors operations of a divided wall column tower

- **Launched in 2000 to drive energy efficiency improvements**
 - Optimize the base.....Share and implement best practices
 - Invest for step change improvement.....e.g. heat integration and waste heat recovery projects
 - Sustain improvements.....Maintenance, monitoring, and continued optimization

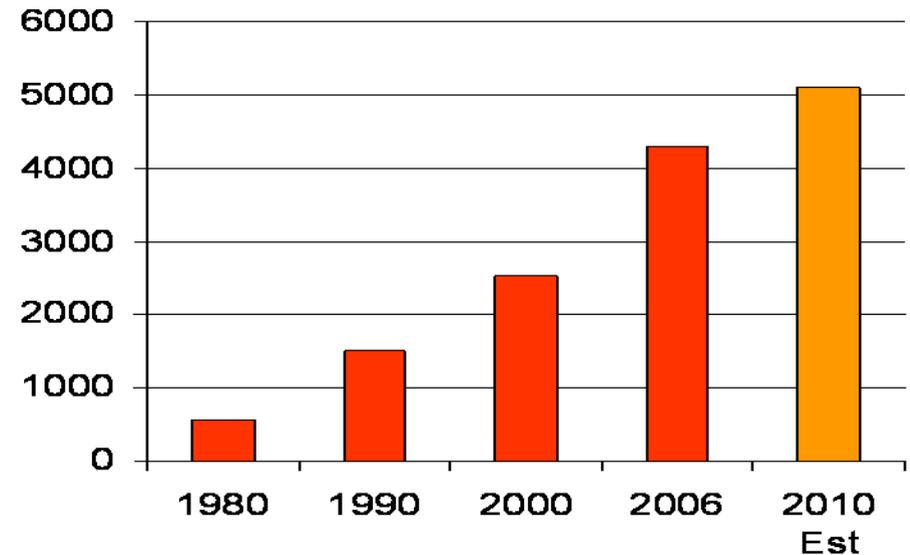
- **Identified opportunities to save 15-20% of energy consumed at Refining and Chemical facilities**

- > 50% opportunities captured
- Energy cost savings ~\$750 million in 2006
- Associated CO₂ reduction of ~ 8 million metric tons per year

Cogeneration

- Cogeneration is the simultaneous production of electricity and thermal heat or steam
 - Reduces energy consumption
 - Improves energy efficiency
- First ExxonMobil installation in 1950's
- Interest in ~100 facilities in > 30 locations
- 4,300 MW installed, with more projects under development around the world
- Reduces CO₂ emissions >10.5 million metric tons per year

ExxonMobil Cogeneration Capacity (MW)



Beaumont Cogen
Texas, USA

Flare Reduction Projects



- Investing ~\$3 billion in Nigeria to increase gas utilization and reduce gas flaring
 - Gas re-injected into reservoirs
 - Gas utilized for fuel
- Currently Nigeria flaring reduced by ~45% compared to 2006; additional projects being worked
- Potential to reduce GHG by ~5 MtCO₂/yr

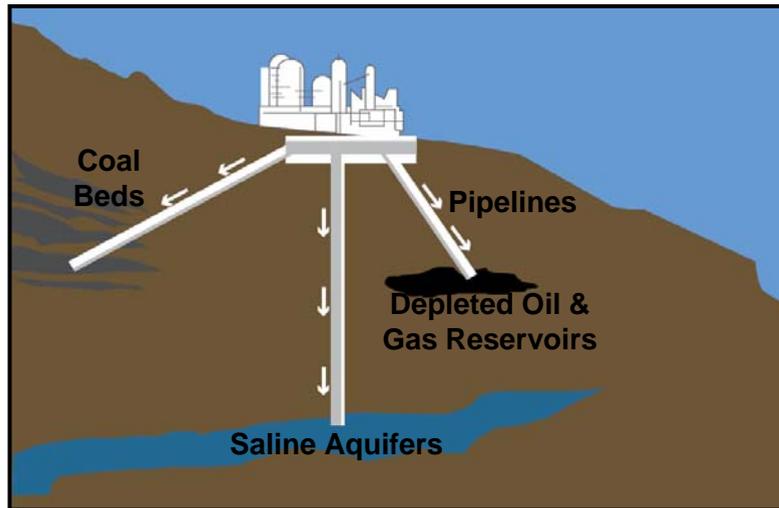
- West Africa is our largest contributor to flare volume; Nigeria our largest single source of flaring
 - Periodic flaring for safety reason or result of operating events
 - Gas produced along with oil that has no economic outlet and/or infrastructure



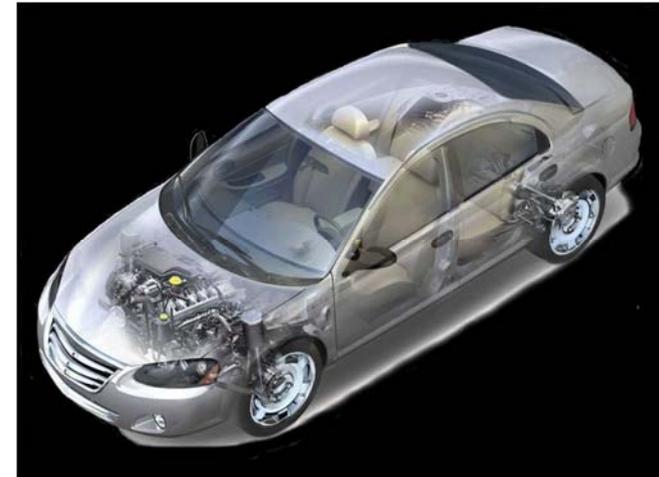
AOR Compression Complex

ExxonMobil Technology Research to Address GHG Emissions

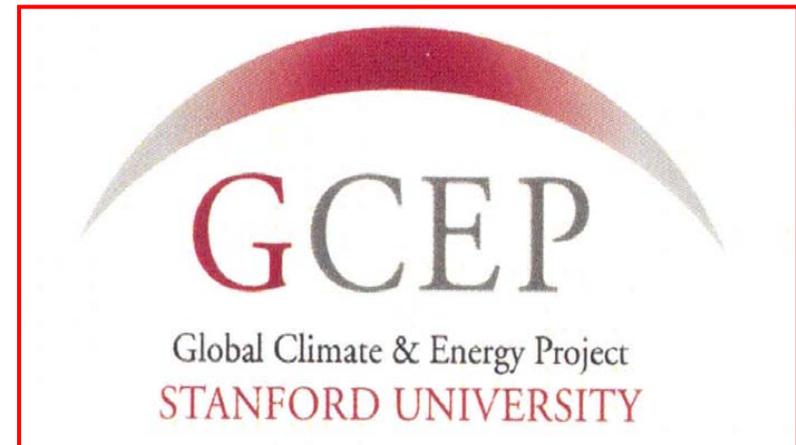
Carbon Capture & Sequestration



Advanced Vehicle & Fuels

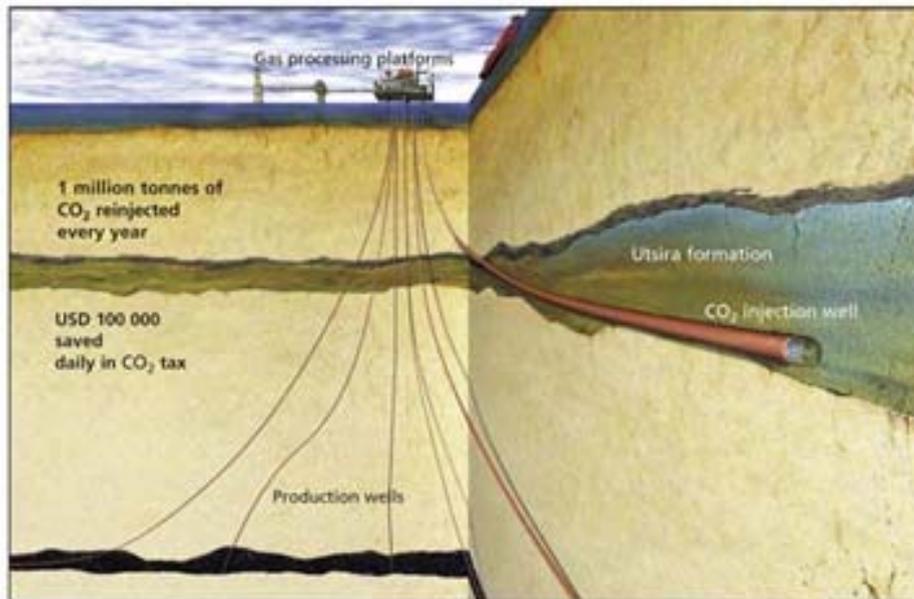


Breakthroughs



ExxonMobil CCS Activities

- Industrial scale experience for over three decades: CO₂ capture, compression, transport by pipeline and geological storage
- Projects involving CCS in place or under consideration in Australia, Asia, Europe, Africa, North America
- Research support: IEA GHG R&D Programme, CO2ReMoVe, Battelle, Georgia Tech, MIT, Stanford, U Texas



**Sleipner Field,
North Sea
(1 MtCO₂/yr)**

CCS: EM Capabilities and Research

Proprietary research and technologies

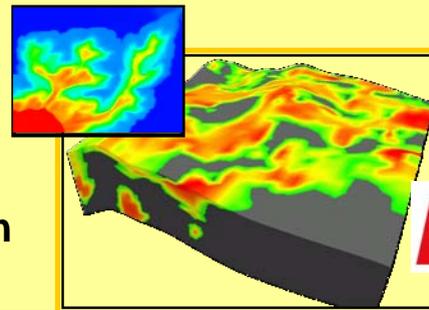
Sponsored research to lower costs and improve performance of CCS: Battelle, Georgia Tech, MIT, Stanford, U Texas, IEA GHG R&D Programme, CO2ReMoVe,



Controlled Freeze Zone™ Pilot



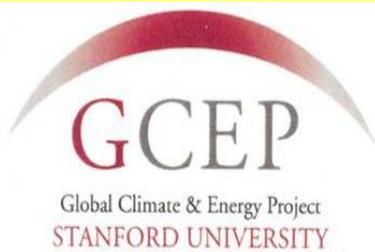
Gas Flooding Laboratory



Reservoir Simulation



External CCS Research



CO₂ REMOVE



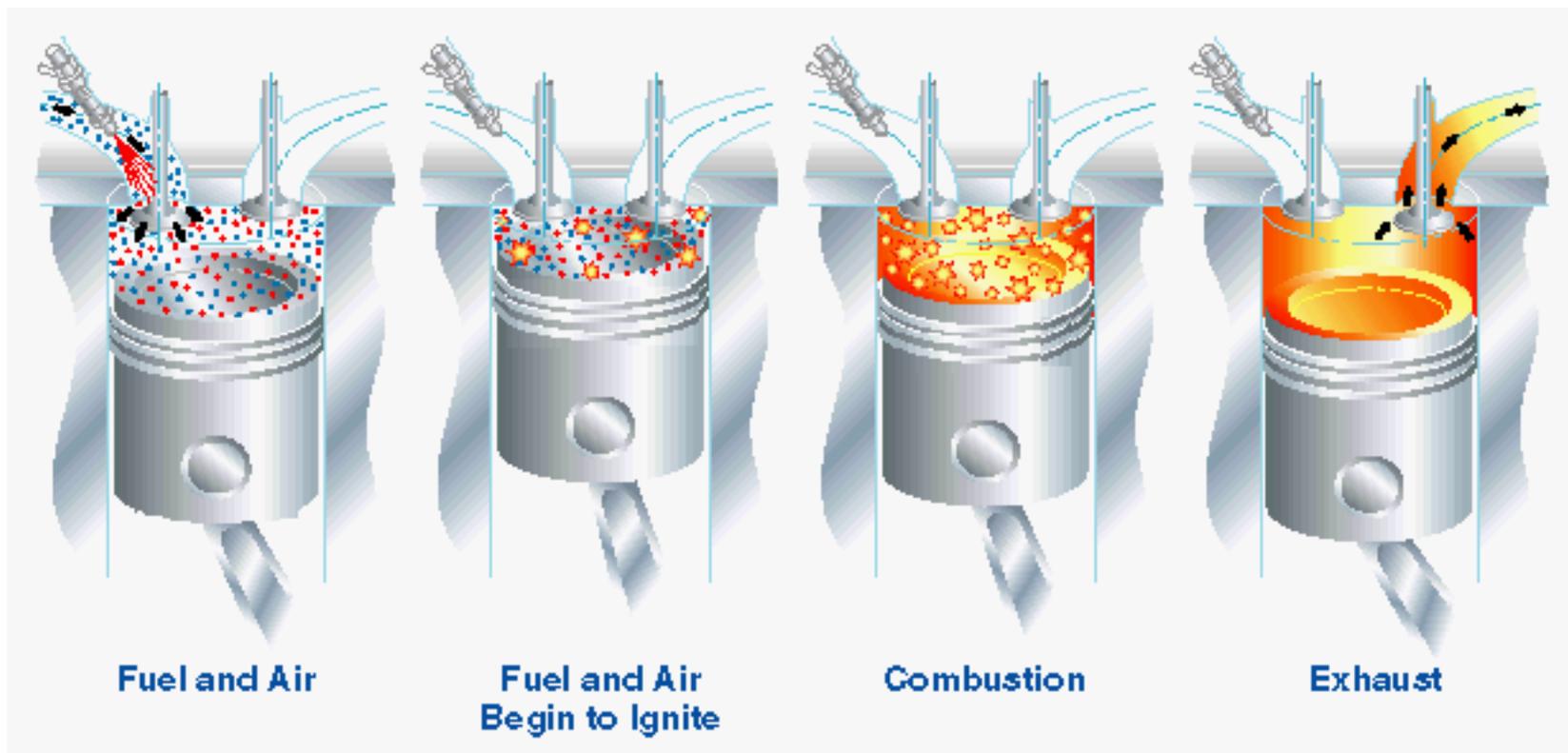
research
monitoring
verification

Carbon Capture & Sequestration Technologies @ MIT

GEOLOGICAL STORAGE



Advanced Combustion: ExxonMobil Activities in HCCI*



- Potential for up to 30% fuel economy improvement with very low emissions
- Applicable to multiple vehicle types (including hybrids); can be combined with other vehicle technologies for even larger impact
- Subject of research partnerships with auto and engine manufacturers

Advanced H₂ Reforming: ExxonMobil Research



- Unique proprietary technology to convert hydrocarbons to high purity hydrogen
- Potential for high efficiency and low emissions
- Enables use of existing fueling infrastructure
- Can eliminate need for hydrogen storage on-board fuel cell vehicles
- Scalable from vehicle to refinery applications

These and other energy efficiency gains via advanced technologies can be cost-effective and attractive GHG mitigation steps.



The Global Climate and Energy Project



Mission

- Research on low-GHG technologies
- Fundamental and pre-commercial focus
- Applications in the 10-50 years timeframe

Strategy

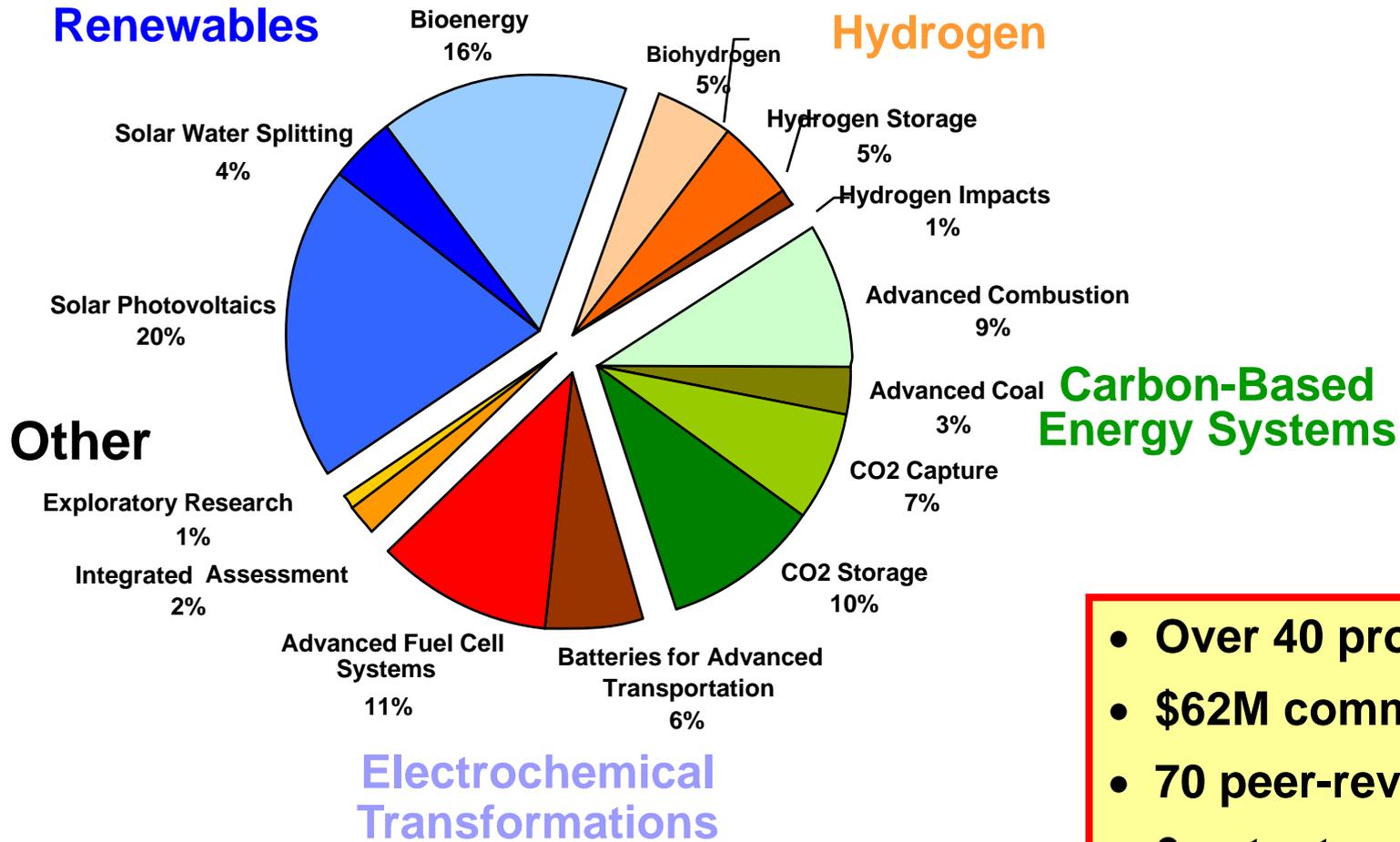
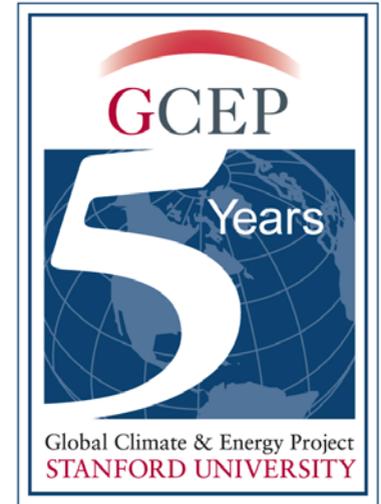
- Promote research with significant potential to reduce global GHG emissions
- Seek new leads for breakthrough options
- Pursue high risk / high reward options
- Work at Stanford and other institutions around the world

Schedule and Budget

- 10 years (2003 – 2013+)
- \$225 M



GCEP Research Portfolio



- Over 40 programs
- \$62M committed
- 70 peer-reviewed papers
- 6 patent applications



GCEP – Building Global Engagement



USA

Stanford
Boise State University
Brigham Young University
California Institute of Technology
Carnegie Institution of Washington
Harvard University

Purdue University
SRI International
UC Santa Cruz
University of Montana
University of Wisconsin

Europe

ECN
ETH Zurich
IRDEP/CNRS
TU Delft
University of Dundee
Ghent University

Japan
RITE

Australia
UNSW
University of Sydney



GCEP – Building Human Capacity



At Stanford University

- 12 Stanford Staff: 3 Director level, 5 analysts, 4 admin
- 70 Principal Investigators
- 300+ graduate students and post-doctoral fellows

