Bridging to a Reduced-Carbon Future Energy System

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Importance of Bridging

- From PAST...
  - Benefits from history
    - Possible successful transition approaches.
    - How long should it take?
    - What resources might be needed?

- And PRESENT...
  - Examines key features of current state, opportunities for change

- To FUTURE:
  - Build to new system from existing
Advantages of Bridging

- **Reduced transition cost**
  - Lower capital requirements

- **Improved penetration rates**
  - “piggy-backing” on current system

- **Immediate and long-term benefits**
  - Improves current system toward future system
  - Not just ‘incrementalism’ but planned integration

- **Intentionally addresses questions on “How do we get there from here?”**
Bridging to Reduced Carbon Energy

- **What:**
  - Energy Supply By Fuel: Historic, recent

- **Where:**
  - Consumption By Region
  - Sector Issues

- **Link to other reduction opportunities:**
  - Current GHG Reduction opportunities

- **Other bridges to consider**
  - Policy bridges
  - Business
  - Technical resource and educational needs
Bridge 1: What to Change
Global Primary energy supply

- Historic trends
  - Expected rates of change.
  - Move toward lower carbon.

- Recent changes
  - What are the more likely transitions?
Changing the World’s Energy Supply Is a Slow Process

Historical and Projected Trends in Global Primary Energy Consumption (Fraction of Global Energy Market)

Typical Penetration Rates: 1-10% or 10-30% = 30-50 years

Global Primary Energy Supply
Recent Trends

1973
6034 MTOE

2003
10029 MTOE

Source: IEA Key Energy Statistics 2003
Some Conclusions on “What”

- Needs to meet growth
  - 2/3 Increase over 30 years in total supply

- Hydrocarbons still the energy of the future
  - Coal maintaining
    - Reserves-Infrastructure-Cost advantages
    - Oil dropping in share
    - Gas growing; appears able to expand

- Fit to slow decarbonization trend
  (Coal to Oil to Gas)
  - 1973: 25-45-15
  - Now: 23-35-20

- Suggests a natural gas bridge???
A Natural (Gas) Step Toward H2

Molecules Hydrogen per 100 Carbon atoms

- Coal
- Oil
- Methane

Coal: 100
Oil: 150
Methane: 400
Greenhouse Advantage of Gas

Life-Cycle Greenhouse Gas Emissions - Power Generation

- Austr Brown Coal
- Austr Black Coal
- Mid-East Oil
- LNG

kg CO2 Eq/MWhr
Advantages of Natural Gas Transition

- Affordable today
- Potential double benefits
  - Flare reduction example
- Current dominant source of hydrogen; likely best source for decades
  - Gas distribution infrastructure facilitates hydrogen transition
Bridge 2: Where to Change

- Regional picture
- Expected Investment trends
- Sectoral Opportunities
“Where” Observations

- Developed Country dominance shrinking
  - Down from 62% to 52%

- Substantial opportunities to affect energy supply in both developed AND developing world
  - Considerable new investments in developed regions (although not large relative to existing infrastructure)
  - Developing regions (esp Asia) largest growth area
    - Greatest opportunity areas to change carbon intensity
Expected “Where” Profile of Future Energy Investments (to 2030)

Source: IEA
Expected Energy Investment Distribution to 2030

Source: IEA
Transportation

Transport 1973
959 MTOE

2001
1802 MTOE

- Almost doubled in 30 years
- Continued dominance of oil

Source: IEA Key Energy Statistics 2003
Bridge 3: Current opportunities for GHG reduction

Petroleum industry example

- Distribution by emissions type
- The Flare Reduction multiple opportunity
  - Reduce emissions
  - Increase gas supply
  - Improve resource use effectiveness
‘Typical’ Petroleum Company GHG Emissions Profile

- **Combustion**: 64.0%
- **Flaring**: 28.0%
- **Other**: 8.0%
Potential Areas for Petroleum Industry Emissions Reduction Projects

- **Combustion**
  - Power and steam generation
  - Energy efficiency
  - Fuel switching

- **Alternate energy**
  - Solar, wind, geothermal

- **Flare Reduction**
  - Enhance competition vs non-associated gas use
Addressing Global Gas Flaring Reduction

- Combustion: 64.0%
- Flaring: 28.0%
- Other: 8.0%
Large quantities of gas produced as a byproduct of oil production are flared worldwide.

Solutions are needed that enable this valuable resource to be utilized effectively.
Magnitude of the Issue

- **Wasted Resource - 110 Bcm/yr (>3 TCF)**
  - 37 BCM Flared in Africa = 200 TWh of CCGT power production
    - enough power for 85 million low-income urban households

- **An environmental problem - 300+ Mt CO₂e**
  - >10% of Annex 1 countries’ Kyoto commitments
  - Local effects - health and ecosystems near flaring sites
**Flaring Reduction Options**

- Bring Gas To Market
- Re-injection
- Stop Production (“Shut-in”)
Gas to Market Technical Solutions

- LNG
- CNG Shipping
- Gas-To-Liquids
- Gas Treating & Reinjection
- "Gas To Wires"?
- Pipelines

Source: U Houston
### Gas to Market Barriers

- Distance from markets
- Lack of local utilization or export infrastructure
- Cost competitiveness against non-associated gas resources
- Regional fiscal terms
- Regional political stability
Multiple Potential Benefits: The West African Gas Pipeline Example

1. Nigeria Today

80 Million T Carbon

Gas Flares

2. What Would Otherwise Occur

80 Million T Carbon

Ghana

100 Million T Carbon

Fuel Oil

Charcoal

Fuel Choice Based on Lowest Cost

Trees

3. Same Growth But With Pipeline

0 Million T Carbon

80 Million T Carbon

Gas Pipeline

Trees

Additional Benefits:
- Reduce Air Pollution
- Reduce Desertification
- Preserve Bio-Diversity
- Improve Health
- Sequestration in Trees
Capture and Storage

- Extends prospects for fossil fuels

- Current applications...
  - Enhanced oil recovery (EOR)
  - Offshore Norway (avoid high CO2 tax)

- Larger use inhibited by...
  - High capture cost
  - Source/sink matches for EOR applications

Source: Statoil
Capture and Storage Bridging Strategy

- **Demonstrate safe storage first**
  - Pre-concentrated streams
    - Refinery hydrogen plants
    - Natural gas separation
    - Ammonia plants
  - High value end-uses
    - EOR
  - Coal bed methane??
  - Match source and sink locations
    - Intentional siting of new facilities

- **Improve capture costs**

Source: Statoil
Some Other Important Bridges

- Governmental
  - Policy bridges
- Business
- Technical Capability
Policy Bridges I
Expanded Scope

- From single governments to Inter-governmental

- Simplified routes to concurrence
  - From 170 parties to bottoms up?
    - From bilateral/multilateral/regional approaches

- From local/regional to global thinking
  - Changes appropriate policy approaches
    - Local controls very likely sub-optimum
    - E.g. Californina control on vehicle GHGs
Policy Bridges II
Building Cooperation

- North-South balance
  - From conflicting to cooperative
  - Mutual wins needed
    - e.g. Clean Development Mechanism
Clean Development Mechanism

- Provides GHG reduction credits to projects in developing countries

- Gives incentive for...
  - developing countries to choose cleaner technologies
  - developed county participants to fund these projects
Example Offset/Credit Opportunities

- Forestry (West Australia, Louisiana, Brazil)
- Fuel Switching
  - From higher carbon fuels to natural gas
    - Korea, Ghana
  - Gas vs oil for steam generation
- Geothermal energy generation (Indonesia)
- Flare Reduction (Nigeria, Angola)
- Geologic storage (Australia)
- Wind Energy (Netherlands)
- Hydrogen production/fuel cells
Policy Bridges II
Building Cooperation

- Multi-stakeholder processes
  - Increased involvement of businesses/Non-governmental organizations
  - Johannesburg Partnership model
- Flaring example
International Partnership Example: Global Gas Flaring Reduction Partnership

- Public-private partnership to support flaring reduction
  - Help national governments achieve real reductions
  - Improve framework for private sector investments
- Becoming the key player in flaring policy, credits, associated gas regulations.
Policy Bridges III
Market Approaches

- $/ton focus
  - From command and control to maximum benefit focus
    - Emissions trading
    - Addressing market access issues
      - Flared gas
      - Grid access

- From Environmental Economics ("Triple Bottom Line")
  to "Economic Environmentalism"
  - Harness profit motive
Wrong Directions
- Limits market for reductions – one state, one sector
  - Further isolates Ca vehicles, possibly fuels
  - Drives ‘leakage’ of emissions outside of CA
- Very likely high $/ton; ignores lower cost approaches
- Subject to legal challenges

Questionable benefit
- Only shifts emissions?
  - If electric, GHGs from power generation
  - Combined with CAFÉ (Federal) Standards...
    - California reductions enable others to emit
    - No national emission changes result
    - Californians pay
A Better Bridge For California?

Climate-Friendly Vehicle

California 2004
Voluntary “Green Vehicle” Certificate Program?

- State sells certificates offsetting vehicle emissions
- Uses funds to support emissions reducing projects world-wide (or purchases from other credible sources e.g. CDM, PCF, etc)

Multiple Benefits:
- Real emissions reductions
  - Enhances global solutions, cooperation
  - Supports reduced carbon infrastructure deployment

- Market experience
  - Creates access to low-cost credits
  - Experience/influence in emerging global carbon markets

- Resolves Vehicle GHG program issues
  - No legal challenges
  - No isolation of markets, vehicles, fuels

- Easily Deployed
  - Can be gradually deployed, easily scaled
  - Can utilize existing “Registry” program
From “denial” to active integration into business development

- Inventory
- Capital Projects GHG Evaluation
- Projections
- R&D
- New Business development
Capital Projects GHG Evaluation Flowchart

Early Project Scoping Stage

Evaluate impact of GHG emissions

- "Minimal"
- "Small"
- "Large"
- "Medium"

- GHG analysis integral to early examination of alternatives
- GHG analysis of key project alternatives
- Detailed GHG analysis of chosen alternative
- Document Analysis results

- Capture GHG learnings and improved processes
- Look back
- Lessons learned

No GHG analysis required
Bridging to a New Energy Business Model

- From short-term to sustainable approaches
  - Focus on effective resource utilization
  - Potential shifts in corporate portfolios
    - Oil to gas to renewables?
    - Simultaneous creation of economic, human, and environmental capital
      - E.g. Close integration of social and environmental programs with new project development
## Technical Capability Bridge I. From Complicated to Complex

*after Kastenberg, UC Berkeley*

<table>
<thead>
<tr>
<th>Uncertainty</th>
<th>Complicated</th>
<th>Complex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge of physical world</td>
<td>E.g. Rate of change of atmospheric CO2</td>
<td>Chaotic or indeterminate nature of problem</td>
</tr>
<tr>
<td>Unambiguous and observable effect or output</td>
<td>E.g. Climate response to CO2 level</td>
<td>Ambiguous effects, outputs</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ambiguity</th>
<th>Local, observable, slow or reversible</th>
<th>Regional/global, hard to measure, long term or irreversible</th>
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Technical Capability Bridge II.
Role Changes

- Engineers/technical contributors
  - Need to be partners in process vs isolated
  - Need global knowledge; appreciation of regional, cultural concerns, approaches and priorities

- Suggests changes in engineering curricula to expand skills of engineer
  - E.g. training to manage shift in application arena
    - to developing country focus
    - Engineers Without Borders approach
Call for a different Engineer?

- Need to consider other cultures, other approaches, other ethics and values
  - Huston Smith
    - Importance of pre-modern ‘traditional’ approaches
      - ‘participation’ vs ‘control’
      - intuitive vs reductionist
      - broad vs narrow view
  - Dalai Lama
    - Need for ‘engineering heart’

- By any model, role changing
  - from engineering to ‘ecogenuity’?
Bridging to a Reduced Carbon Energy Future

- Hydrocarbons a likely part of the solution
  - Strong role for gas
- Key opportunities in developing regions and power generation
- Some immediate GHG reduction opportunities
  - Flaring example
  - Growing capture and storage
Bridging to a Reduced Carbon Energy Future

- Need for new governmental and business approaches
  - Think global
  - Think long-term

- Need for new engineers to address complex global scale issues
“When you are inspired by some great purpose, some extraordinary project, all your thoughts break their bonds, your mind transcends limitations, your consciousness expands in every direction, and you find yourself in a new, great and wonderful world.

Dormant forces, faculties and talents become alive, and you discover yourself to be a greater person by far than you ever dreamed yourself to be.”

Pantajali, First to Third Century BC
“Do not be desirous of having things done quickly. Do not look at small advantages. Desire to have things done quickly prevents their being done thoroughly (or well). Looking at small advantages prevents great affairs from being accomplished.”

Confucius, 551 – 479 BC
“The greater danger for most of us is not that our aim is too high and we miss it… but that it is too low, and we reach it.”

Michelangelo
15\textsuperscript{th}-16\textsuperscript{th} C. AD