



# Russian Natural Gas Supply: Some Implications for Japan

Peter Hartley

Kenneth B Medlock III

Jill Nesbitt

**James A. Baker III**  
**Institute for Public Policy**  
**RICE UNIVERSITY**



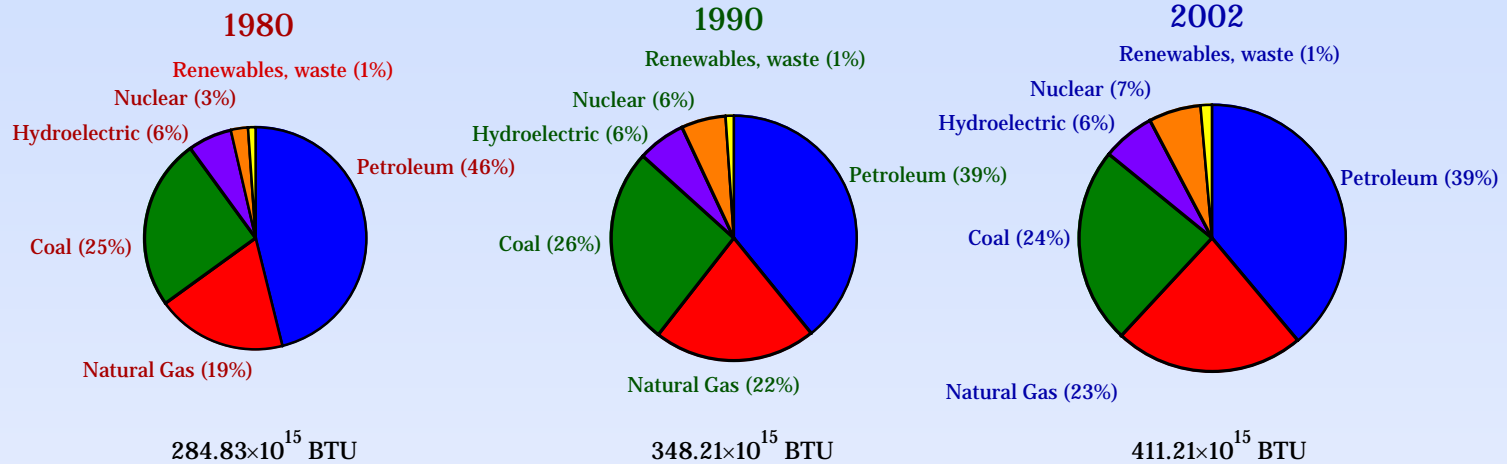
# *Japan and natural gas*

- Japan has been the main market for LNG, but it will increasingly face competition from other countries
  - ◆ South Korea began importing gas in 1986, but gas was < 5% of Korean primary energy supply until 1994 and is now > 10%
  - ◆ Technological, institutional and environmental developments favoring gas have increased actual and projected gas demand
    - ❖ Gas share of energy demand is rising in developed world
  - ◆ Loss of North American self-sufficiency in natural gas supplies has led to interest in importing LNG
  - ◆ As North Sea gas supplies dwindle, Europe may also see LNG as a possible source of supply
  - ◆ China and India have large projected demands for energy over the next few decades and both have started importing LNG
  - ◆ Falling LNG shipping costs are changing the LNG market and increasing competition for gas supplies



# *Growing demand for natural gas*

■ Share of gas in primary energy supply is rising:



Source: EIA

- ◆ Environmental pressure for cleaner fuels
- ◆ Pro-competitive deregulation of wholesale electricity markets and the development of CCGT
- ◆ Gas may supply transport fuel needs (GTL, tar sands, fuel cell)
- ◆ Possible contrary influence is that coal gasification, solar, hydro and/or nuclear power could displace gas in electricity generation, perhaps assisted by falling costs of HVDC



# *Where will supply come from?*

- World gas supply potential is large, but:
  - ◆ Gas reserves are concentrated in areas remote from markets
  - ◆ Production and transport infrastructure is required
  - ◆ Unstable political regimes may make investments unattractive
  - ◆ Prices need to rise to finance the needed investments
- Russia could be a big supplier of gas to both Europe and Asia, making developments there critical to Japan
  - ◆ How important is Russian gas to Japan?
    - ❖ What happens if political developments restrict the access of Japan, and northeast Asia more generally, to Russian gas?
- The Rice World Gas Trade Model (RWGTM) gives a microeconomic framework to examine political and economic influences on the future world gas market



# *Rice World Gas Trade Model*

- Model framework: *Market Builder* from *Altos Partners*
  - ◆ Calculate *equilibrium* prices and quantities across a fixed number of locations and time periods
    - ❖ In each period, allow gas to be produced or transported until there are no opportunities for profitable spatial arbitrage
      - Transport links transmit prices as well as gas – for example, linking to a high priced market raises prices at the supply node
    - ❖ Producers schedule resource extraction to eliminate profitable (in *net present value* terms) temporal arbitrage opportunities
      - High current prices accelerate depletion, raising future prices
      - Also, if producers *anticipate* high prices in future period  $t$ , they may
        - delay some supply from periods before  $t$ , raising prices before  $t$
        - accelerate investment to exploit those prices, affecting prices after  $t$
        - The arbitrage actions imply actual prices at  $t$  would not rise as much
    - ❖ Price changes affect future as well as current consumer demand
      - For this reason, too, current prices affect future prices
- Model supply data is based on USGS *World Resource Assessment* updated with latest reserve revisions
- Demand forecasts based on EIA *International Energy Outlook 2004* and IEA *World Energy Outlook 2002*



# Why a world market model?

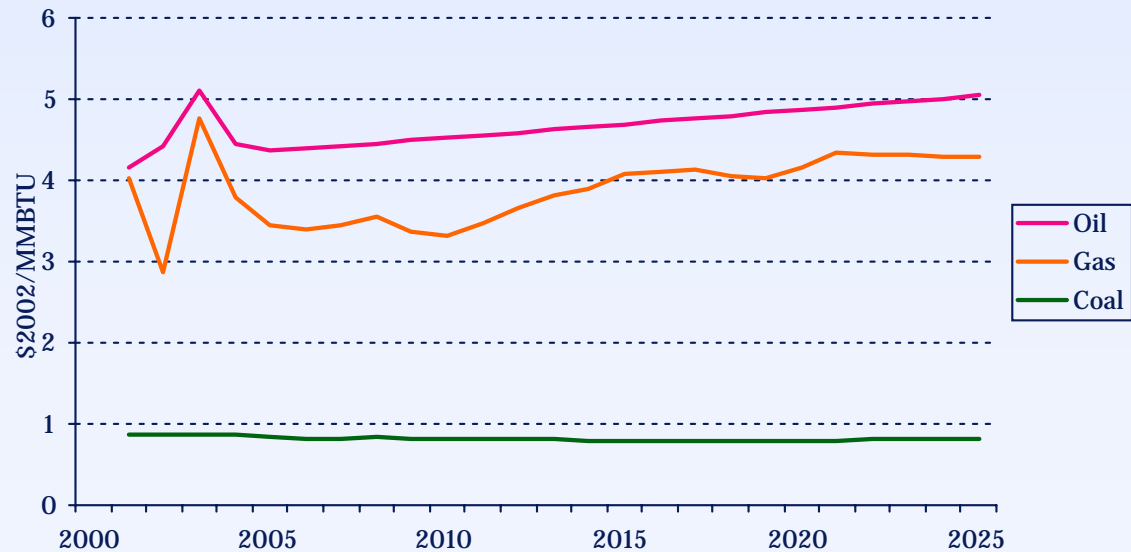
- The model examines a *world* market of expanding depth and geographical extent
- Transition to a world market could be rapid
  - ◆ An *expectation* of new market dynamics encourages moving away from bilateral trading
    - ❖ More *potential* trading partners lowers the risk of investing without complete long-term contract coverage
    - ❖ A decrease in average distances between suppliers and/or customers increases arbitrage opportunities
- Bilateral contracts can be fulfilled by *swap agreements* as increased market depth increases the number of profitable alternatives
  - ◆ Contracts can be viewed as financial arrangements that do not necessarily constrain physical trades



# Forecasting gas demand

- Used 23 years of IEA data from 29 OECD economies to estimate own and cross-price elasticities of demand
- Calibrated base demand growth to the EIA “reference case” forecasts based on average expected GDP and population growth in each country and assuming the reference case EIA US energy prices as graphed but:
  - ◆ Carried forward to 2040, maintaining the oil price growth rate and average inter-fuel price relativities
  - ◆ Translated internationally using the RWGTM with 2002 infrastructure to calculate location specific discounts/premiums on the US gas prices

**EIA Reference Case Prices**





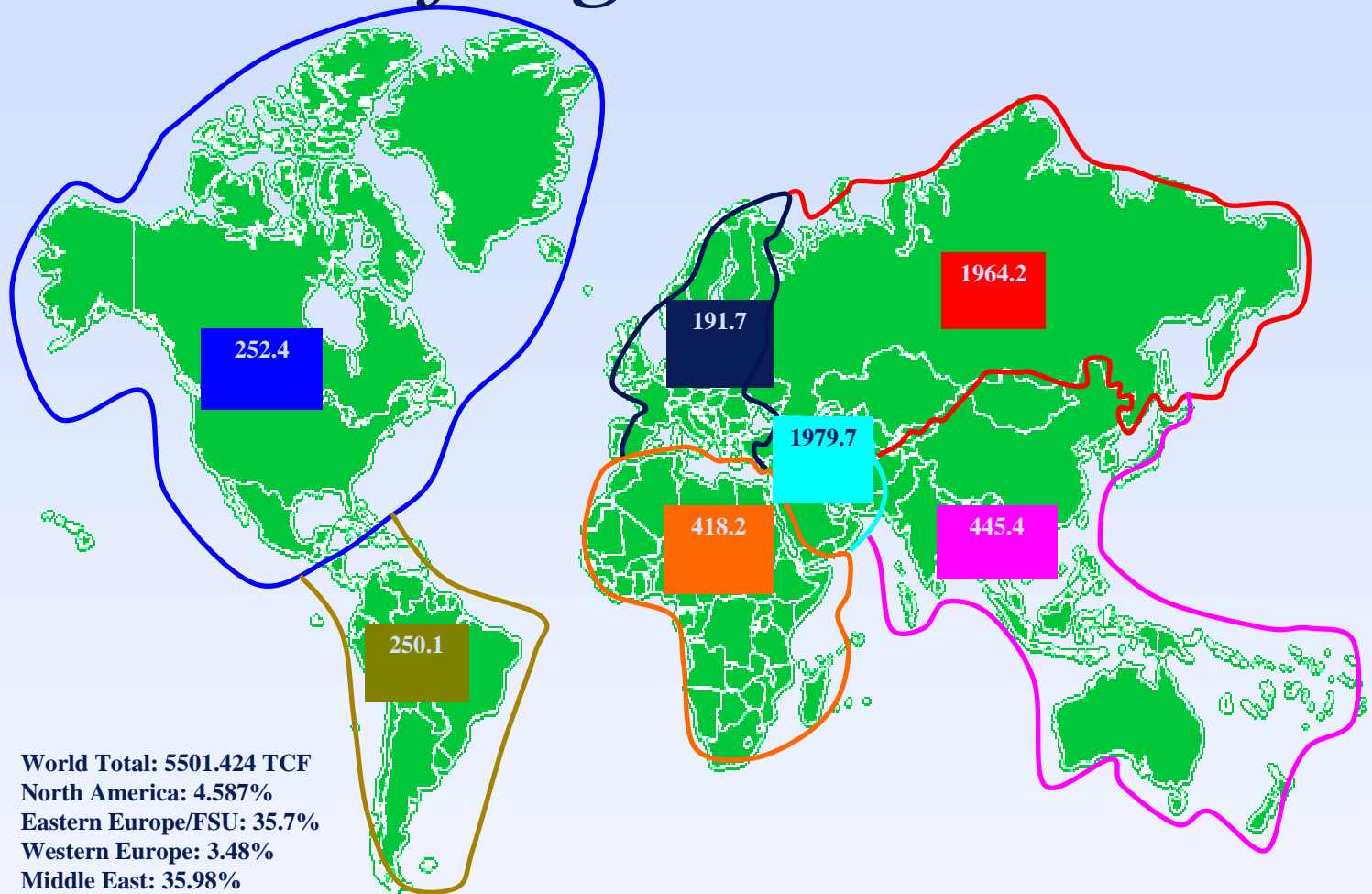
# *Backstop technology*

- Expected future prices affect current supply and price
- Estimated demand elasticity reflects historical substitution possibilities, not potential ones
  - ◆ Technological change is difficult to predict, but
    - ❖ IGCC, nuclear and renewable sources provide alternative sources of electricity supply
    - ❖ DOE says IGCC competitive at \$4 per mcf of gas (2004 prices)
    - ❖ Gasification of coal may also satisfy other uses
- We assume that, starting in 2030, demand is lost to new technologies at prices above \$5 with up to 2.5% lost at \$5.50 and 5% lost at \$10
  - ◆ Each year, the proportion of demand vulnerable to the backstop at each price above \$5 increases until in 2040 all base case demand could be satisfied at a price of \$10





# USGS proved natural gas reserves by region, 2003

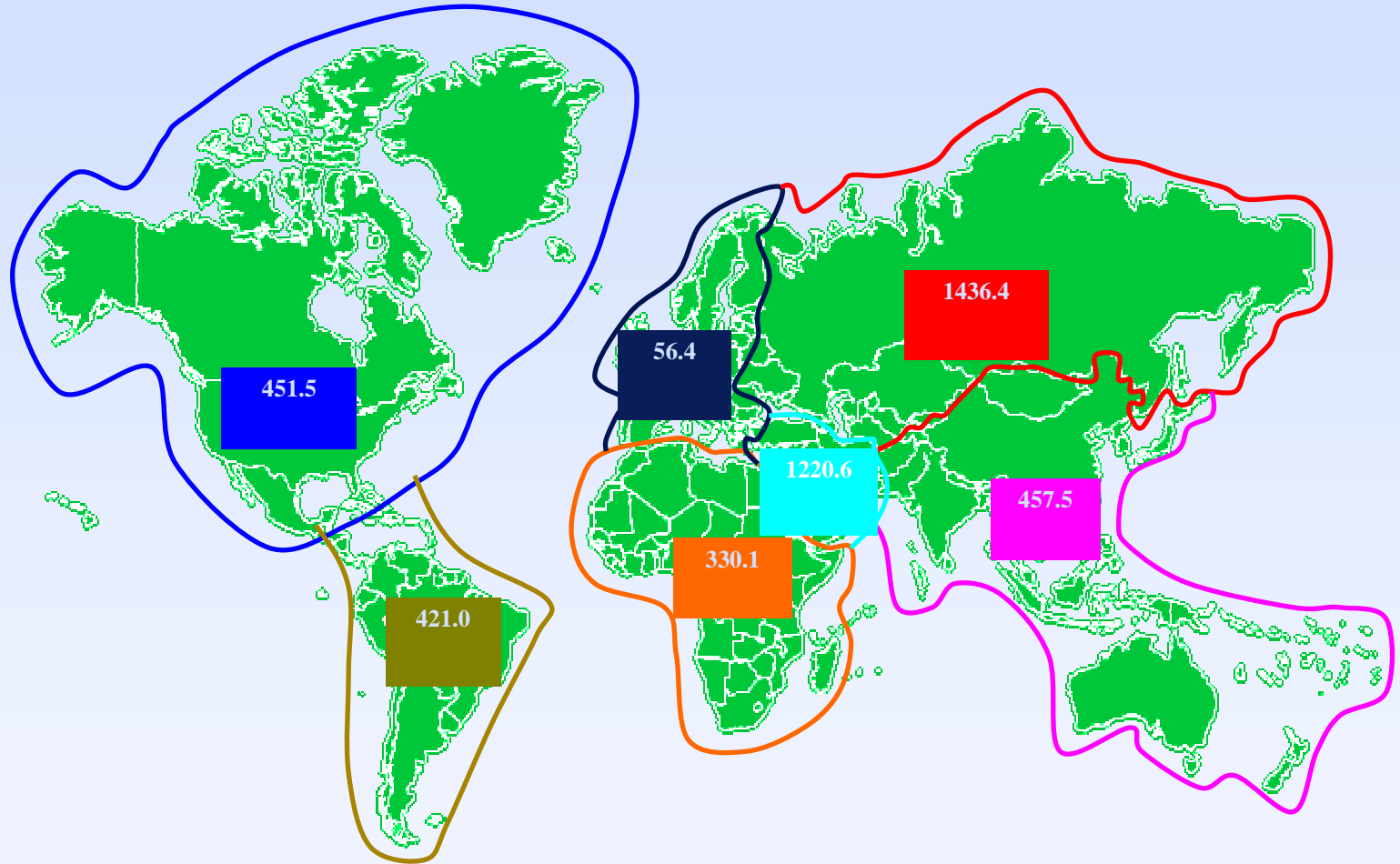


World Total: 5501.424 TCF  
North America: 4.587%  
Eastern Europe/FSU: 35.7%  
Western Europe: 3.48%  
Middle East: 35.98%  
Asia & Oceania: 8.01%  
Africa: 7.6%  
Central/South America: 4.55%

Units: Trillion Cubic Feet  
Source: USGS



# *Undiscovered natural gas by region, 2001 estimates*



Units: Trillion Cubic Feet  
Source: USGS



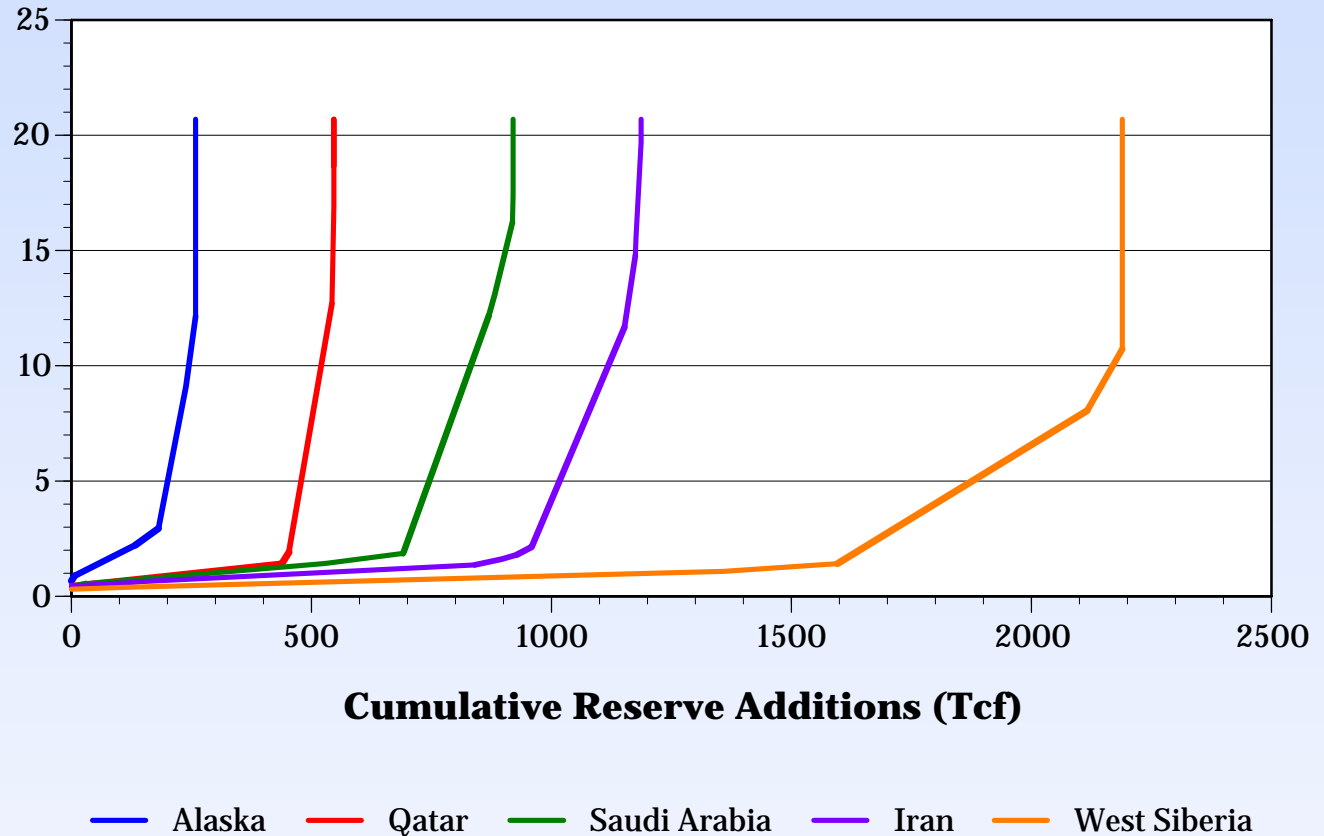
# *More detail on supply*

- Regional resource potential of
  - ◆ associated and unassociated natural gas resources,
  - ◆ both conventional and unconventional gas deposits in North America and Australia (CBM), and
  - ◆ conventional gas deposits in the rest of the worldwas assessed in three categories:
  - ◆ proved reserves (2003 *Oil & Gas Journal* estimates)
  - ◆ growth in known reserves (P-50 USGS estimates)
  - ◆ undiscovered resource (P-50 USGS estimates)
- Cost estimates, based on information for North America and resource base characteristics, include:
  - ◆ capital cost of development as resources deplete, and
  - ◆ operating and maintenance costs
- Supplies isolated from markets, or in areas lacking infrastructure, earn lower rents and are extracted last



# Example cost of supply curves

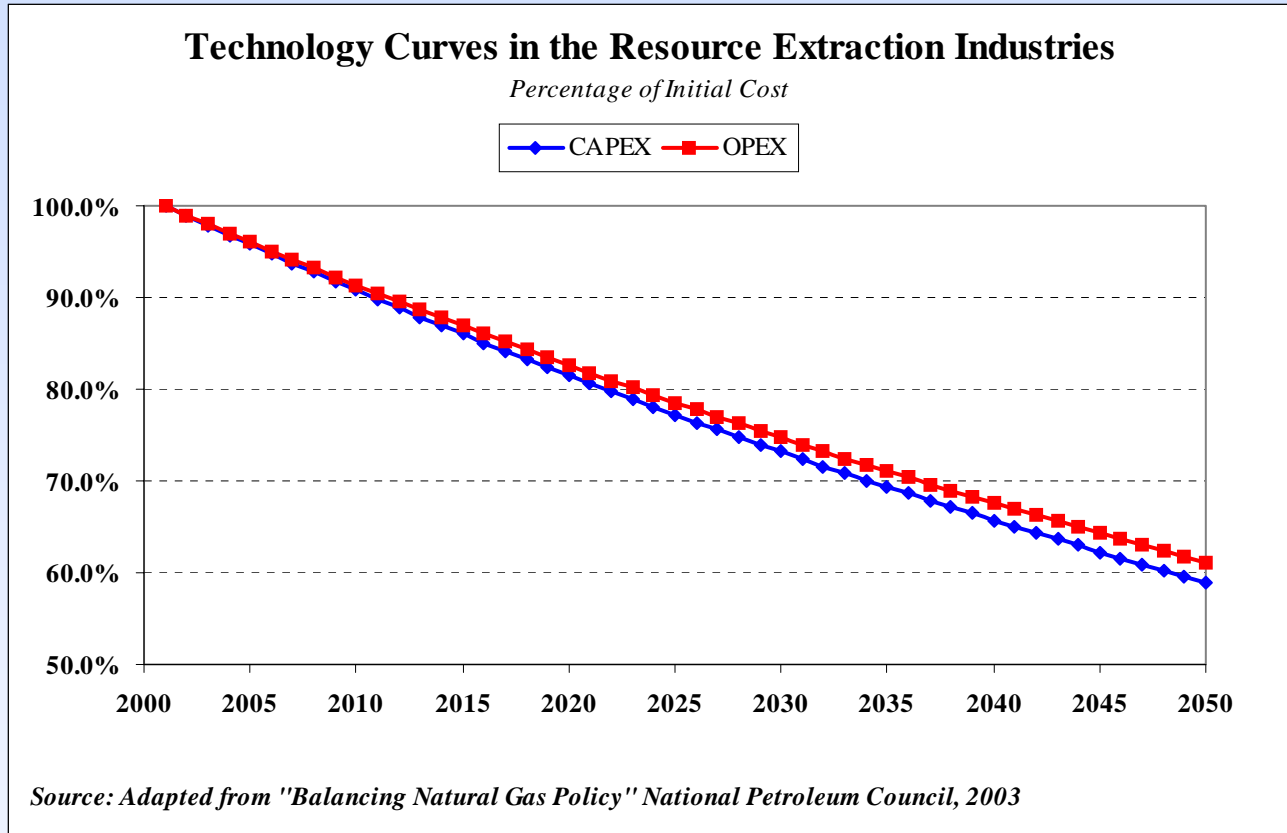
## Comparative Cost of Supply Curves for Selected Regions



Sources: USGS, EIA, author calculations

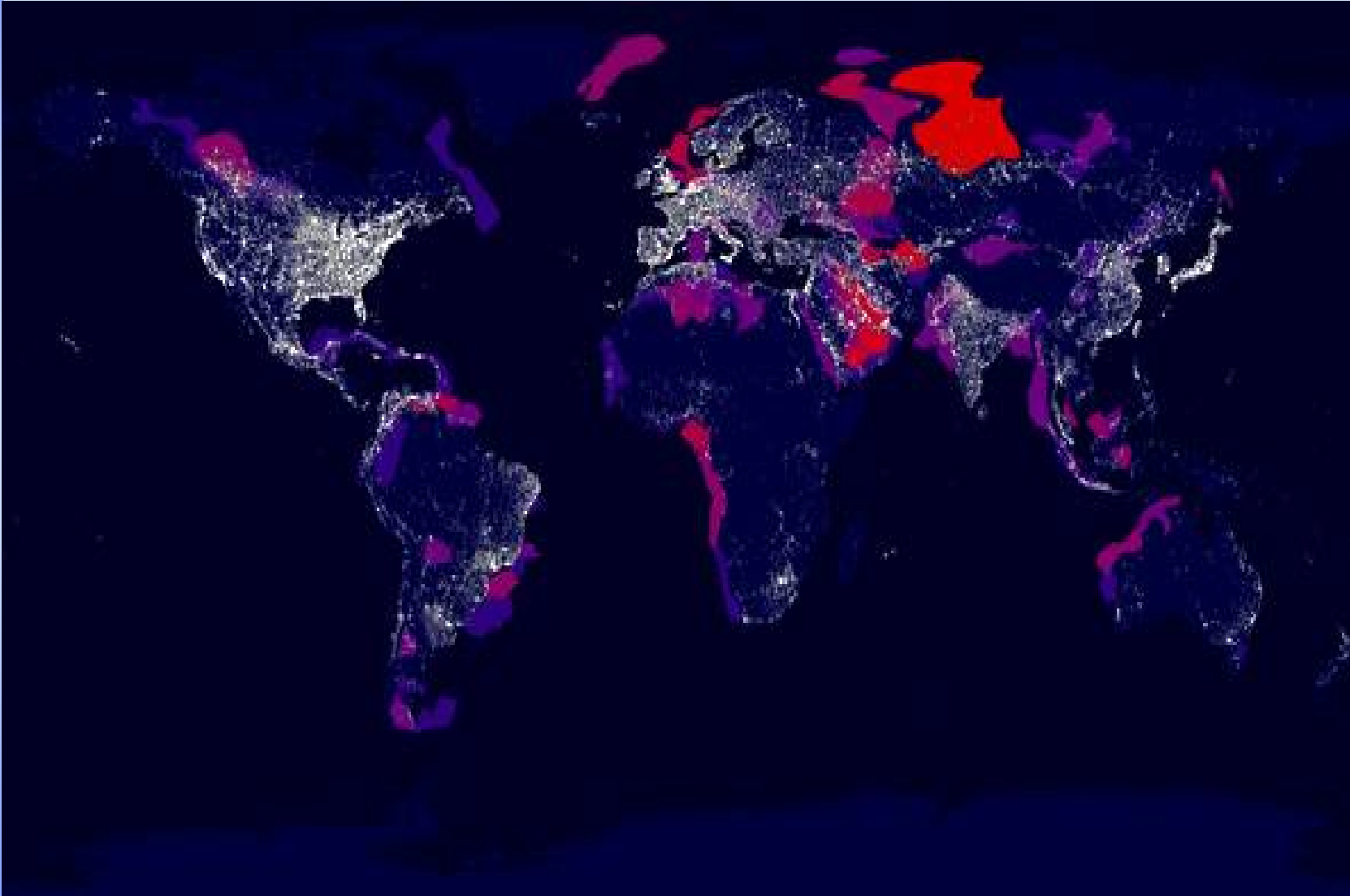


# Technological change in mining





# *Linking supply with demand*





# *Representing transport networks*

- Pipeline networks in North America and Europe are the main transportation systems
  - ◆ LNG is only about 5% of world demand, but is important in Japan & Korea, and increasing in US and Europe
- Aggregate supplies and demands into discrete “nodes”
- Parallel pipes are aggregated into a single link
  - ◆ Ignore minor distribution and gathering pipes
- Transport links are inherently discrete
  - ◆ Allow many potential links
  - ◆ Use a hub and spoke representation for LNG
- Model chooses new or expanded transport capacity from supply sources to demand sinks based on:
  - ◆ capital costs of expansion, and
  - ◆ operating and maintenance costs of new and existing capacity

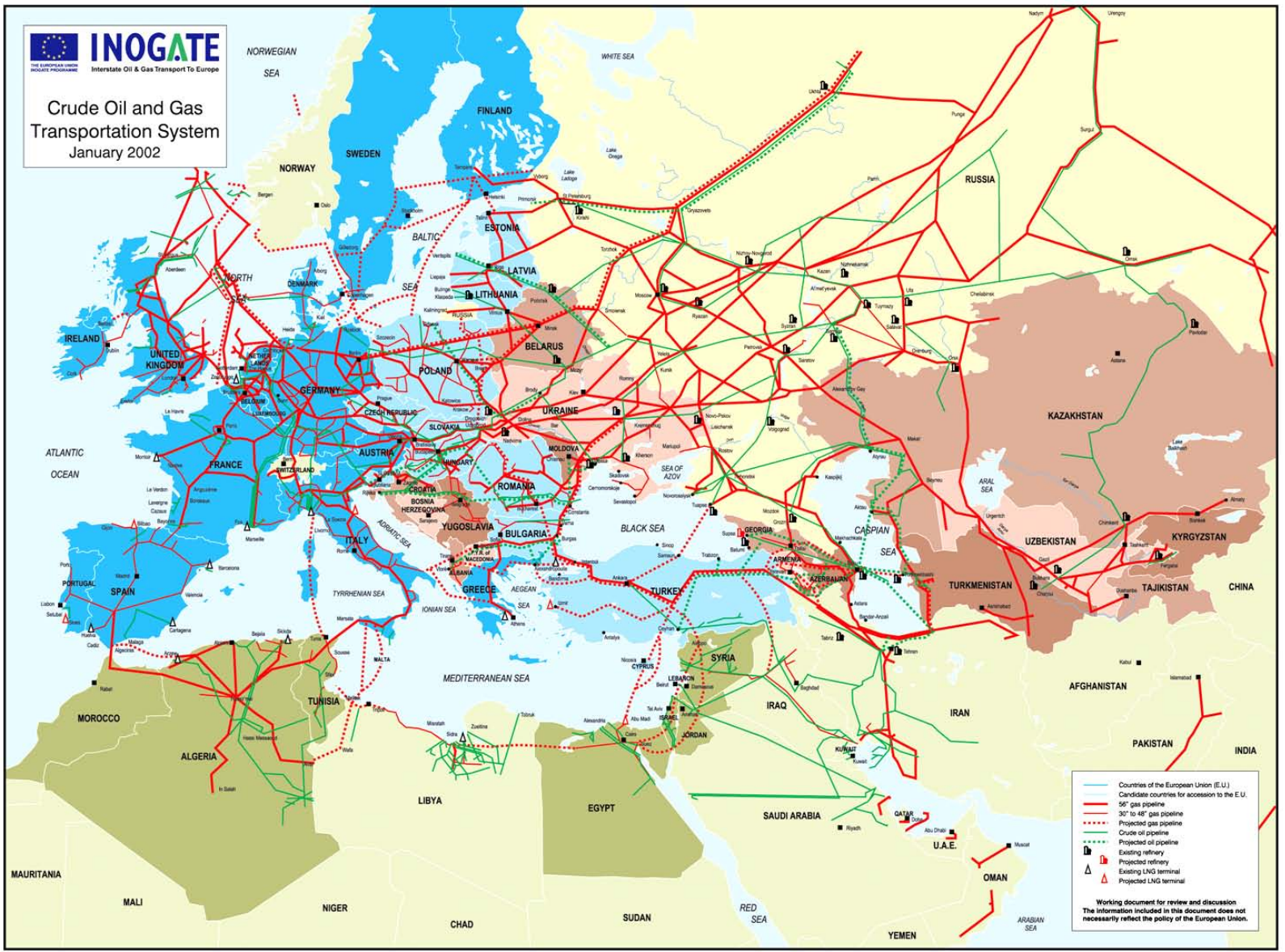
# Pipeline link example



RICE  
UNIVERSITY



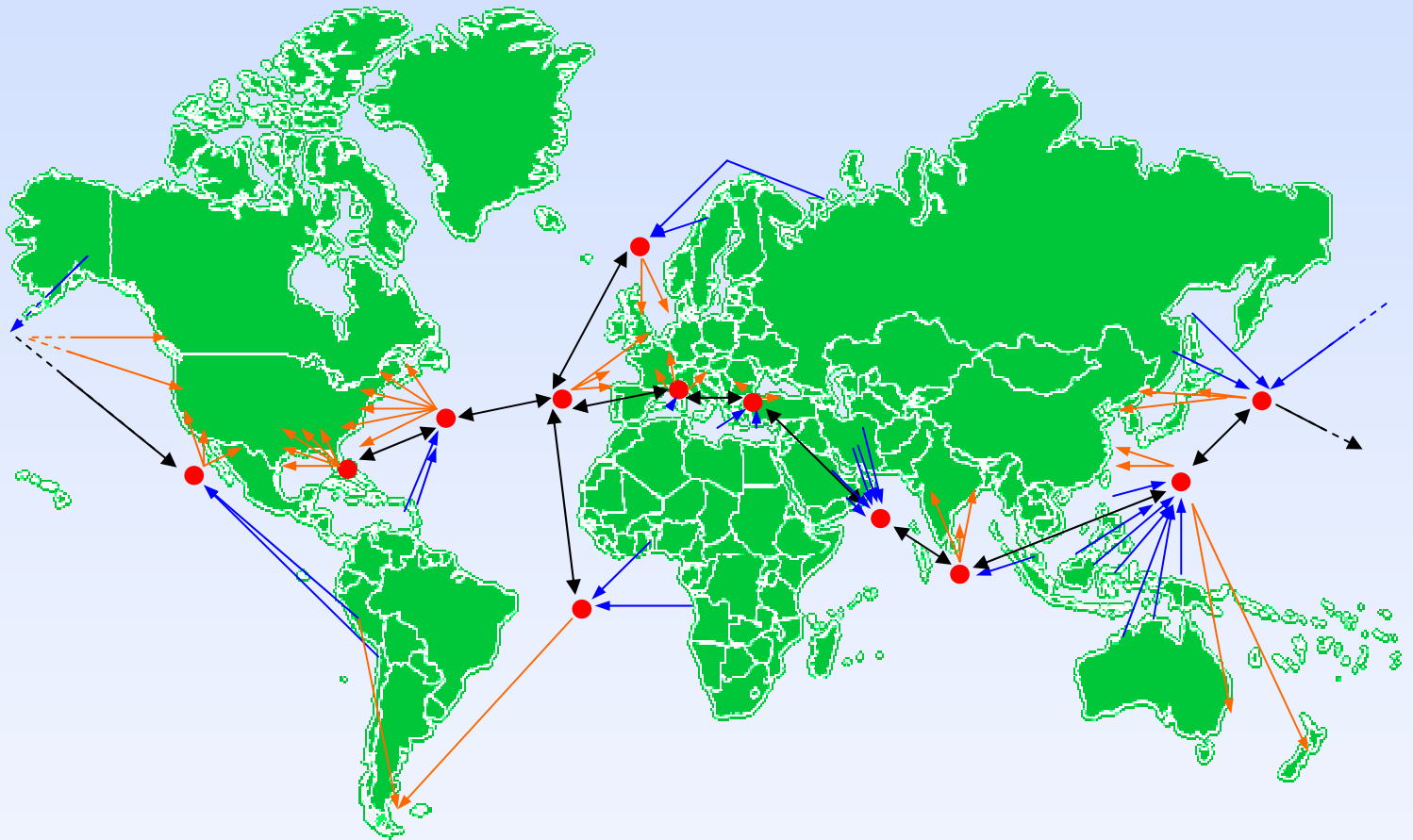
Crude Oil and Gas  
Transportation System  
January 2002







# *LNG transportation network*





# *Pipeline costs*

- EIA published cost data for 52 pipeline projects
- Using this data, we estimated an equation relating specific capital cost (annual cost per unit of capacity) to project characteristics
  - ◆ Project cost is raised by:
    - ❖ Pipeline length
    - ❖ Crossing mountains
    - ❖ Moving offshore or crossing a lake or sea
    - ❖ Developing in more populous areas
  - ◆ Higher capacity reduces *per unit* costs as a result of scale economies



# *LNG costs*

- Consulted a variety of sources (including a 2003 EIA report) and industry contacts
- Liquefaction costs are a fixed cost (\$4.11/mcf/yr) plus a variable feed gas cost (model calculated)
- Shipping costs were based on a data set of estimated lease rates
  - ◆ These were converted to implicit costs of using the hub and spoke network via regression analysis
- Regasification costs vary by location (primarily because land costs vary)
  - ◆ Based on industry, IEA and EIA reports



# *Indicative LNG costs, 2002*

Price required for expansion, including capital costs

<b>Route</b>	<b>Feed gas</b>	<b>Liquefaction</b>	<b>Shipping</b>	<b>Regasification</b>	<b>Total</b>
<b>Trinidad to Boston</b>	\$0.48	\$1.01	\$0.32	\$0.69	<b>\$2.50</b>
<b>Algeria to Boston</b>	\$0.69	\$1.03	\$0.45	\$0.69	<b>\$2.84</b>
<b>Algeria to Gulf of Mexico</b>	\$0.69	\$1.03	\$0.63	\$0.28	<b>\$2.63</b>
<b>Qatar to Gulf of Mexico</b>	\$0.42	\$1.00	\$1.30	\$0.37	<b>\$3.10</b>
<b>NW Shelf to Baja</b>	\$0.44	\$1.01	\$0.95	\$0.33	<b>\$2.83</b>
<b>Norway to Cove Point</b>	\$0.85	\$1.05	\$0.54	\$0.51	<b>\$2.95</b>

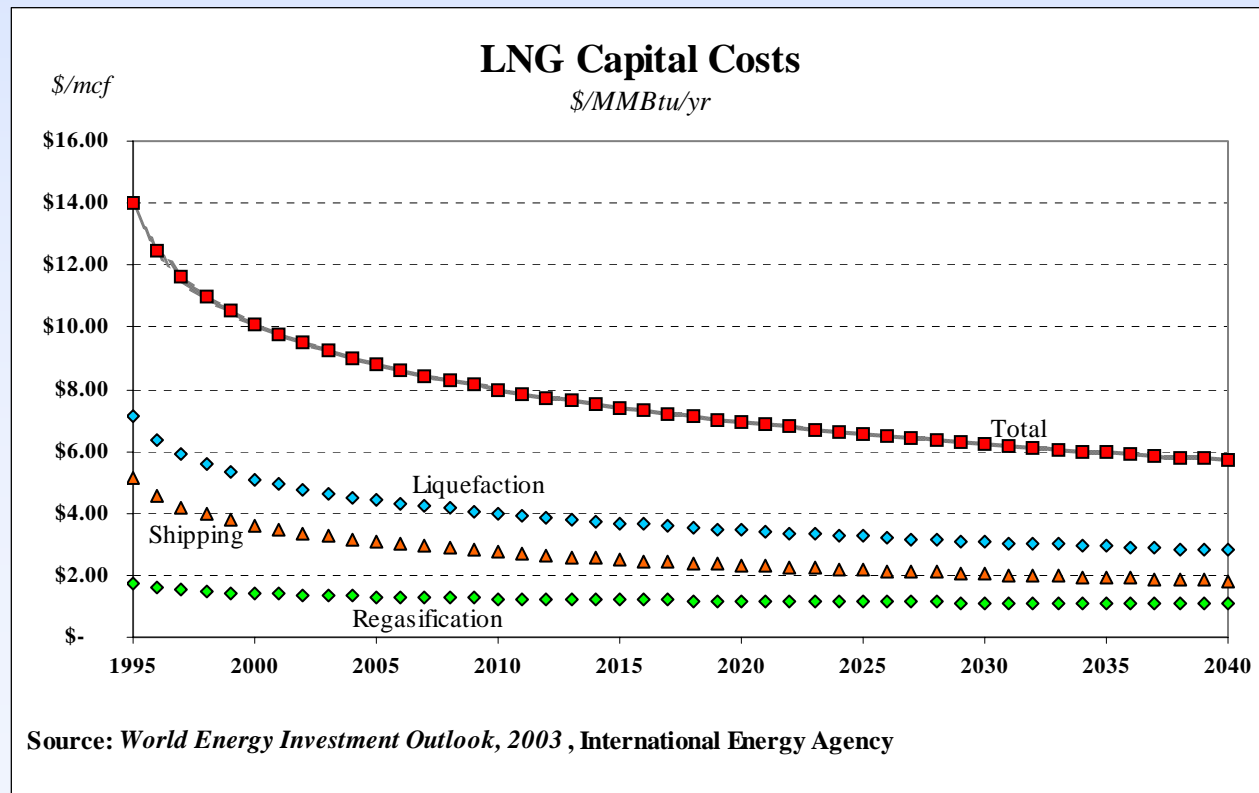
Sources:

1. "The Global Liquefied Natural Gas Market: Status and Outlook" (December 2003), US Energy Information Administration
2. Various Industry Consultant Reports
3. Author calculations



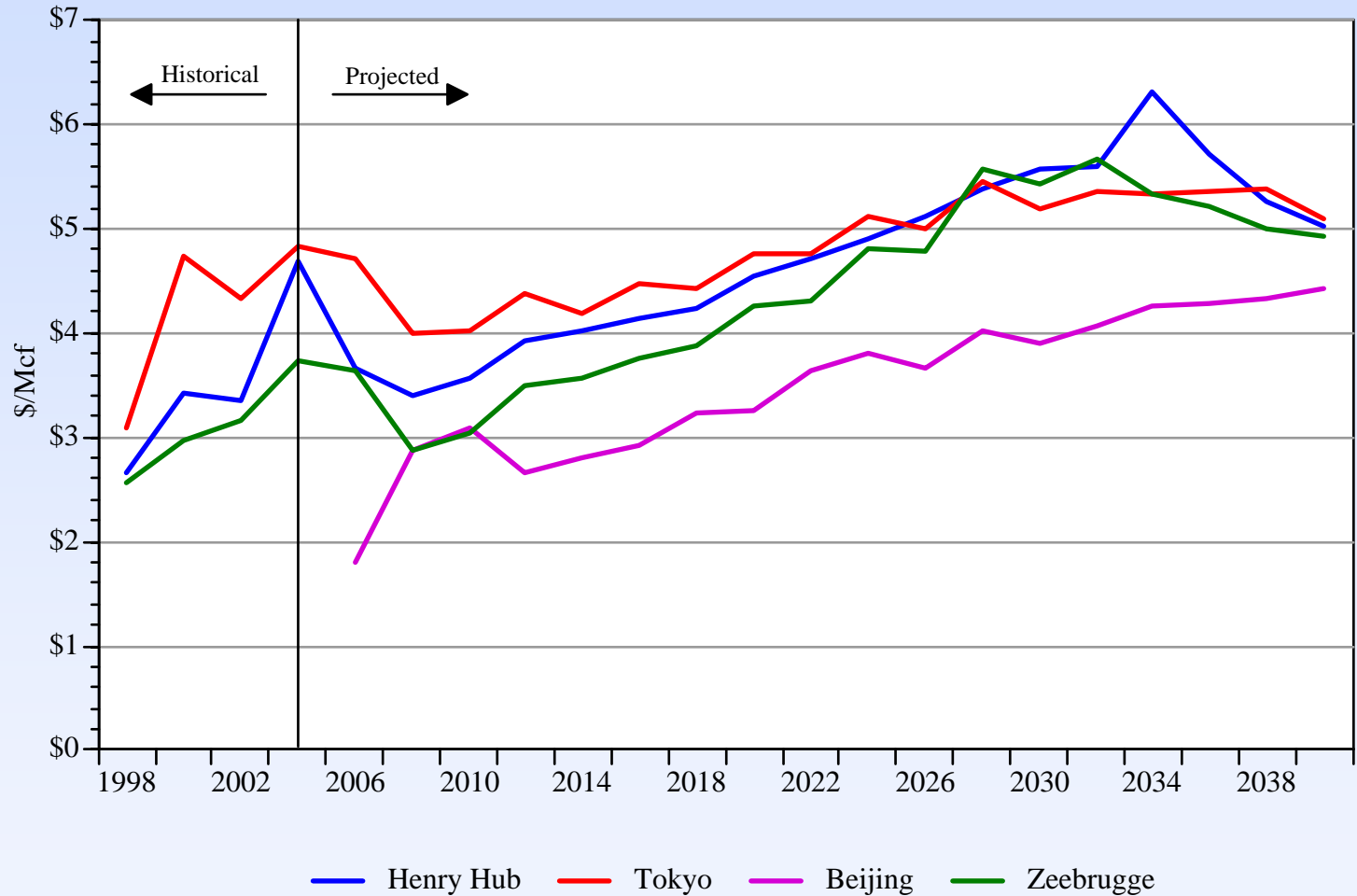
# Technological change in LNG

- LNG transport, liquefaction, and regasification capital and O&M costs are expected to decline
  - ◆ Rates of change in the model are based on a statistical fit to WEIO rates



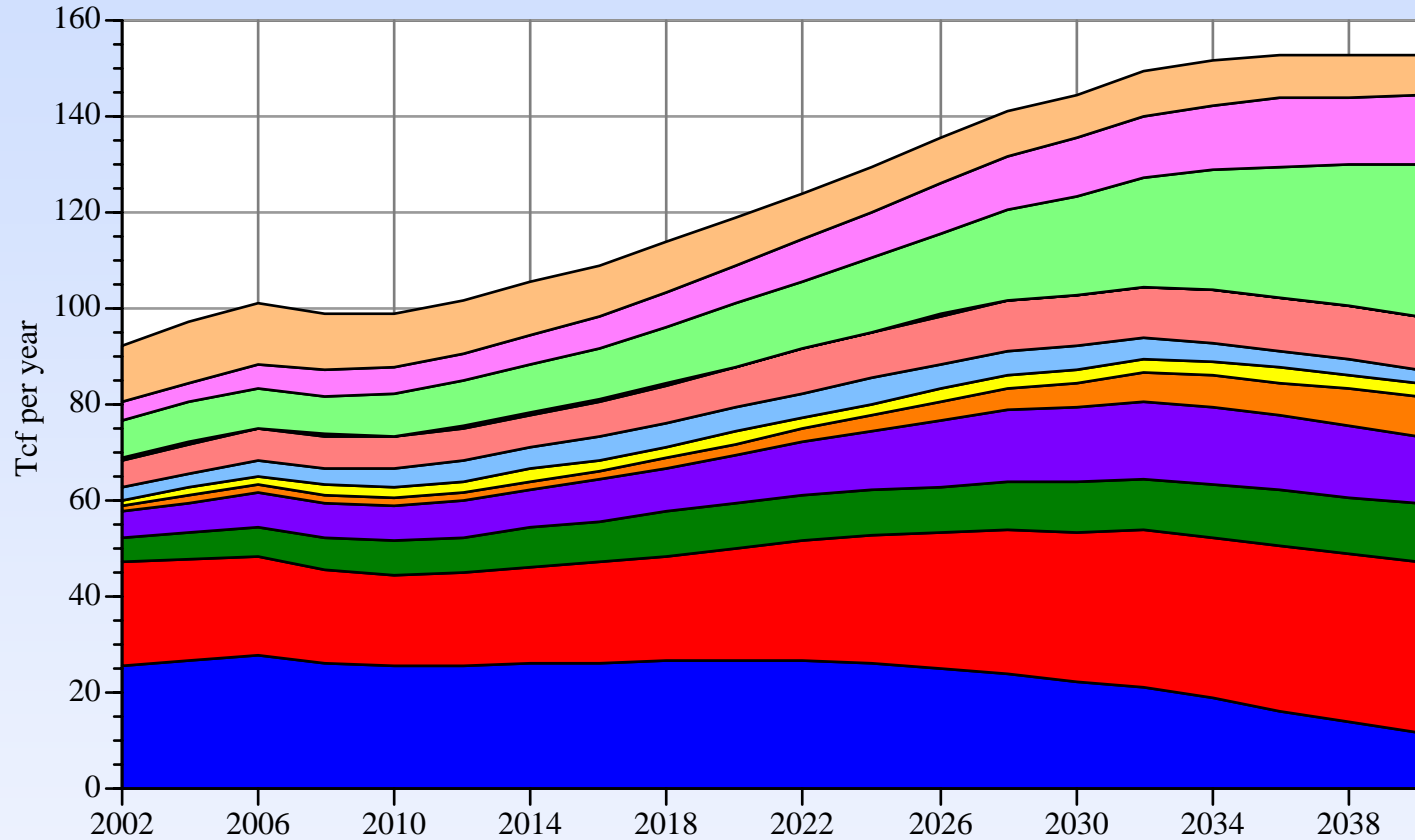


# Selected price projections





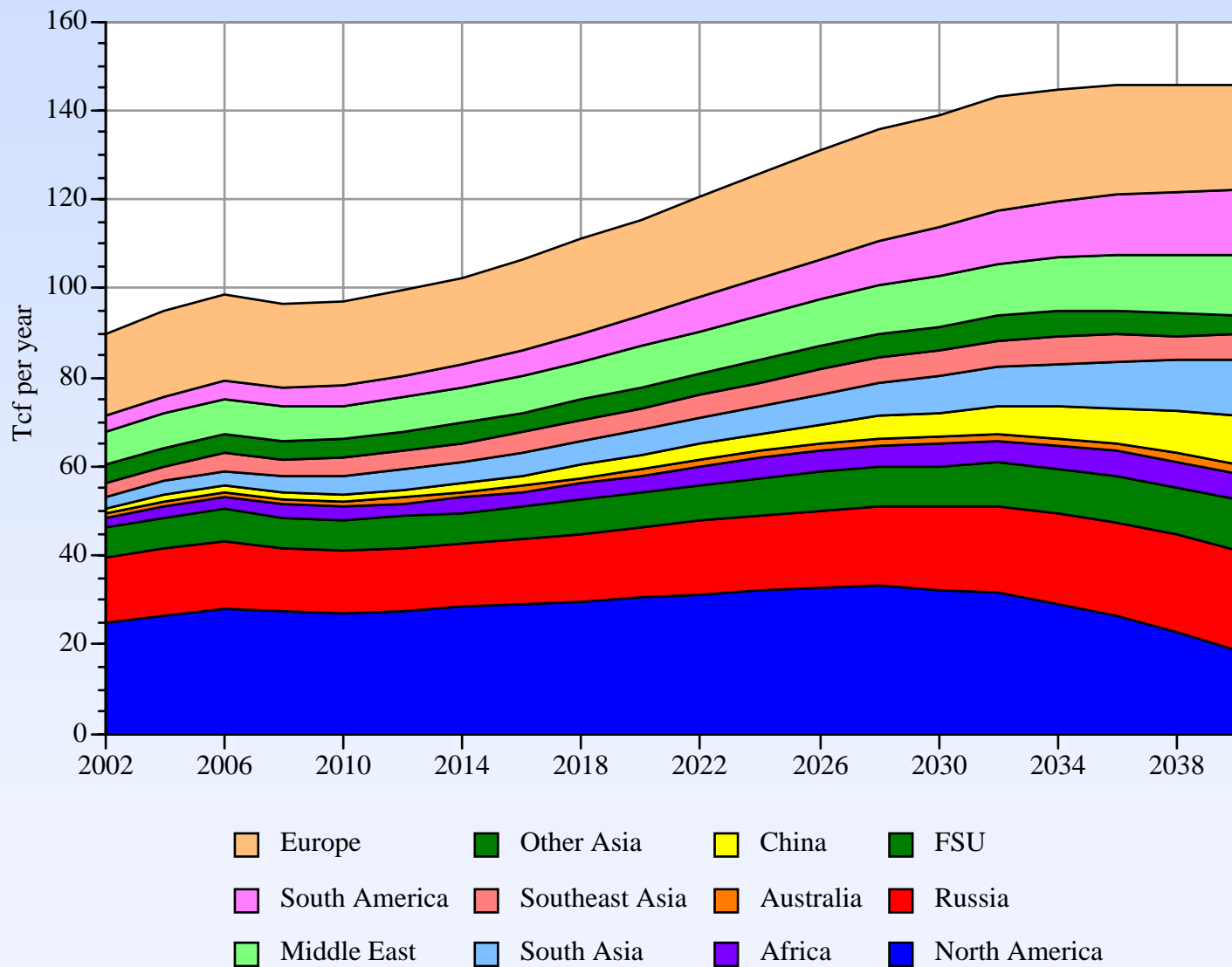
# Supply projections



# Demand projections



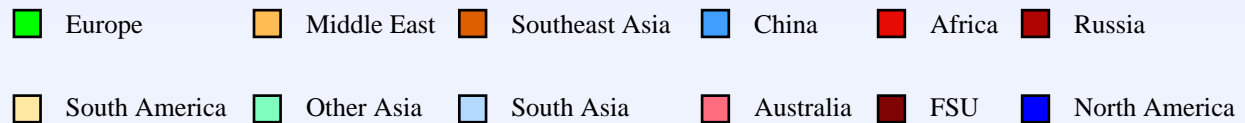
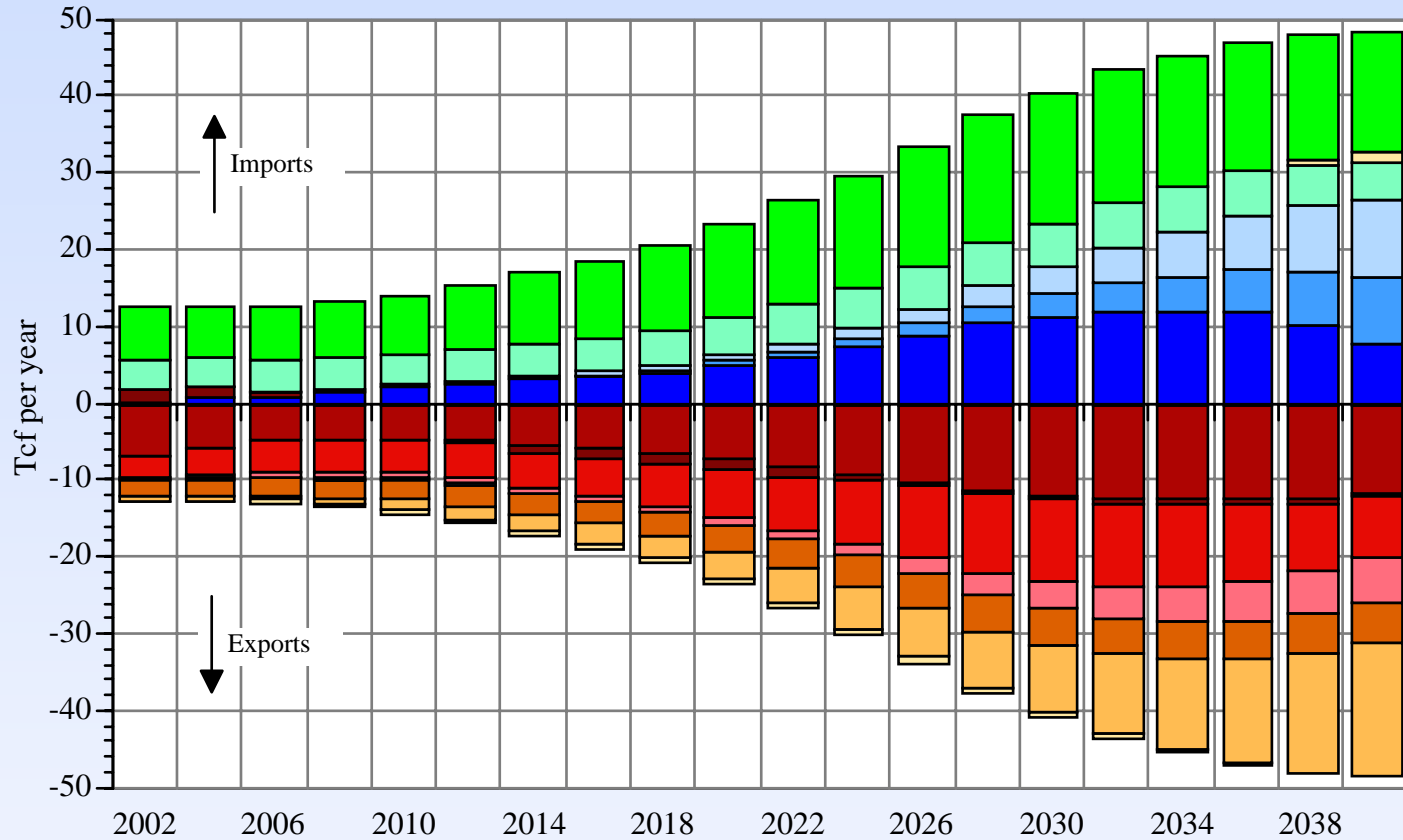
RICE  
UNIVERSITY





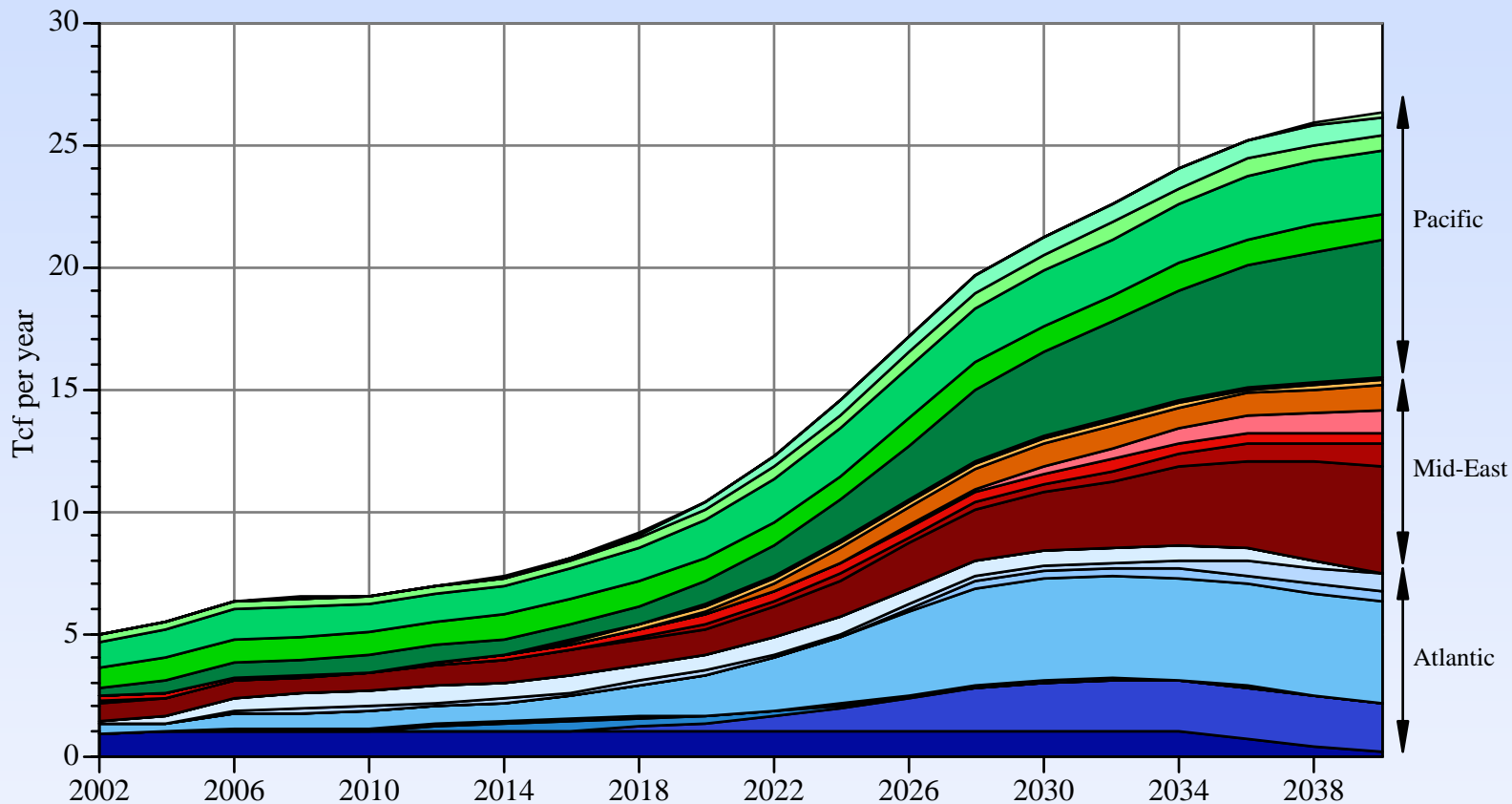


# Natural gas trades





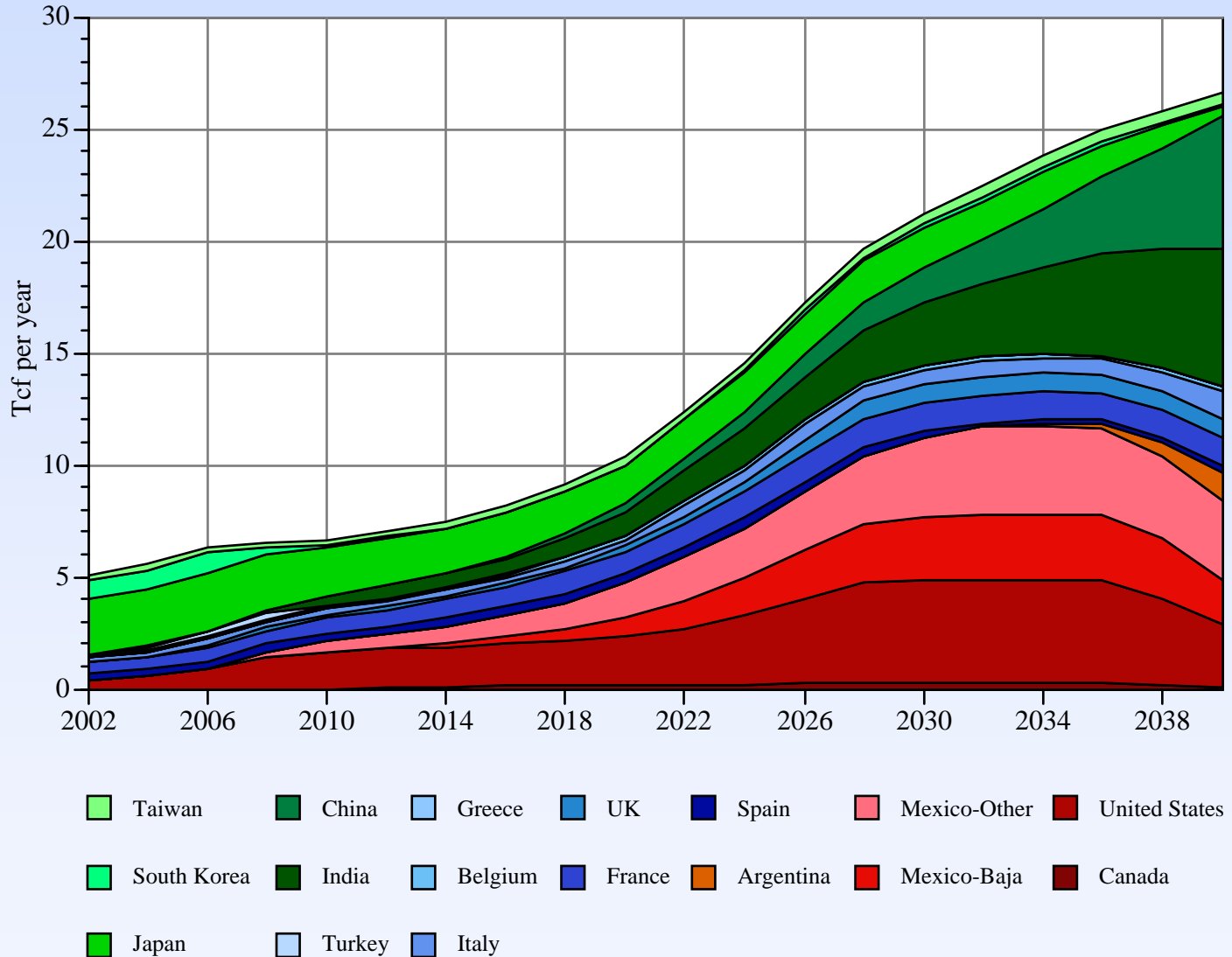
# LNG exporters



- |                         |                      |           |                   |         |
|-------------------------|----------------------|-----------|-------------------|---------|
| Russia-Sakhalin/Nahodka | Australia            | Oman      | Trinidad & Tobago | Libya   |
| Papua New Guinea        | Peru/Chile (Bolivia) | UAE       | Norway            | Egypt   |
| Brunei                  | Iran                 | Qatar     | Russia-Barents    | Angola  |
| Indonesia               | Yemen                | Venezuela | Nigeria           | Algeria |
| Malaysia                | Saudi Arabia         |           |                   |         |

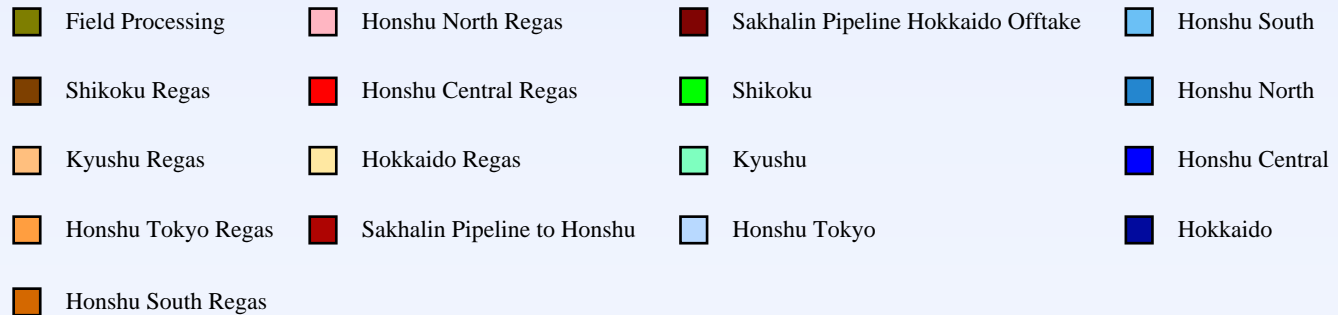
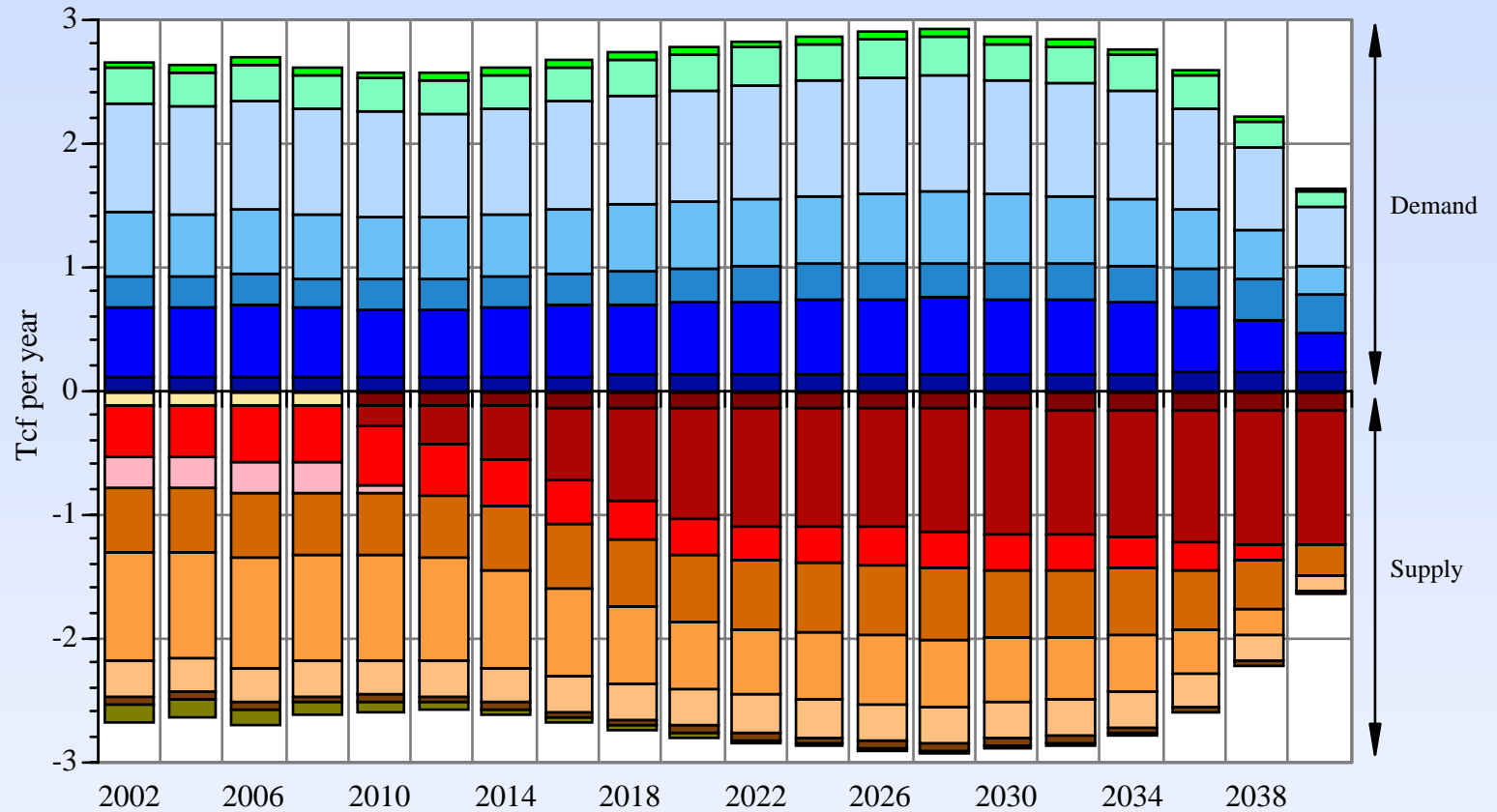


# LNG importers





# Japan





# *Scenario analyses*

- Reduced Russian supply, perhaps as result of:
  - ◆ Monopolization of Russian industry
  - ◆ Export tax on natural gas
  - ◆ Internal Russian politics discourages investment
- Pipelines to China and Korea from Russia, and from Vietnam to China, don't get built
- Sakhalin pipeline is not built
- Higher growth in Chinese demand for gas
- Higher growth in Japanese demand for gas



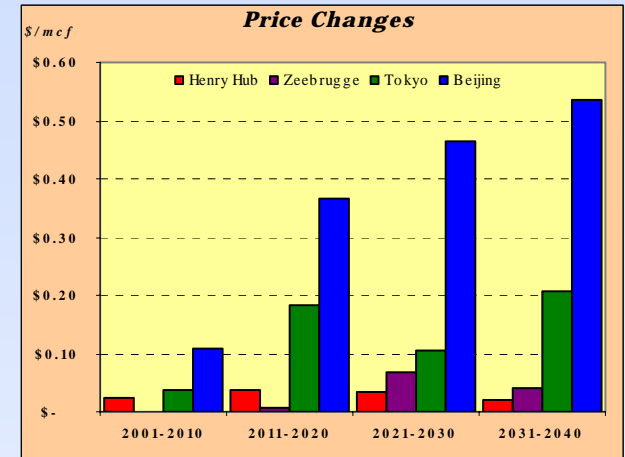
# Delayed Russian Development

<i>Supply Changes</i>	<b>2010</b>	<b>2020</b>	<b>2030</b>	<b>2040</b>
<b>Total (Tcf)</b>	<b>-3.810</b>	<b>-7.128</b>	<b>-7.666</b>	<b>-9.022</b>
<b>Pipeline (Tcf)</b>	<b>-3.934</b>	<b>-7.677</b>	<b>-8.467</b>	<b>-9.123</b>
<b>Share of Total</b>	-0.40%	-1.05%	-1.41%	-1.15%
<b>Share of Pipeline Shipments</b>				
Russia	-4.56%	-7.21%	-7.21%	-5.16%
FSU	1.16%	1.24%	1.56%	0.41%
Europe	0.45%	0.67%	0.57%	0.27%
North Africa	0.26%	0.43%	0.42%	0.33%
Other Africa	0.04%	0.09%	0.06%	0.13%
Qatar	0.02%	0.05%	0.05%	0.08%
Other Middle East	0.38%	0.88%	1.36%	1.66%
South Asia	0.16%	0.41%	0.35%	0.25%
Indonesia	0.10%	0.12%	0.16%	0.17%
Other Southeast Asia	0.06%	0.18%	0.21%	0.02%
Australia	0.05%	0.11%	0.11%	0.13%
North America	1.24%	1.85%	1.32%	0.70%
South America	0.27%	0.59%	0.69%	0.88%
Rest of World	0.37%	0.60%	0.34%	0.13%
<b>LNG (Tcf)</b>	<b>0.123</b>	<b>0.548</b>	<b>0.801</b>	<b>0.101</b>
<b>Share of Total Shipments</b>	0.40%	1.05%	1.41%	1.15%
<b>Share of LNG Shipments</b>				
Russia	0.00%	-0.20%	-0.84%	-1.61%
FSU	0.00%	0.00%	0.00%	0.00%
Europe	-0.05%	-0.09%	-0.03%	0.93%
North Africa	0.61%	-0.72%	-0.15%	-0.14%
Other Africa	-0.20%	-1.09%	-0.41%	0.30%
Qatar	-0.10%	-0.62%	-0.65%	-0.11%
Other Middle East	-0.02%	0.05%	-0.20%	0.32%
South Asia	0.00%	0.00%	0.00%	0.00%
Indonesia	-0.33%	0.21%	-0.02%	0.29%
Other Southeast Asia	-0.36%	1.40%	0.05%	0.35%
Australia	0.34%	1.68%	2.44%	-0.27%
North America	0.00%	0.00%	0.00%	0.00%
South America	-0.02%	-0.32%	-0.12%	-0.03%
Rest of World	0.13%	-0.29%	-0.07%	-0.05%



# Delayed Russian Development

<i>Demand Changes</i>	<u>2010</u>	<u>2020</u>	<u>2030</u>	<u>2040</u>
<b>World Total (Tcf)</b>	<b>-0.998</b>	<b>-2.504</b>	<b>-4.814</b>	<b>-8.178</b>
<b>Share of Total</b>				
<b>Russia</b>	-0.39%	-0.69%	-0.90%	-0.49%
<b>FSU</b>	-0.09%	-0.22%	-0.30%	-0.14%
<b>Europe</b>	0.12%	0.14%	-0.02%	-0.72%
<b>Africa</b>	0.04%	0.05%	0.10%	0.22%
<b>Middle East</b>	0.00%	0.08%	0.16%	0.36%
<b>South Asia</b>	0.02%	0.08%	0.15%	0.40%
<b>Southeast Asia</b>	0.02%	0.08%	0.11%	0.14%
<b>Australia</b>	0.01%	0.02%	0.01%	0.05%
<b>China</b>	-0.01%	-0.03%	-0.11%	-0.26%
<b>Other Asia</b>	0.03%	-0.06%	-0.07%	-0.72%
<b>North America</b>	0.19%	0.37%	0.62%	0.52%
<b>South America</b>	0.05%	0.18%	0.26%	0.64%



<i>Disposition of Russia Gas</i>	<u>2010</u>	<u>2020</u>	<u>2030</u>	<u>2040</u>
<b>Total Supply (Tcf)</b>	<b>-4.834</b>	<b>-8.926</b>	<b>-10.576</b>	<b>-8.993</b>
<b>Share of World Supply</b>	<b>-4.32%</b>	<b>-6.75%</b>	<b>-6.51%</b>	<b>-4.80%</b>
<b>Disposition by Share</b>				
<b>Own Use</b>	10.15%	22.48%	14.10%	13.82%
<b>Pipeline to Europe</b>	-7.86%	-19.40%	-10.80%	-7.29%
<b>Pipeline to China</b>	-0.76%	1.51%	0.57%	-1.85%
<b>Pipeline to Japan</b>	-1.53%	-2.17%	-0.84%	-1.05%
<b>Pipeline to South Korea</b>	0.00%	-2.33%	-2.81%	-2.57%
<b>to LNG</b>	0.00%	-0.09%	-0.21%	-1.05%



# China, Korea pipelines not built

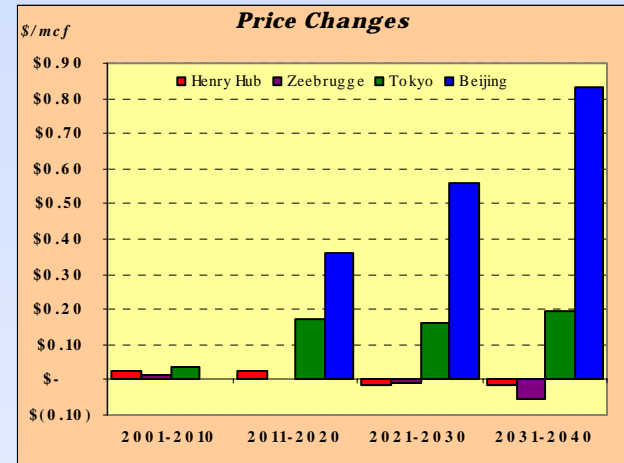
<i>Supply Changes</i>	<u>2010</u>	<u>2020</u>	<u>2030</u>	<u>2040</u>
<b>Total (Tcf)</b>	<b>0.316</b>	<b>-0.354</b>	<b>-0.013</b>	<b>-2.020</b>
<b>Pipeline (Tcf)</b>	<b>0.118</b>	<b>-1.148</b>	<b>-1.870</b>	<b>-2.820</b>
<b>Share of Total</b>	-0.18%	-0.70%	-1.29%	-0.76%
<b>Share of Pipeline Shipments</b>				
Russia	-0.06%	-0.82%	-1.28%	-0.52%
FSU	0.02%	0.08%	-0.02%	-0.88%
Europe	-0.03%	0.11%	0.11%	0.23%
North Africa	0.01%	0.01%	0.02%	0.08%
Other Africa	0.00%	-0.01%	0.04%	0.08%
Qatar	-0.01%	0.01%	0.01%	0.02%
Other Middle East	0.03%	-0.03%	0.19%	0.37%
South Asia	-0.02%	0.05%	0.05%	0.08%
Indonesia	0.06%	-0.02%	0.03%	0.01%
Other Southeast Asia	-0.02%	-0.01%	0.10%	-0.07%
Australia	0.01%	0.04%	0.04%	0.07%
North America	-0.02%	0.26%	0.28%	0.20%
South America	0.03%	0.08%	0.06%	0.21%
Rest of World	-0.01%	0.25%	0.38%	0.12%
<b>LNG (Tcf)</b>	<b>0.198</b>	<b>0.793</b>	<b>1.857</b>	<b>0.800</b>
<b>Share of Total Shipments</b>	0.18%	0.70%	1.29%	0.76%
<b>Share of LNG Shipments</b>				
Russia	0.00%	-0.18%	2.31%	2.05%
FSU	0.00%	0.00%	0.00%	0.00%
Europe	-0.08%	-0.12%	-0.07%	-0.44%
North Africa	0.40%	-0.63%	-0.25%	0.00%
Other Africa	-0.32%	-1.16%	-2.65%	-0.76%
Qatar	-0.23%	-0.85%	-1.13%	-0.54%
Other Middle East	1.23%	0.06%	-0.85%	-0.04%
South Asia	0.00%	0.00%	0.00%	0.00%
Indonesia	-0.54%	0.13%	0.10%	0.27%
Other Southeast Asia	-0.57%	1.49%	-0.08%	0.42%
Australia	0.04%	1.83%	2.91%	-0.91%
North America	0.00%	0.00%	0.00%	0.00%
South America	-0.12%	-0.45%	-0.25%	-0.05%
Rest of World	0.18%	-0.13%	-0.05%	-0.01%





# China, Korea pipelines not built

<i>Demand Changes</i>	<u>2010</u>	<u>2020</u>	<u>2030</u>	<u>2040</u>
<b>World Total (Tcf)</b>	<b>-0.131</b>	<b>-0.374</b>	<b>-0.323</b>	<b>-1.599</b>
<b>Share of Total</b>				
<b>Russia</b>	0.05%	0.23%	0.28%	0.60%
<b>FSU</b>	0.02%	0.08%	0.08%	0.22%
<b>Europe</b>	0.01%	0.04%	0.19%	0.92%
<b>Africa</b>	0.00%	-0.01%	0.01%	0.05%
<b>Middle East</b>	0.01%	0.01%	0.06%	0.09%
<b>South Asia</b>	-0.02%	0.00%	0.01%	0.10%
<b>Southeast Asia</b>	-0.01%	0.02%	0.05%	0.02%
<b>Australia</b>	0.00%	-0.01%	-0.04%	-0.02%
<b>China</b>	0.00%	-0.11%	-0.34%	-1.38%
<b>Other Asia</b>	0.00%	-0.16%	-0.22%	-0.72%
<b>North America</b>	-0.10%	-0.12%	-0.07%	-0.01%
<b>South America</b>	0.04%	0.03%	-0.01%	0.13%



<i>Disposition of Russia Gas</i>	<u>2010</u>	<u>2020</u>	<u>2030</u>	<u>2040</u>
<b>Total Supply (Tcf)</b>	<b>-0.030</b>	<b>-1.142</b>	<b>-1.460</b>	<b>-0.849</b>
<b>Share of World Supply</b>	<b>-0.1%</b>	<b>-0.9%</b>	<b>-1.0%</b>	<b>-0.3%</b>
<b>Disposition by Share</b>				
<b>Own Use</b>	1.7%	4.4%	4.2%	3.1%
<b>Pipeline to Europe</b>	1.0%	2.1%	2.9%	6.8%
<b>Pipeline to China</b>	-3.1%	-4.7%	-6.8%	-9.1%
<b>Pipeline to Japan</b>	0.4%	0.6%	0.4%	0.2%
<b>Pipeline to South Korea</b>	0.0%	-2.3%	-2.8%	-2.6%
<b>to LNG</b>	0.0%	-0.1%	2.0%	1.7%



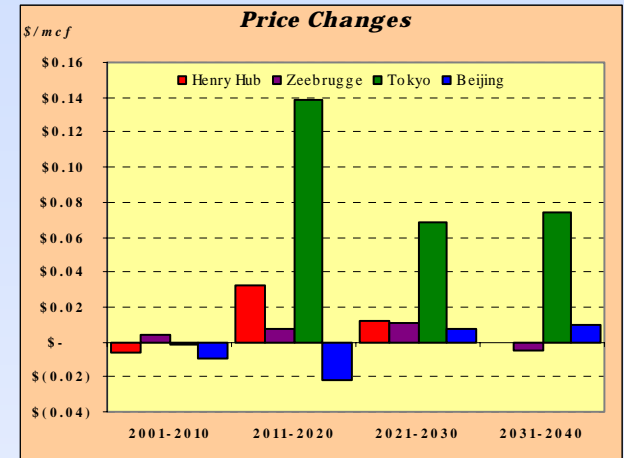
# Sakhalin pipeline not built

<i>Supply Changes</i>	<u>2010</u>	<u>2020</u>	<u>2030</u>	<u>2040</u>
<b>Total (Tcf)</b>	<b>0.055</b>	<b>-0.368</b>	<b>-0.100</b>	<b>-1.135</b>
<b>Pipeline (Tcf)</b>	<b>-0.151</b>	<b>-1.119</b>	<b>-0.978</b>	<b>-1.662</b>
<b>Share of Total</b>	-0.20%	-0.66%	-0.62%	-0.48%
<b>Share of Pipeline Shipments</b>				
Russia	-0.24%	-0.87%	-0.76%	-0.70%
FSU	0.06%	0.08%	0.05%	-0.10%
Europe	0.01%	0.10%	0.06%	0.06%
North Africa	0.01%	0.07%	0.06%	0.05%
Other Africa	0.01%	0.00%	0.01%	0.03%
Qatar	0.00%	0.01%	0.01%	0.02%
Other Middle East	0.04%	0.12%	0.20%	0.22%
South Asia	-0.03%	0.08%	0.08%	0.06%
Indonesia	0.02%	0.02%	0.00%	0.03%
Other Southeast Asia	-0.01%	0.05%	0.13%	0.03%
Australia	0.01%	0.02%	-0.05%	0.01%
North America	0.07%	0.25%	0.14%	0.12%
South America	0.02%	0.03%	0.03%	0.14%
Rest of World	0.04%	0.04%	0.03%	0.03%
<b>LNG (Tcf)</b>	<b>0.206</b>	<b>0.751</b>	<b>0.878</b>	<b>0.527</b>
<b>Share of Total Shipments</b>	0.20%	0.66%	0.62%	0.48%
<b>Share of LNG Shipments</b>				
Russia	2.46%	2.86%	3.57%	2.22%
FSU	0.00%	0.00%	0.00%	0.00%
Europe	-0.08%	-0.12%	-0.03%	0.03%
North Africa	-0.61%	-1.13%	-0.25%	-0.05%
Other Africa	-0.34%	-1.19%	-1.23%	-0.37%
Qatar	-0.08%	-0.62%	-0.40%	-0.21%
Other Middle East	0.26%	-0.50%	-0.44%	-0.14%
South Asia	0.00%	0.00%	0.00%	0.00%
Indonesia	-0.56%	-0.07%	-0.47%	-0.28%
Other Southeast Asia	-0.60%	0.46%	-0.74%	-0.42%
Australia	-0.17%	0.90%	0.20%	-0.72%
North America	0.00%	0.00%	0.00%	0.00%
South America	-0.28%	-0.42%	-0.12%	-0.02%
Rest of World	0.00%	-0.18%	-0.08%	-0.06%



# Sakhalin pipeline not built

<i>Demand Changes</i>	<u>2010</u>	<u>2020</u>	<u>2030</u>	<u>2040</u>
<b>World Total (Tcf)</b>	<b>0.021</b>	<b>-0.353</b>	<b>-0.219</b>	<b>-0.819</b>
<b>Share of Total</b>				
<b>Russia</b>	0.02%	0.05%	0.02%	0.08%
<b>FSU</b>	0.00%	0.02%	0.01%	0.03%
<b>Europe</b>	-0.02%	0.02%	0.00%	0.08%
<b>Africa</b>	0.01%	0.00%	0.00%	0.01%
<b>Middle East</b>	0.00%	0.01%	0.09%	0.03%
<b>South Asia</b>	-0.01%	0.01%	0.01%	0.04%
<b>Southeast Asia</b>	-0.02%	0.01%	0.01%	0.01%
<b>Australia</b>	0.00%	0.00%	-0.01%	0.00%
<b>China</b>	0.01%	-0.01%	-0.01%	0.01%
<b>Other Asia</b>	0.00%	-0.05%	-0.06%	-0.35%
<b>North America</b>	0.00%	-0.07%	-0.06%	-0.03%
<b>South America</b>	0.01%	0.01%	0.00%	0.08%



<i>Disposition of Russia Gas</i>	<u>2010</u>	<u>2020</u>	<u>2030</u>	<u>2040</u>
<b>Total Supply (Tcf)</b>	<b>-0.085</b>	<b>-0.855</b>	<b>-0.366</b>	<b>-0.725</b>
<b>Share of World Supply</b>	<b>-0.10%</b>	<b>-0.66%</b>	<b>-0.24%</b>	<b>-0.30%</b>
<b>Disposition by Share</b>				
<b>Own Use</b>	1.14%	2.07%	0.64%	0.74%
<b>Pipeline to Europe</b>	-0.53%	0.71%	0.28%	0.78%
<b>Pipeline to China</b>	0.03%	0.24%	0.14%	0.22%
<b>Pipeline to Japan</b>	-1.53%	-4.51%	-3.72%	-3.58%
<b>Pipeline to South Korea</b>	0.00%	0.06%	0.06%	0.06%
<b>to LNG</b>	0.89%	1.43%	2.61%	1.79%



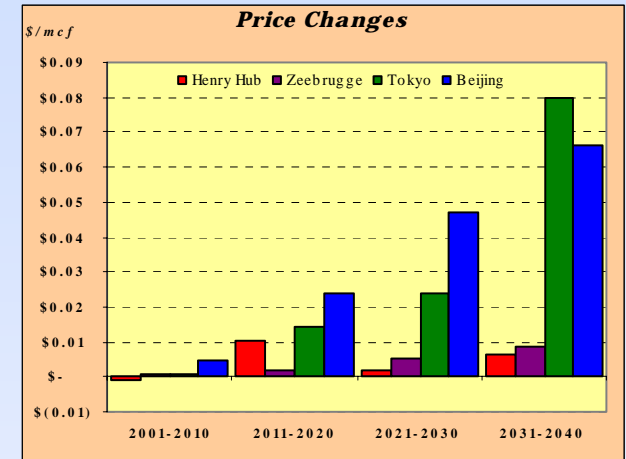
# Higher Chinese demand growth

<i>Supply Changes</i>	<u>2010</u>	<u>2020</u>	<u>2030</u>	<u>2040</u>
<b>Total (Tcf)</b>	<b>0.185</b>	<b>0.184</b>	<b>0.595</b>	<b>0.416</b>
<b>Pipeline (Tcf)</b>	<b>0.186</b>	<b>0.163</b>	<b>0.346</b>	<b>0.014</b>
<b>Share of Total</b>	0.01%	0.00%	-0.11%	-0.22%
<b>Share of Pipeline Shipments</b>				
Russia	-0.03%	0.03%	0.03%	0.05%
FSU	-0.01%	-0.01%	-0.03%	0.01%
Europe	-0.03%	-0.01%	-0.01%	-0.02%
North Africa	0.00%	-0.01%	0.01%	0.02%
Other Africa	0.00%	0.00%	-0.02%	-0.01%
Qatar	0.00%	0.00%	0.00%	0.01%
Other Middle East	-0.01%	0.00%	-0.04%	-0.02%
South Asia	-0.01%	-0.01%	-0.01%	0.04%
Indonesia	0.02%	-0.04%	0.01%	0.00%
Other Southeast Asia	-0.04%	0.03%	0.03%	-0.09%
Australia	0.07%	-0.01%	0.03%	0.04%
North America	-0.05%	-0.04%	-0.05%	0.00%
South America	-0.03%	-0.05%	-0.03%	-0.02%
Rest of World	0.13%	0.12%	0.09%	0.00%
<b>LNG (Tcf)</b>	<b>-0.001</b>	<b>0.021</b>	<b>0.249</b>	<b>0.403</b>
<b>Share of Total Shipments</b>	-0.01%	0.00%	0.11%	0.22%
<b>Share of LNG Shipments</b>				
Russia	0.00%	-0.07%	-0.36%	-0.30%
FSU	0.00%	0.00%	0.00%	0.00%
Europe	0.00%	0.00%	-0.01%	0.04%
North Africa	-0.21%	-0.29%	-0.10%	-0.01%
Other Africa	0.00%	-0.12%	-0.12%	-0.25%
Qatar	0.05%	-0.02%	-0.11%	0.10%
Other Middle East	0.00%	0.20%	-0.10%	0.30%
South Asia	0.00%	0.00%	0.00%	0.00%
Indonesia	0.00%	0.10%	-0.09%	0.05%
Other Southeast Asia	0.00%	0.04%	0.45%	0.47%
Australia	-0.01%	0.18%	0.48%	-0.37%
North America	0.00%	0.00%	0.00%	0.00%
South America	0.17%	-0.01%	-0.04%	-0.02%
Rest of World	0.00%	0.00%	-0.01%	-0.01%



# Higher Chinese demand growth

<i>Demand Changes</i>	<u>2010</u>	<u>2020</u>	<u>2030</u>	<u>2040</u>
<b>World Total (Tcf)</b>	<b>0.035</b>	<b>0.195</b>	<b>0.697</b>	<b>0.662</b>
<b>Share of Total</b>				
<b>Russia</b>	-0.01%	-0.03%	-0.09%	-0.12%
<b>FSU</b>	0.00%	-0.01%	-0.04%	-0.06%
<b>Europe</b>	-0.01%	-0.04%	-0.12%	-0.11%
<b>Africa</b>	0.00%	-0.01%	-0.02%	-0.02%
<b>Middle East</b>	-0.02%	-0.01%	-0.03%	-0.04%
<b>South Asia</b>	0.00%	-0.01%	-0.03%	-0.04%
<b>Southeast Asia</b>	-0.03%	-0.03%	-0.03%	-0.07%
<b>Australia</b>	0.01%	0.00%	-0.01%	-0.02%
<b>China</b>	0.06%	0.21%	0.56%	0.96%
<b>Other Asia</b>	0.02%	-0.01%	-0.03%	-0.11%
<b>North America</b>	-0.01%	-0.09%	-0.15%	-0.32%
<b>South America</b>	-0.01%	0.02%	0.00%	-0.03%



<i>Disposition of Russia Gas</i>	<u>2010</u>	<u>2020</u>	<u>2030</u>	<u>2040</u>
<b>Total Supply (Tcf)</b>	<b>0.012</b>	<b>0.055</b>	<b>0.052</b>	<b>-0.003</b>
<b>Share of World Supply</b>	<b>-0.02%</b>	<b>0.02%</b>	<b>-0.05%</b>	<b>-0.06%</b>
<b>Disposition by Share</b>				
<b>Own Use</b>	0.18%	-0.14%	-0.60%	-0.63%
<b>Pipeline to Europe</b>	-0.25%	-0.09%	-0.43%	-0.57%
<b>Pipeline to China</b>	0.08%	0.21%	1.28%	1.47%
<b>Pipeline to Japan</b>	-0.01%	0.03%	0.00%	0.00%
<b>Pipeline to South Korea</b>	0.00%	0.02%	-0.01%	-0.07%
<b>to LNG</b>	0.00%	-0.03%	-0.24%	-0.20%



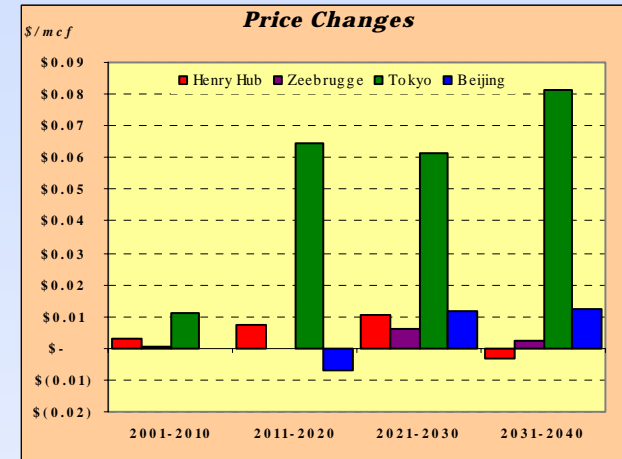
# Higher Japanese demand growth

<i>Supply Changes</i>	<b>2010</b>	<b>2020</b>	<b>2030</b>	<b>2040</b>
<b>Total (Tcf)</b>	<b>0.161</b>	<b>0.188</b>	<b>0.270</b>	<b>-0.212</b>
<b>Pipeline (Tcf)</b>	<b>0.167</b>	<b>0.111</b>	<b>0.049</b>	<b>-0.020</b>
<b>Share of Total</b>	0.02%	-0.05%	-0.13%	0.10%
<b>Share of Pipeline Shipments</b>				
Russia	-0.03%	0.00%	0.01%	0.19%
FSU	0.03%	-0.03%	-0.02%	-0.20%
Europe	-0.04%	0.00%	0.00%	0.02%
North Africa	0.00%	0.04%	0.01%	0.00%
Other Africa	0.00%	0.01%	-0.02%	0.00%
Qatar	0.00%	0.00%	-0.01%	0.00%
Other Middle East	-0.03%	0.05%	-0.01%	-0.01%
South Asia	0.00%	-0.01%	0.01%	0.02%
Indonesia	0.05%	-0.03%	0.01%	-0.03%
Other Southeast Asia	-0.03%	0.04%	0.02%	0.01%
Australia	0.00%	0.01%	0.01%	-0.01%
North America	-0.05%	-0.03%	-0.01%	0.00%
South America	0.03%	-0.06%	-0.04%	0.00%
Rest of World	0.07%	0.02%	0.02%	0.01%
<b>LNG (Tcf)</b>	<b>-0.006</b>	<b>0.078</b>	<b>0.221</b>	<b>-0.193</b>
<b>Share of Total Shipments</b>	-0.02%	0.05%	0.13%	-0.10%
<b>Share of LNG Shipments</b>				
Russia	0.00%	-0.20%	-0.02%	-0.80%
FSU	0.00%	0.00%	0.00%	0.00%
Europe	0.00%	-0.01%	-0.01%	-0.08%
North Africa	-0.03%	-0.11%	0.01%	0.01%
Other Africa	0.01%	-0.34%	-0.21%	0.28%
Qatar	0.05%	-0.21%	-0.37%	0.07%
Other Middle East	0.05%	-0.04%	0.02%	0.26%
South Asia	0.00%	0.00%	0.00%	0.00%
Indonesia	0.02%	0.18%	-0.13%	0.13%
Other Southeast Asia	0.02%	0.31%	0.06%	0.22%
Australia	-0.26%	0.52%	0.64%	-0.07%
North America	0.00%	0.00%	0.00%	0.00%
South America	0.14%	-0.04%	0.03%	-0.01%
Rest of World	0.00%	-0.07%	-0.04%	-0.02%



# Higher Japanese demand growth

<i>Demand Changes</i>	<u>2010</u>	<u>2020</u>	<u>2030</u>	<u>2040</u>
<b>World Total (Tcf)</b>	<b>0.063</b>	<b>0.197</b>	<b>0.152</b>	<b>0.010</b>
<b>Share of Total</b>				
<b>Russia</b>	0.00%	-0.02%	-0.02%	-0.01%
<b>FSU</b>	0.00%	-0.01%	-0.01%	-0.01%
<b>Europe</b>	-0.02%	-0.03%	-0.04%	-0.01%
<b>Africa</b>	0.00%	0.00%	-0.01%	-0.01%
<b>Middle East</b>	-0.04%	0.01%	-0.02%	-0.01%
<b>South Asia</b>	0.00%	0.00%	-0.01%	-0.01%
<b>Southeast Asia</b>	-0.03%	-0.02%	-0.02%	-0.04%
<b>Australia</b>	0.00%	0.00%	-0.01%	-0.01%
<b>China</b>	-0.01%	-0.01%	-0.02%	-0.09%
<b>Other Asia</b>	0.10%	0.19%	0.27%	0.32%
<b>North America</b>	-0.03%	-0.09%	-0.10%	-0.14%
<b>South America</b>	0.03%	-0.01%	-0.02%	0.03%



<i>Disposition of Russia Gas</i>	<u>2010</u>	<u>2020</u>	<u>2030</u>	<u>2040</u>
<b>Total Supply (Tcf)</b>	<b>0.004</b>	<b>0.005</b>	<b>0.029</b>	<b>0.022</b>
<b>Share of World Supply</b>	<b>-0.03%</b>	<b>-0.03%</b>	<b>-0.02%</b>	<b>0.05%</b>
<b>Disposition by Share</b>				
<b>Own Use</b>	0.21%	-0.11%	-0.13%	-0.46%
<b>Pipeline to Europe</b>	-0.18%	0.10%	-0.04%	0.31%
<b>Pipeline to China</b>	-0.02%	0.03%	0.01%	-0.01%
<b>Pipeline to Japan</b>	-0.01%	0.10%	0.04%	0.68%
<b>Pipeline to South Korea</b>	0.00%	-0.03%	0.12%	0.07%
<b>to LNG</b>	0.00%	-0.09%	0.00%	-0.60%



RICE

UNIVERSITY

# *Some implications of the Reference Case*

- Russia becomes a major force in the global gas market
  - ◆ Russian pipeline gas continues to be important for Europe
  - ◆ Russia also becomes a major supplier of natural gas to China, Korea and Japan
    - ❖ Japan continues to import LNG as the high cost of a national gas grid is prohibitive
    - ❖ Ultimately, gas is also piped east from West Siberia
  - ◆ Russia also enters the LNG market possibly supplying the US
    - ❖ “Net-back” prices in Russia have to be equilibrated
- Qatar, Nigeria, and Australia dominate LNG exports (>50% of total), but Russian pipeline gas exports to Europe and Asia remain larger than total LNG exports from these three combined.
- Trans-Saharan pipeline (Nigeria to Algeria) is constructed in the 2020’s.
- India eventually imports Iranian gas via pipeline, while Europe eventually imports gas from Iraq through Turkey.
- North America becomes a major importer of LNG
  - ◆ Alaska gas serves only to replace declines in other North American production having no dramatic impact on prices
  - ◆ Gas prices in the US eventually exceed prices in Japan
  - ◆ Russia, Middle East, Australia retain low gas prices
- South American gas is consumed primarily in South America
  - ◆ Trinidad LNG export growth is limited to the near term
  - ◆ Brazil imports Bolivian and Venezuelan supplies
  - ◆ Argentina imports Bolivian supplies and becomes a LNG importer
- A backstop technology is implemented in Japan, the US, parts of Europe, and Chile, but not India or China before 2040





# *Some implications of the Sensitivity Cases*

- Variations in demand growth in NE Asia have dramatic effects on global gas markets
  - ◆ Higher growth pulls harder on both LNG and Russian pipe
    - ❖ Higher LNG demand raises US price and leads to faster convergence of prices.
    - ❖ Higher Russian pipeline flow to NE Asia diverts flow from Europe thereby raising European prices.
    - ❖ Higher LNG demand raises production in Australia and SE Asia in the short term, and raises production in the Middle East, SE Asia and Russia in the long term.
- Russian ability to exploit monopoly power is limited.
  - ◆ An attempt to raise prices by decreasing production attracts alternative LNG supply from the Middle East and SE Asia and pipeline supply from the FSU and the Middle East.
  - ◆ In the long term, the availability of a backstop resource also places a ceiling on prices.
- Ability of Middle Eastern producer cartel to exploit monopoly power is similarly limited.
  - ◆ Other LNG producers (Australia and Indonesia) increase production to undercut the monopoly.
  - ◆ FSU and Russian production also increase to undercut the monopoly.
  - ◆ Both the Trans-Saharan pipeline and the pipe from West Siberia to East Siberia in Russia are larger
  - ◆ Again, in the long term, the availability of a backstop resource places a ceiling on prices.
- Political constraints on the development of pipeline routes to NE Asia...
  - ◆ ... raise the demand for LNG and increase prices substantially in NE Asia and raise prices slightly in North America.
  - ◆ ... eventually pushes Eastern Siberian gas into European markets, lowering prices there slightly.