Rice University World Gas Trade Model

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What does the model capture?

- World gas supply potential is large
  - But it is concentrated in areas remote from markets
  - Also, some of these areas have limited production and transport infrastructure in place
  - Some large resources are located in countries that may be politically and/or economically unstable
- Potential for demand growth is large
  - China, India, and other less developed countries
  - Environmental pressure for cleaner fuels
- Model gives a microeconomic framework to examine alternative political and economic phenomena that could affect the market

Basic model structure

- Model based on *Market Builder* from *Altos Partners*
  - Access to the model requires a license from *Altos*
- Dynamic spatial equilibrium linked through time by optimal scheduling of resource extraction
  - Eliminate opportunity for *either* spatial or temporal arbitrage
    - Producers consider all *current and future* prices when determining the profitability of developing a unit of reserves
    - Producers, therefore, maximize the *net present value* of resource extraction for the life of the investment
  - If producers *anticipate* prices in period *t* will be high, they
    - Accelerate investment to take advantage of those prices
    - Delay some supply from periods before *t*
    - Actual prices at *t* thus do not rise as much
- Transport links transmit prices as well as gas
  - A link to a market with high prices will raise prices at the origin supply node
- Non-stochastic framework that predicts prices, flows

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Demand for Natural Gas

- Demand has been stimulated by
  - Actual and proposed environmental regulations
  - Pro-competitive deregulation of wholesale electricity markets
  - Development of CCGT
  - Economic and population growth which increase the demand for energy
- Possible future developments?
  - Gas may become a transport fuel via a number of alternative routes
  - Alternatives (solar, nuclear, coal gasification) may displace gas in electricity production
  - HVDC may displace gas transportation

Market structure

- Expanding depth and geographical extent of the gas market
  - Reduces the risk associated with investing in infrastructure
  - Decrease in average distances between suppliers and/or customers increases arbitrage opportunities
- *Expectation* of new market dynamics encourages the transition
  - Change in market structure can happen quickly
- Swaps can eliminate high cost contracted trades if better alternatives are available

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Estimating energy demand

- Used 23 years of IEA data from 29 OECD economies to relate energy demand to:
  - Overall level of economic activity (GDP)
  - Population, and
  - Economic development (GDP/capita)
- Following Medlock and Soligo (2001), we allow energy demand to increase less with GDP growth as an economy develops
  - Coefficient on GDP goes to zero as per capita GDP approaches 12 times US level (85 years @ 3% pa)
  - Increased population without a change in GDP decreases energy use
  - Effects accumulate over time

Estimated gas share

- Depends negatively on own price, positively on prices of competing fuels
- Level of development as measured by GDP per capita alters effect of the "scale variable" GDP on the gas demand share
  - At lower levels of development, increased GDP does more to increase the demand share of gas
  - Per capita GDP where gas *share* stops increasing is close to value where energy demand stops growing
- Again adjustments occur gradually in response to changes

Forecasting demand

- World Bank *Economic Indicators* forecasts of:
  - GDP growth
  - Population growth
- EIA base case oil price forecasts and historical coal/oil price ratio used to forecast alternative fuel prices
- For output discussed below, we used EIA base case demand forecasts with estimated own-price elasticity
- Forecasts using above demand methodology available on Baker web site after conference

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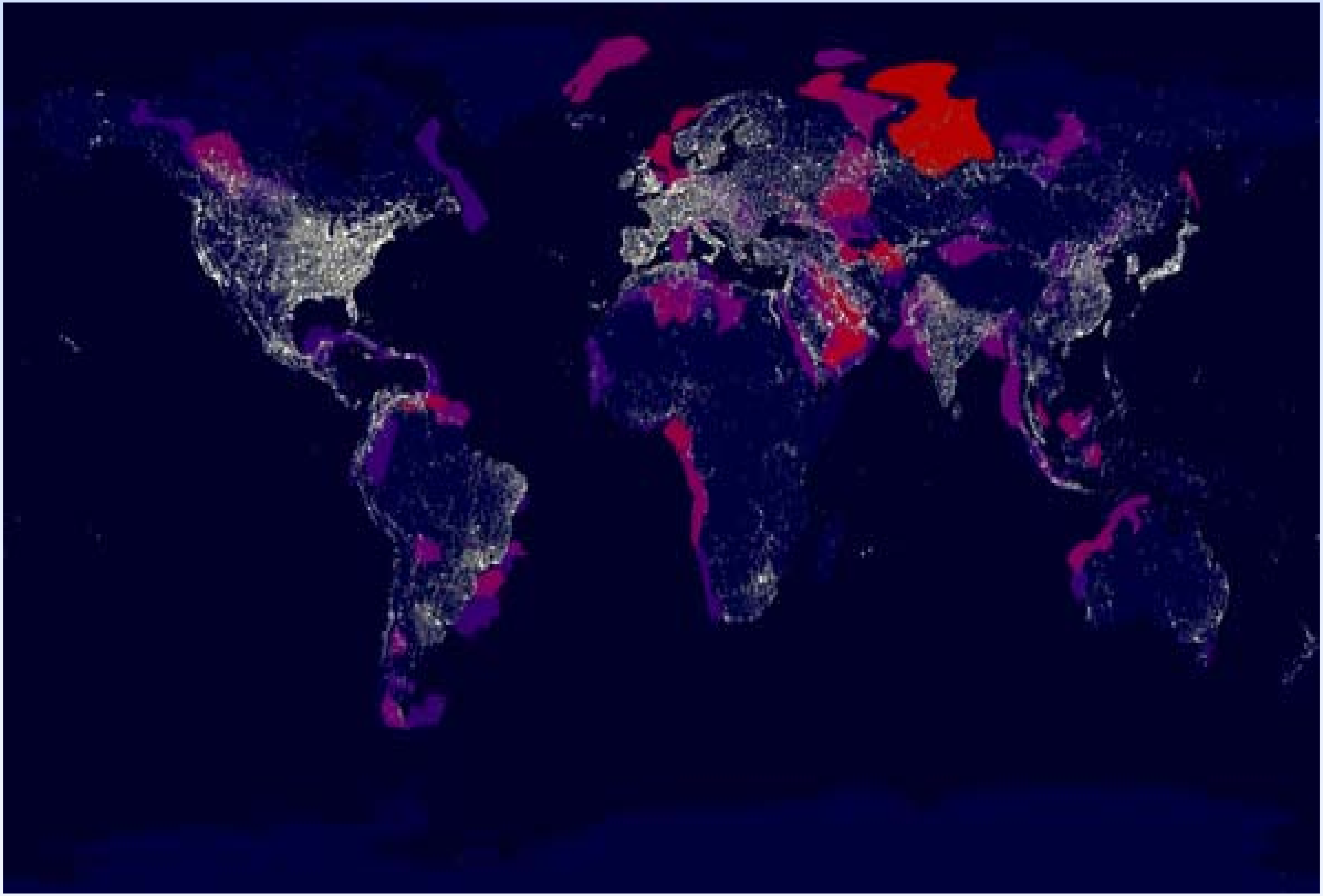
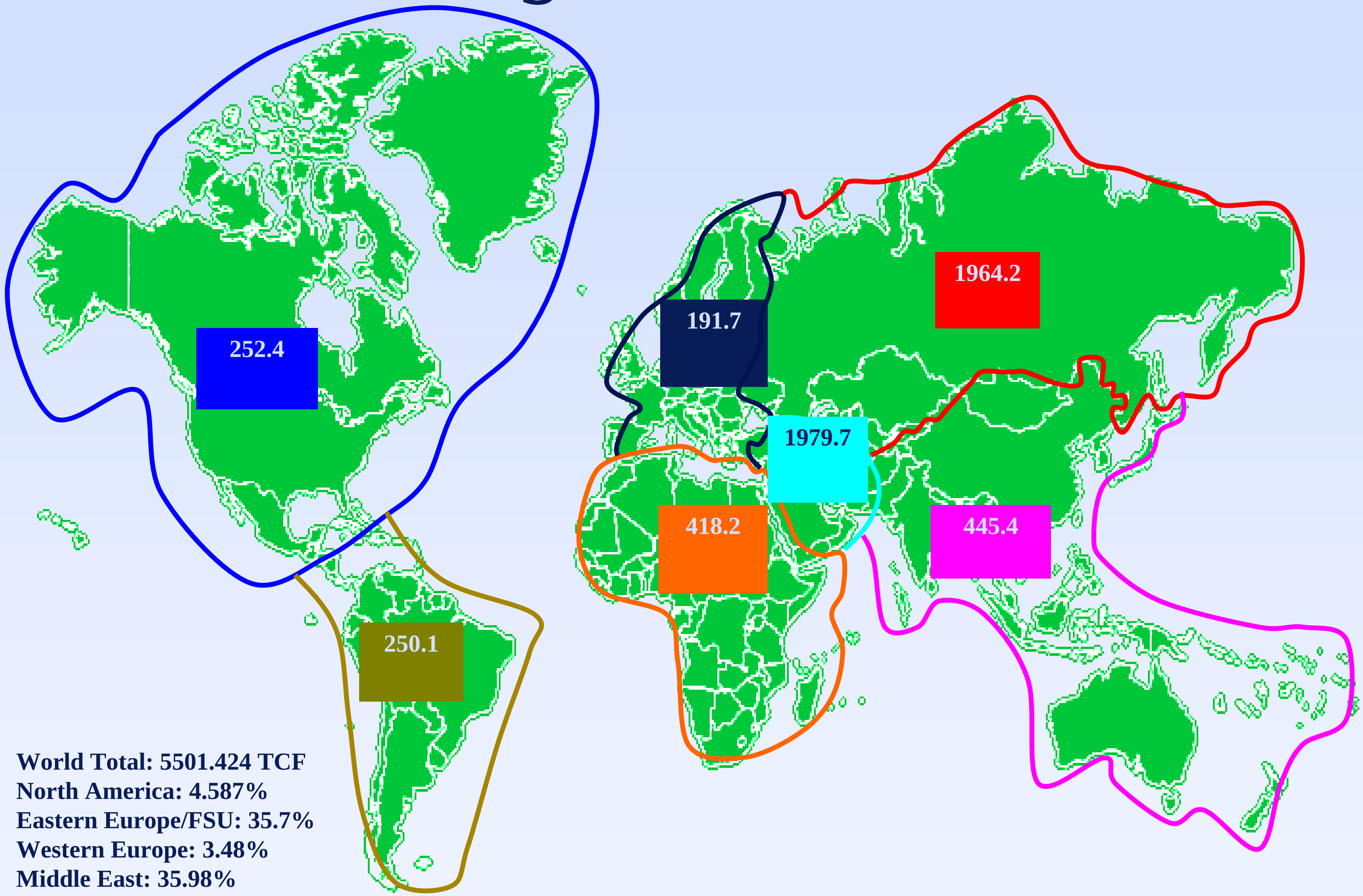
Sources of Natural Gas supply

- We use the resource estimates of the 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

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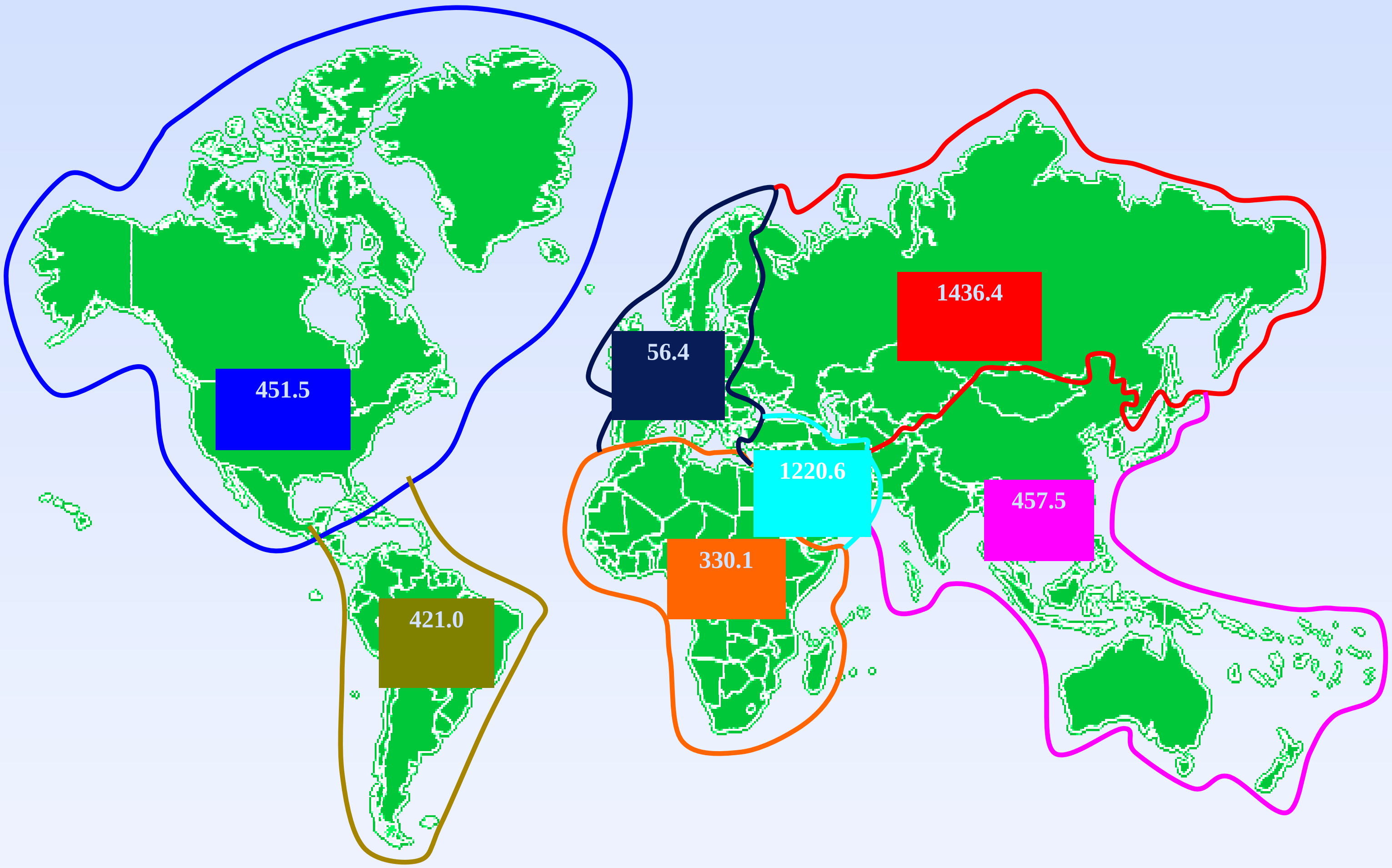
Undiscovered Natural Gas by Region, 2001 estimates



Units: Trillion Cubic Feet
Source: USGS

More detail on supply

- Regional resource potential as in the P-50 resource estimates from the *World Resource Assessment* of the USGS including
  - associated and unassociated natural gas resources
  - both conventional and unconventional gas deposits in North America, and
  - conventional gas deposits in the rest of the world
- Resources are divided into three categories:
  - proved reserves,
  - growth in known reserves, and
  - undiscovered resource
- Resource cost estimates developed as part of the Altos-USGS CRADA.

Scheduling supplies

- Optimal extraction rate for a particular deposit depends on:
  - current and expected future prices net of transport costs,
  - total available resources,
  - capital cost of development,
  - operating and maintenance costs, and
  - production decline profiles by region and type of deposit
- Model also determines new transportation capacity expansion from supply sources to demand sinks based on:
  - capital costs of expansion, and
  - operating and maintenance costs of utilizing new and existing capacity
- Supplies earning greatest rents are extracted first
- Disadvantages supplies isolated from end-use markets or in locations that lack prior infrastructure development.

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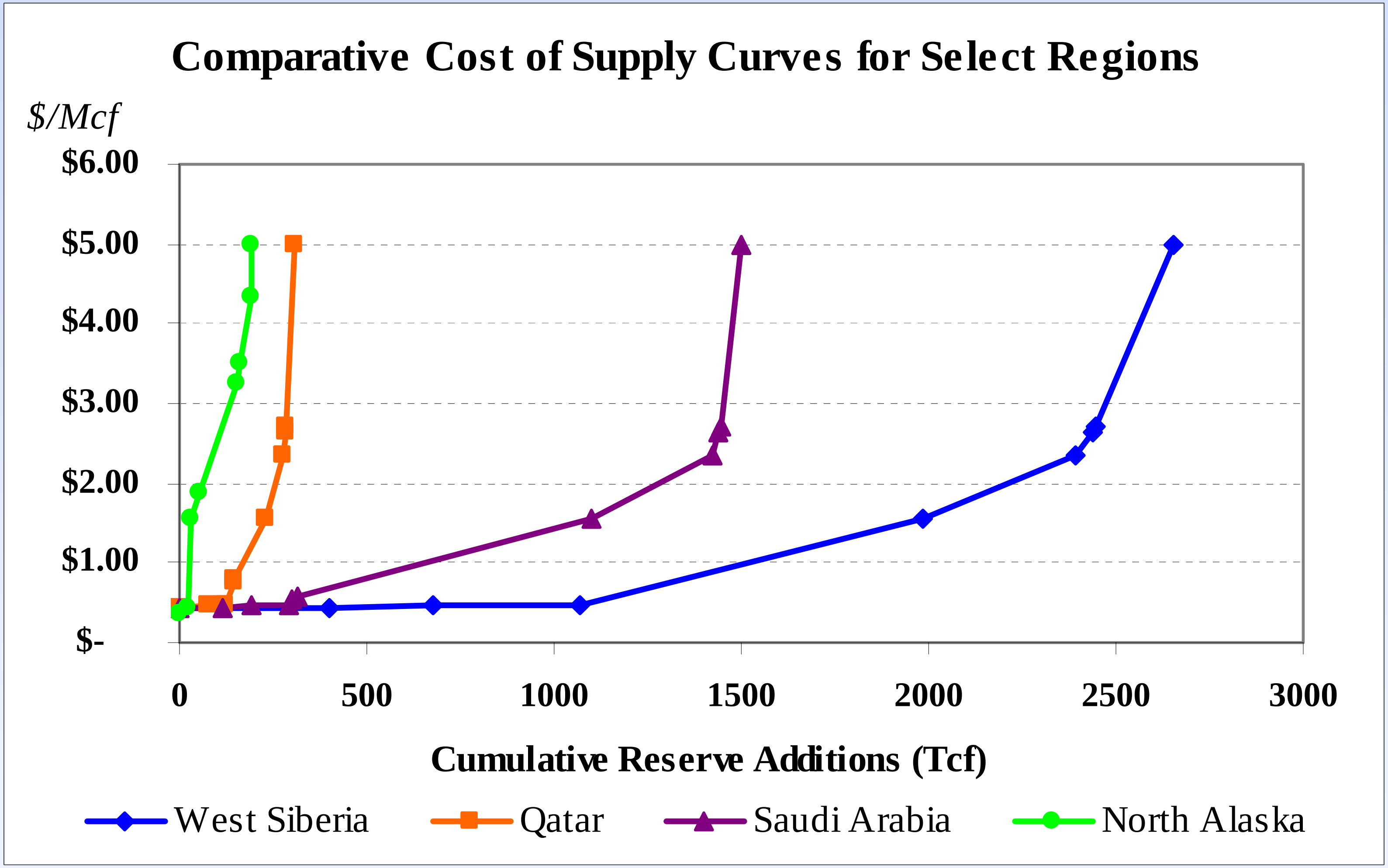
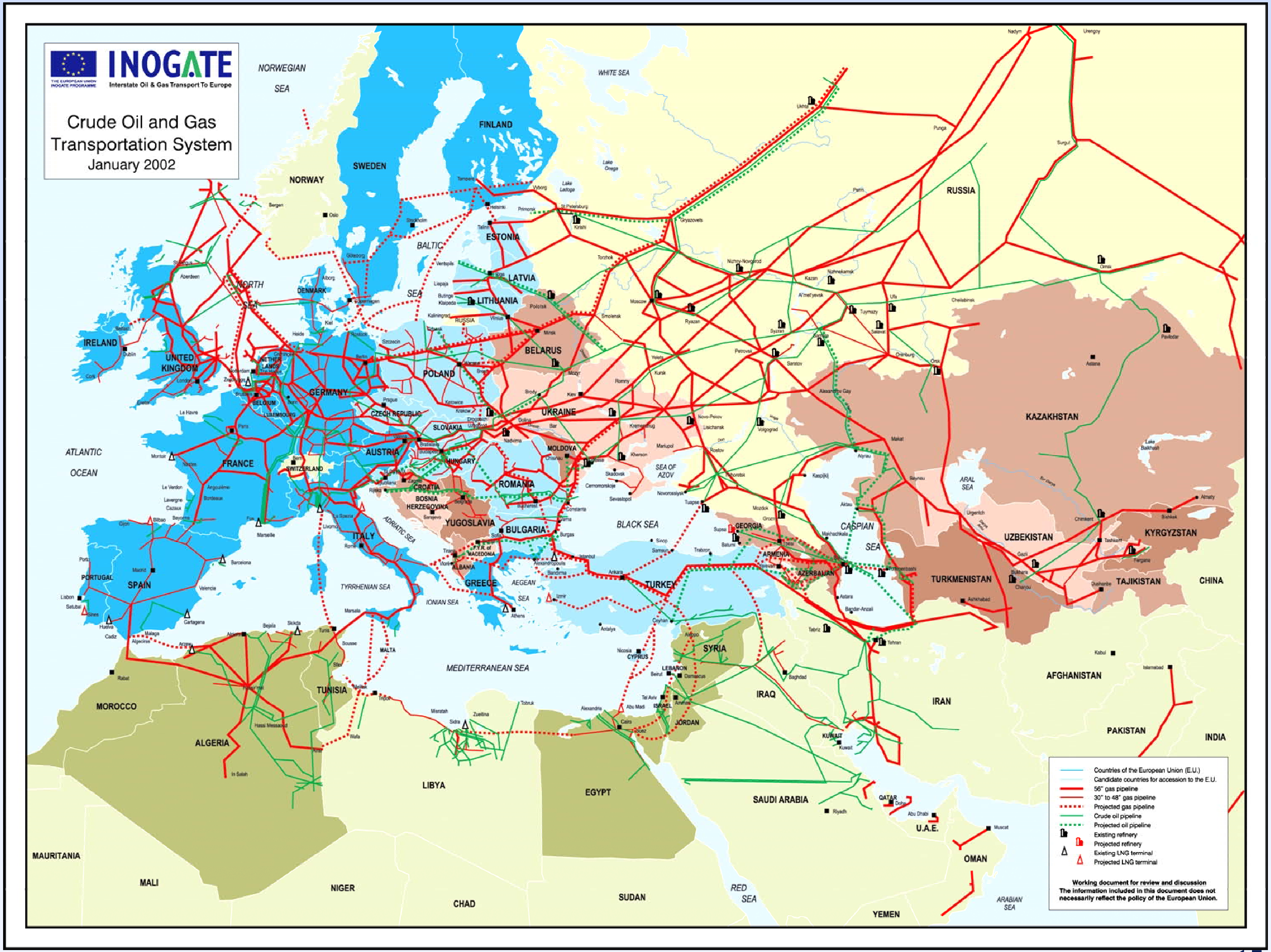
Example cost of supply curves



Pipeline link example



Representing transport networks

- Pipeline networks in North America and Europe are main transportation system
  - LNG about 5% of world demand, but important in Japan, Korea, becoming important in US
- Aggregate supply and demand into discrete "nodes"
- Aggregate parallel pipes 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

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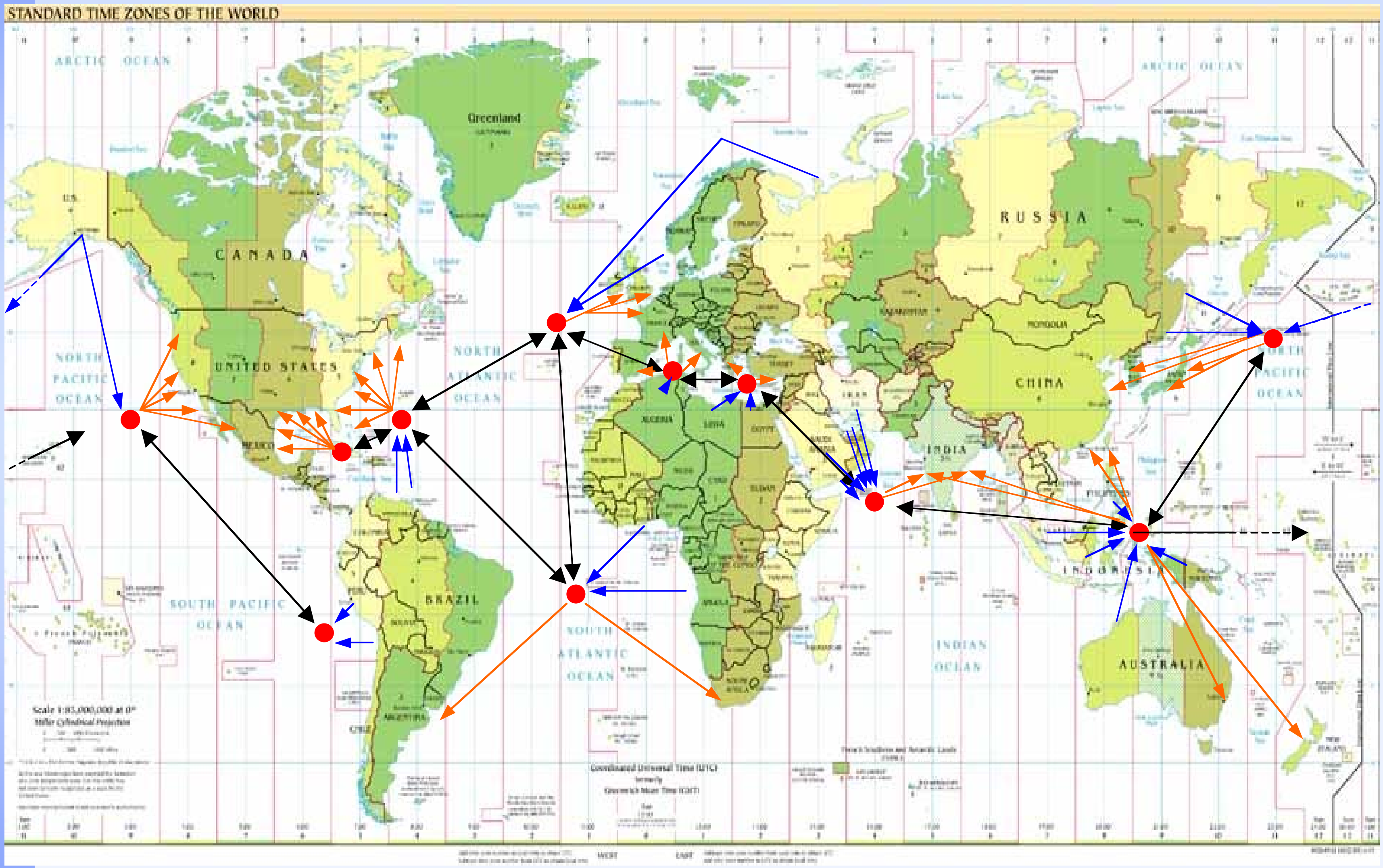
LNG transportation network



Pipeline costs

- EIA has published project specific data for 52 pipeline projects
- Relate specific capital cost (annual cost per unit of capacity) to project characteristics
  - Project cost is raised by:
    - 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 and industry contacts
- Shipping costs split into a fixed capital cost for ship development plus operating costs of:
  - 2.25% of fixed cost of development
  - fuel use during transit (0.15% per day)
- Liquefaction costs are a fixed cost ($4.11/mcf/yr) plus a variable feed gas cost
- Regasification costs vary by location (land costs)

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Indicative LNG costs

Price required for expansion, including capital costs

Route	**Feed gas**	**Liquefaction**	**Shipping**	**Regasification**	**Total cost**	**Model outcome**
Trinidad to Boston	$0.63	$1.02	$0.83	$0.69	$3.18	Yes
Algeria to Boston	$0.85	$1.05	$1.11	$0.71	$3.71	No
Algeria to Gulf of Mexico	$0.85	$1.05	$1.22	$0.29	$3.41	Yes
Qatar to Gulf of Mexico	$0.42	$1.00	$1.82	$0.39	$3.64	No
NW Shelf to Baja	$0.41	$1.00	$1.67	$0.35	$3.44	Yes
Norway to Cove Point	$1.21	$1.08	$1.14	$0.52	$3.96	No

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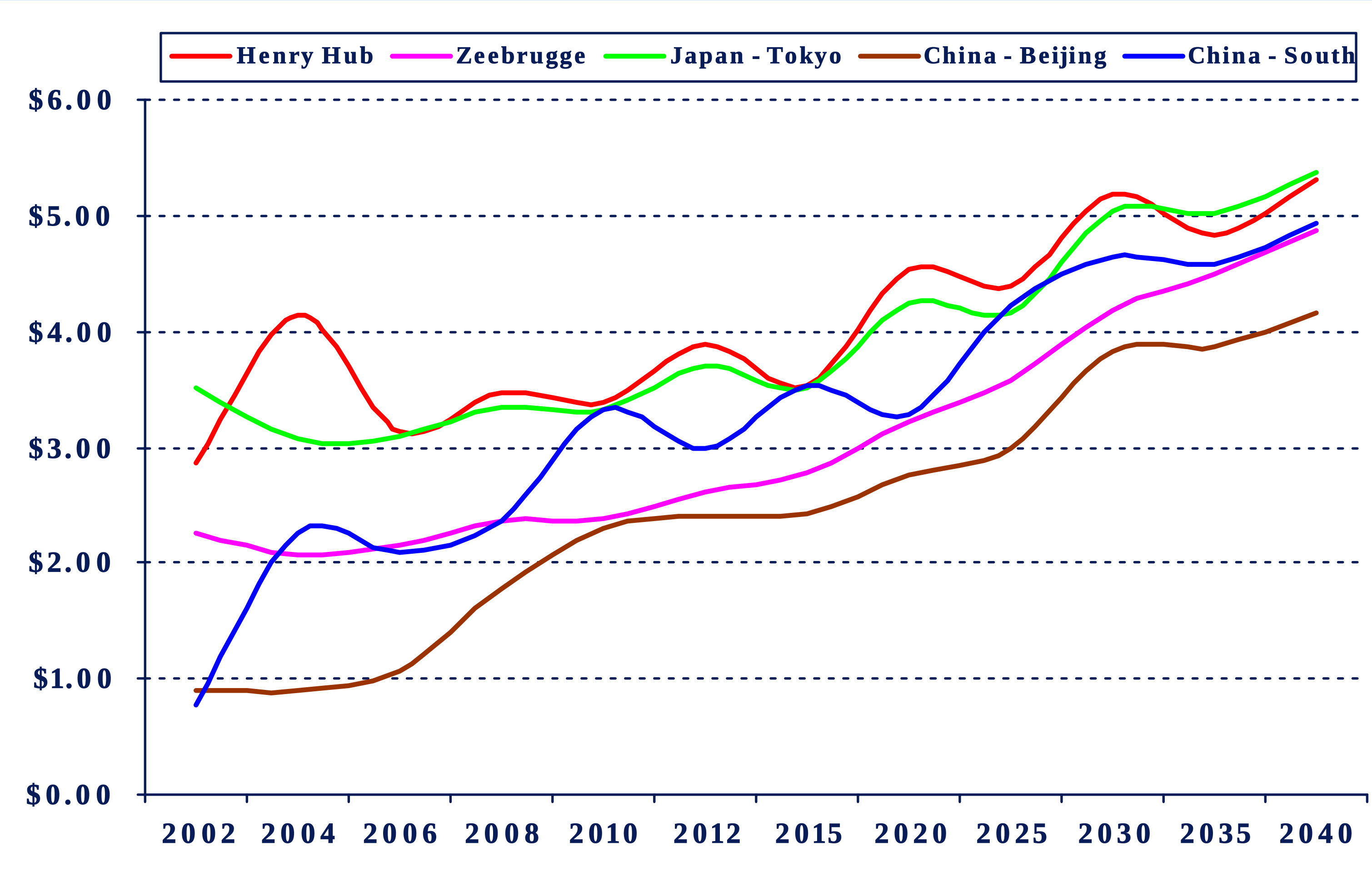
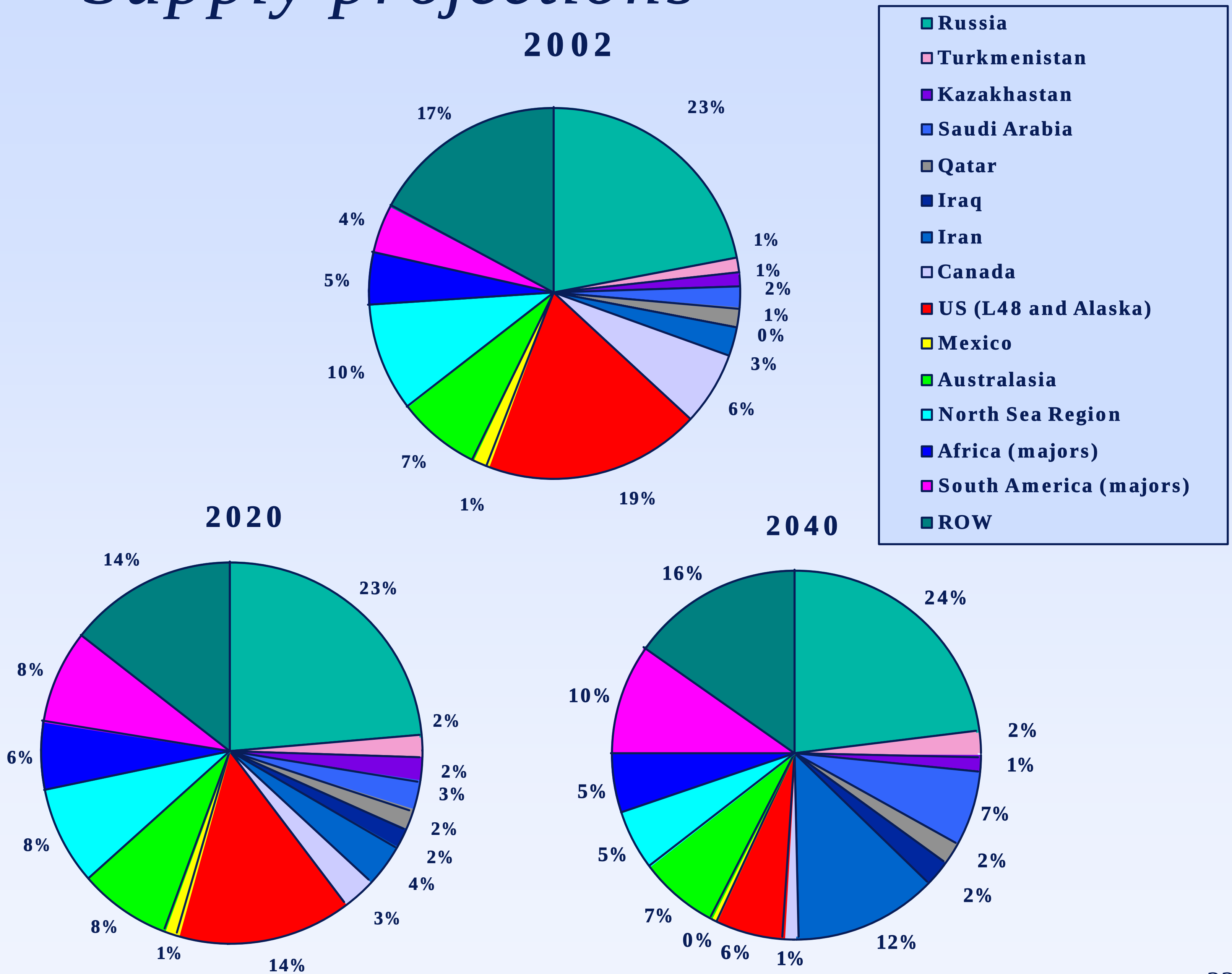
Selected price projections



Supply projections



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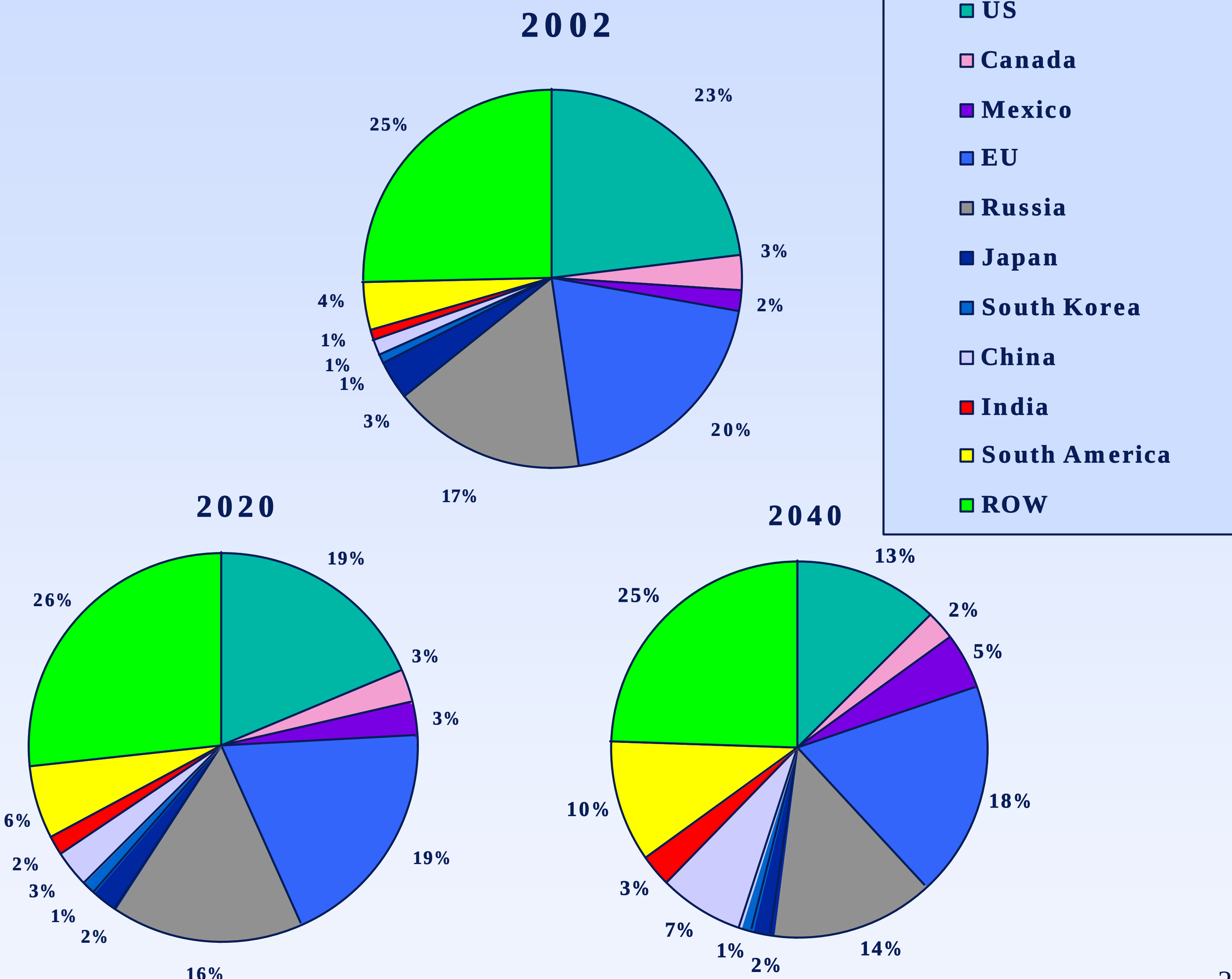
Demand projections



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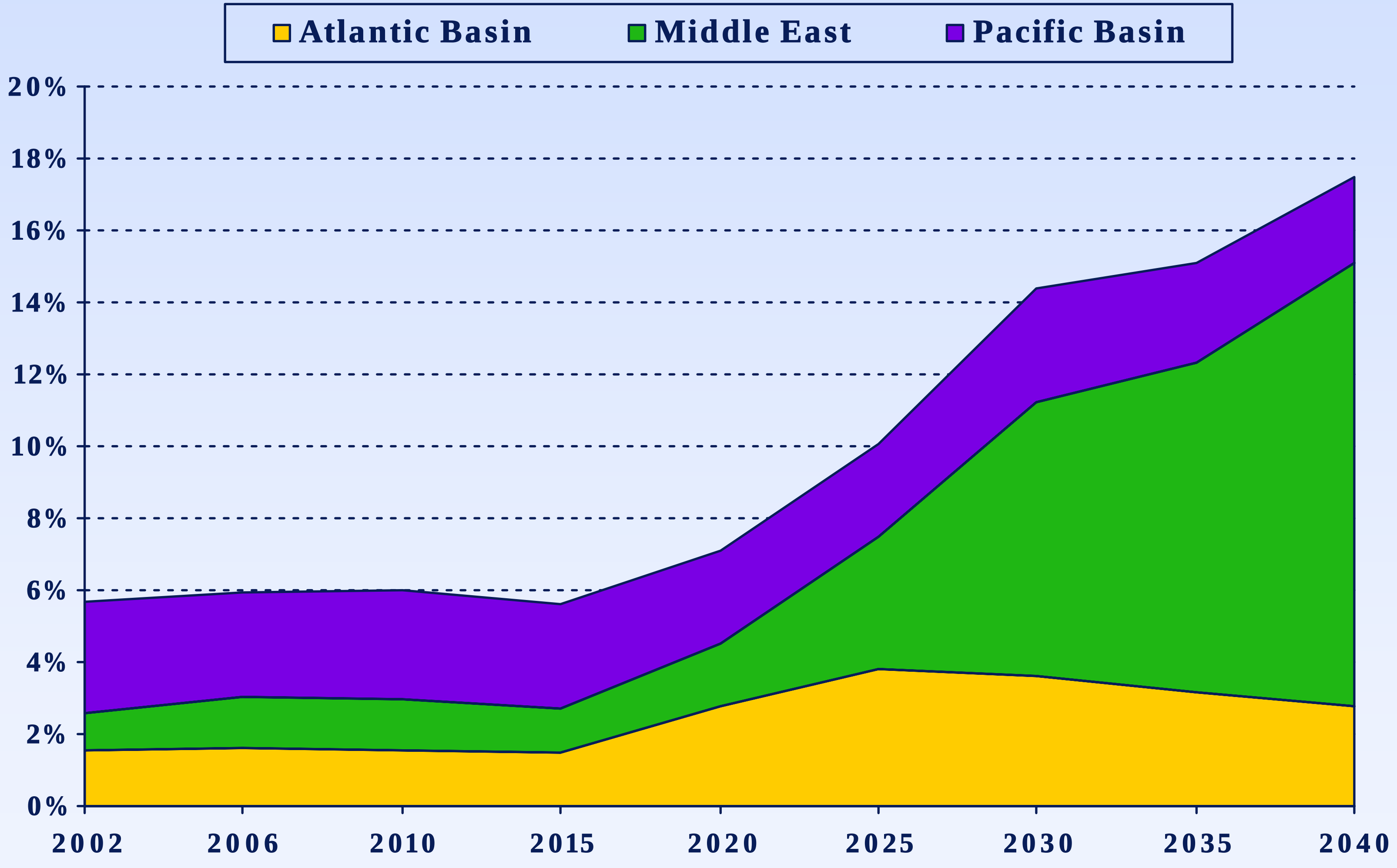
LNG share of world supply by source



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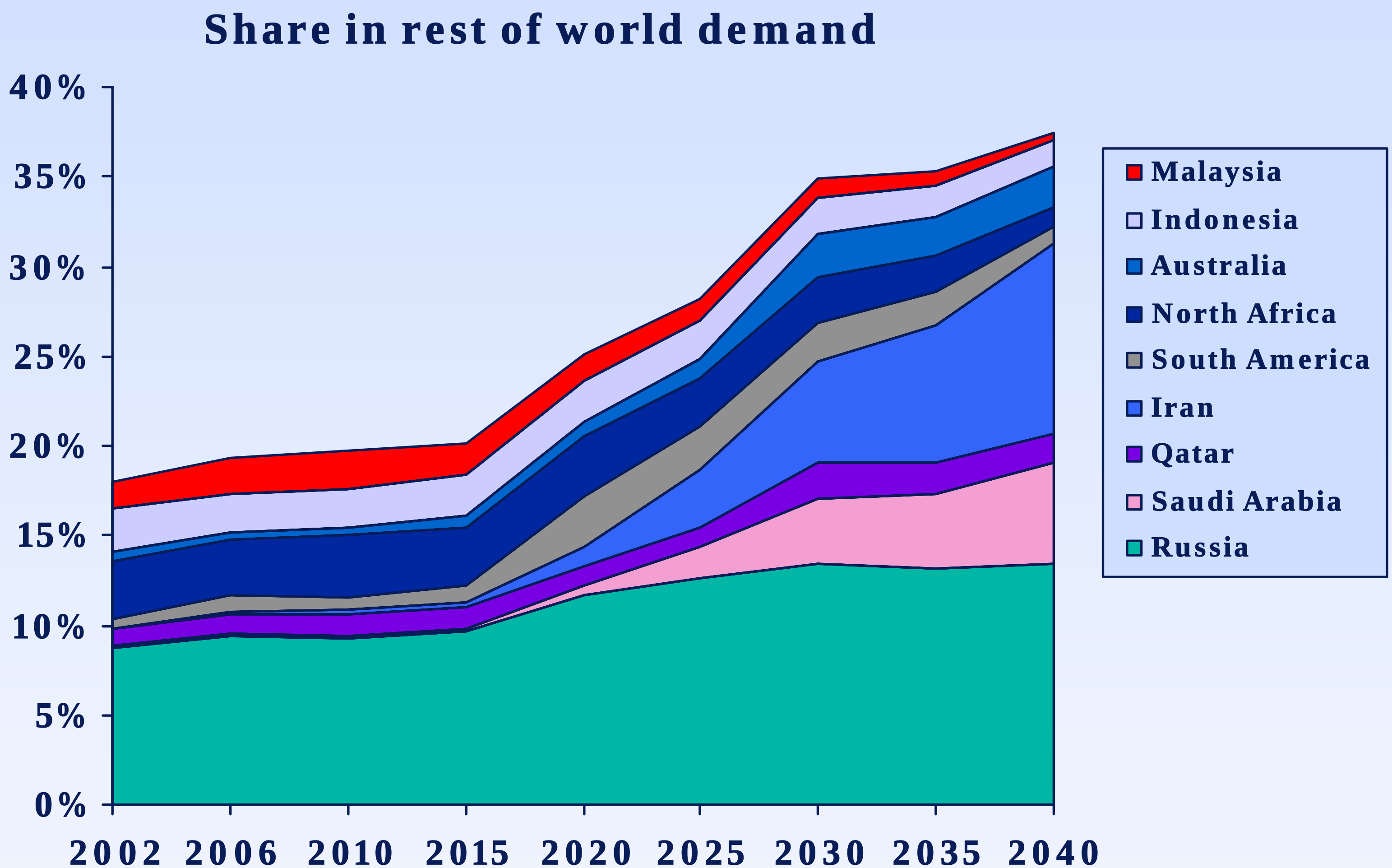
Major exporter projections



Major importer projections