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World Gas Trade Model: Some Implications for South Korea

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Presented at an International Energy Seminar on

Energy Security of Korea for the Next Decades: Economics and Geopolitics

Hosted by

The Policy Committee, The Uri Party

Organized by Korea Energy Economics Institute (KEEI)

Convention Hall, Hyundai Capital Building

Seoul, South Korea

July 22, 2005

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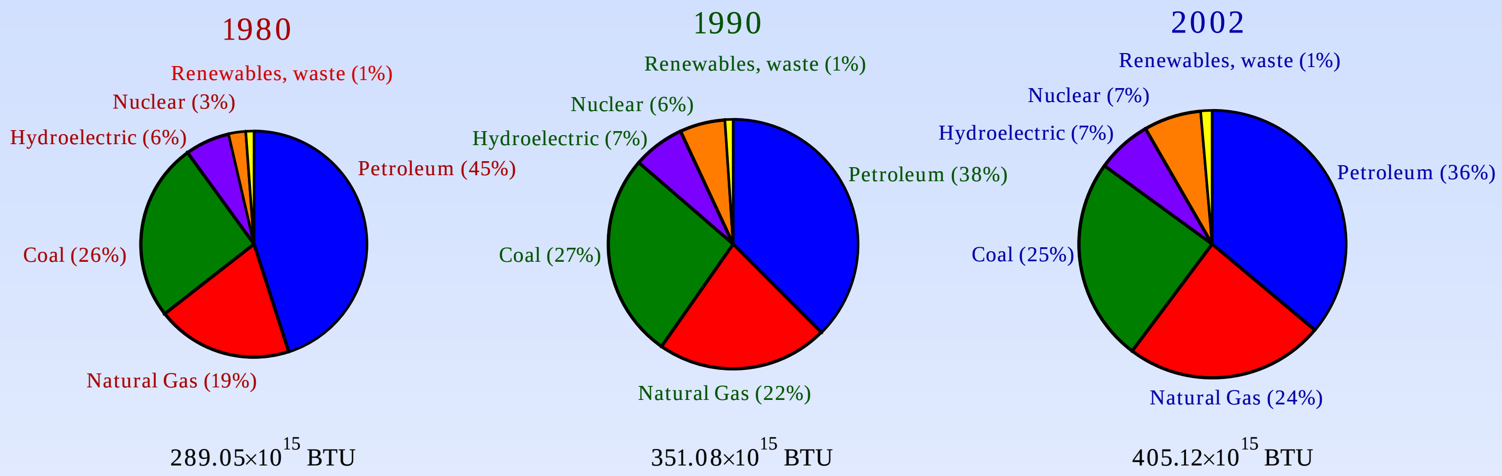
Overview and motivation

- Worldwide, the demand for natural gas is rising:



Source: EIA

- Key reasons for the demand increase:
  - Environmental pressure for cleaner fuels
  - Wholesale electricity market competition raised the demand for smaller scale electricity plant, which CCGT satisfied
- The share of gas may continue to rise:
  - Gas may supply transport fuel needs (GTL, oil shale, fuel cell)
  - A possible contrary influence is that coal gasification, solar, hydro and/or nuclear power, perhaps assisted by falling costs of HVDC, could displace gas in electricity generation

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Overview and motivation

- South Korea began importing gas in 1986, but gas was < 5% of Korean primary energy demand until 1994 and is now > 10%
- South Korea will face more competition for LNG supplies
  - There is high growth in energy demand in China and India
  - Declining North American and North Sea reserves with increasing demand has stimulated actual and planned LNG import
  - Falling LNG shipping costs have expanded the options for suppliers
- World gas supply potential is large, but:
  - It is concentrated in areas remote from markets
  - Production and transport infrastructure is required
  - Prices need to rise in real terms to finance the investments
  - Unstable political regimes may make investments unattractive
- Russia could be a big supplier of natural gas to both Europe and Asia, making developments there critical
- The Rice World Gas Trade Model, based on economic and geological fundamentals, can be used to examine political and economic influences on the world market for natural gas

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Rice World Gas Trade Model

- Model framework: *Market Builder* from Altos Partners
  - The model calculates equilibrium prices and quantities across a fixed number of locations and time periods
    - In each period, gas is produced or transported until there are no opportunities for profitable arbitrage across locations
    - Producers schedule production to eliminate profitable arbitrage across time periods
    - Supplies isolated from markets, or in areas lacking infrastructure, earn lower rents and are extracted last
    - Consumers shift the timing of demand in response to anticipated changes in prices
- The supply data is based on the USGS *World Resource Assessment* updated with latest reserve revisions
- The econometric model for forecasting demand was developed using
  - EIA *International Energy Outlook* 2004,
  - IEA *World Energy Outlook* 2002 and
  - World Bank data on population and economic growth
- The demand for natural gas is related to:
  - The level of economic development (GDP/capita)
    - Following Medlock and Soligo (2001), energy demand increases with GDP/capita but at a decreasing rate
    - But the natural gas share in primary energy demand also increases with development
  - Population
  - Country-specific effects reflecting, for example, resource endowment or climate
  - Prices (wholesale industrial $/BTU) of natural gas, oil and coal

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Backstop technology

- Future supply possibilities are important because expected future prices affect current supply and price
- The estimated demand elasticity reflects historical substitution possibilities, not possible future ones
  - Technological change is difficult to predict, but
    - IGCC, nuclear and renewable sources provide sources of electricity supply that compete with natural gas
    - DOE says IGCC is competitive at $4 per mcf of gas (2004 prices)
    - Gasification of coal may also satisfy other uses of natural gas
- 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

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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 world

  was 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 for North America (including Canada and Mexic0) were applied elsewhere based on geological characteristics
  - The North American estimates (developed by Altos & USGS) include:
    - capital cost of development,
    - operating and maintenance costs, and
    - cost changes by region and deposit type as resources deplete

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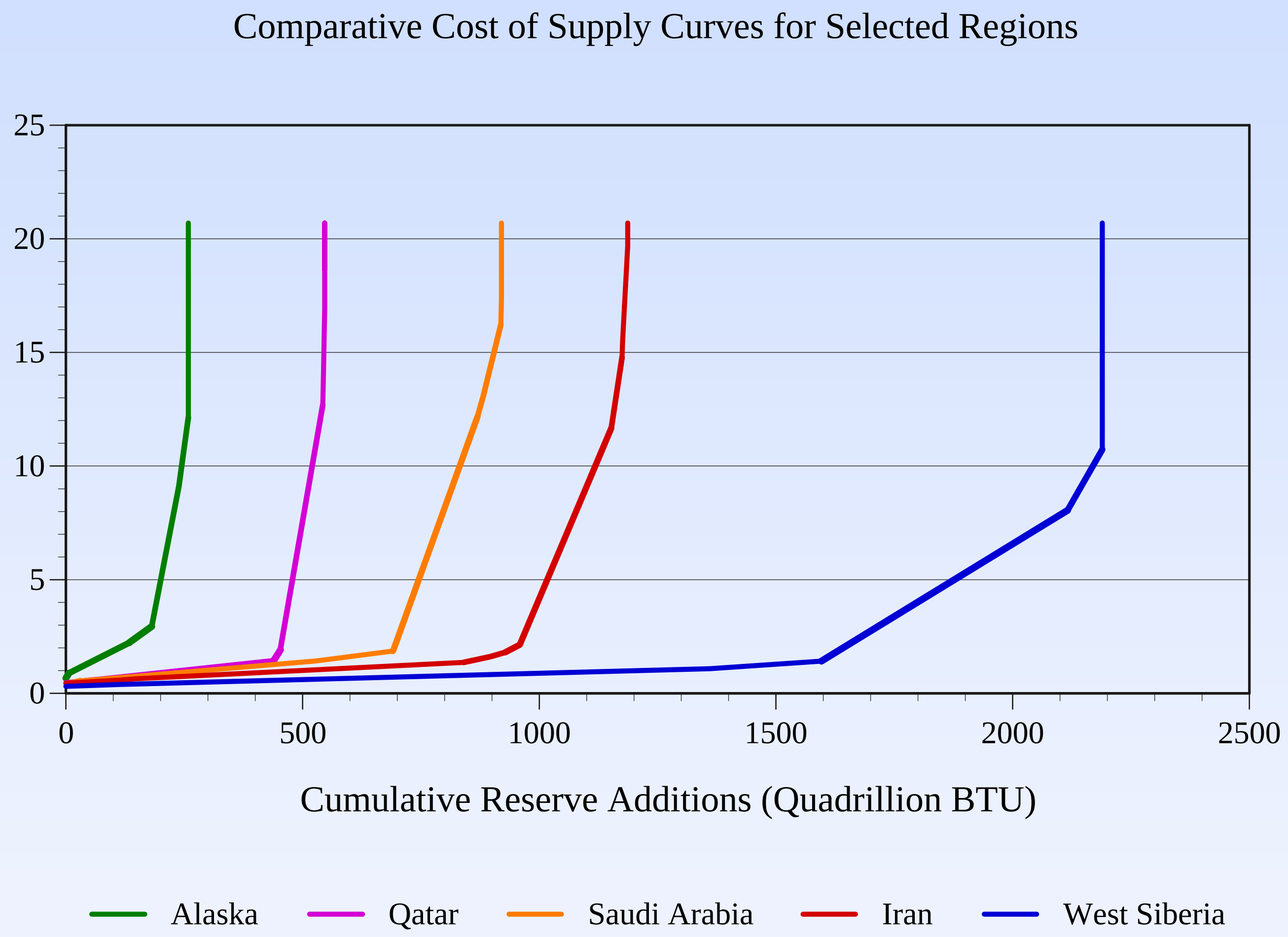
Example cost of supply curves



Sources: USGS, EIA, author calculations

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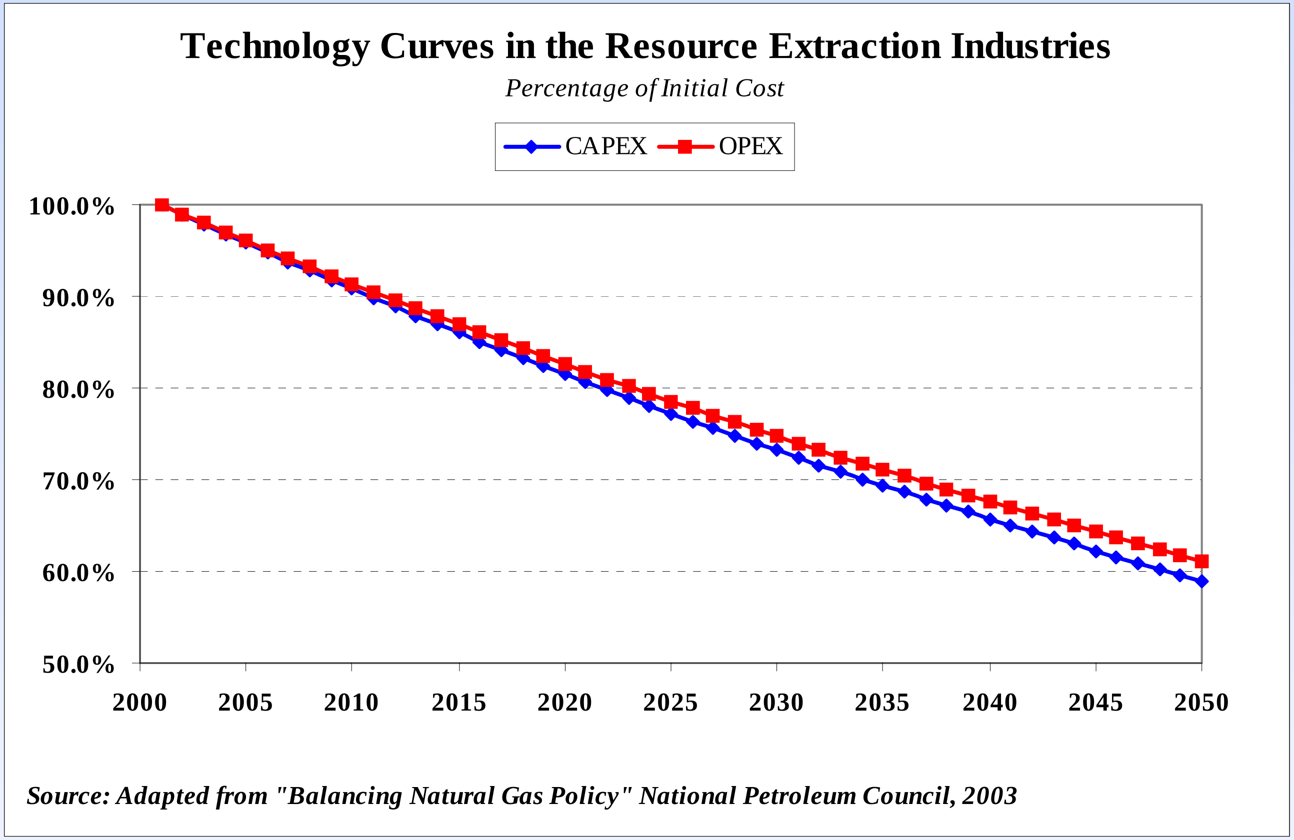
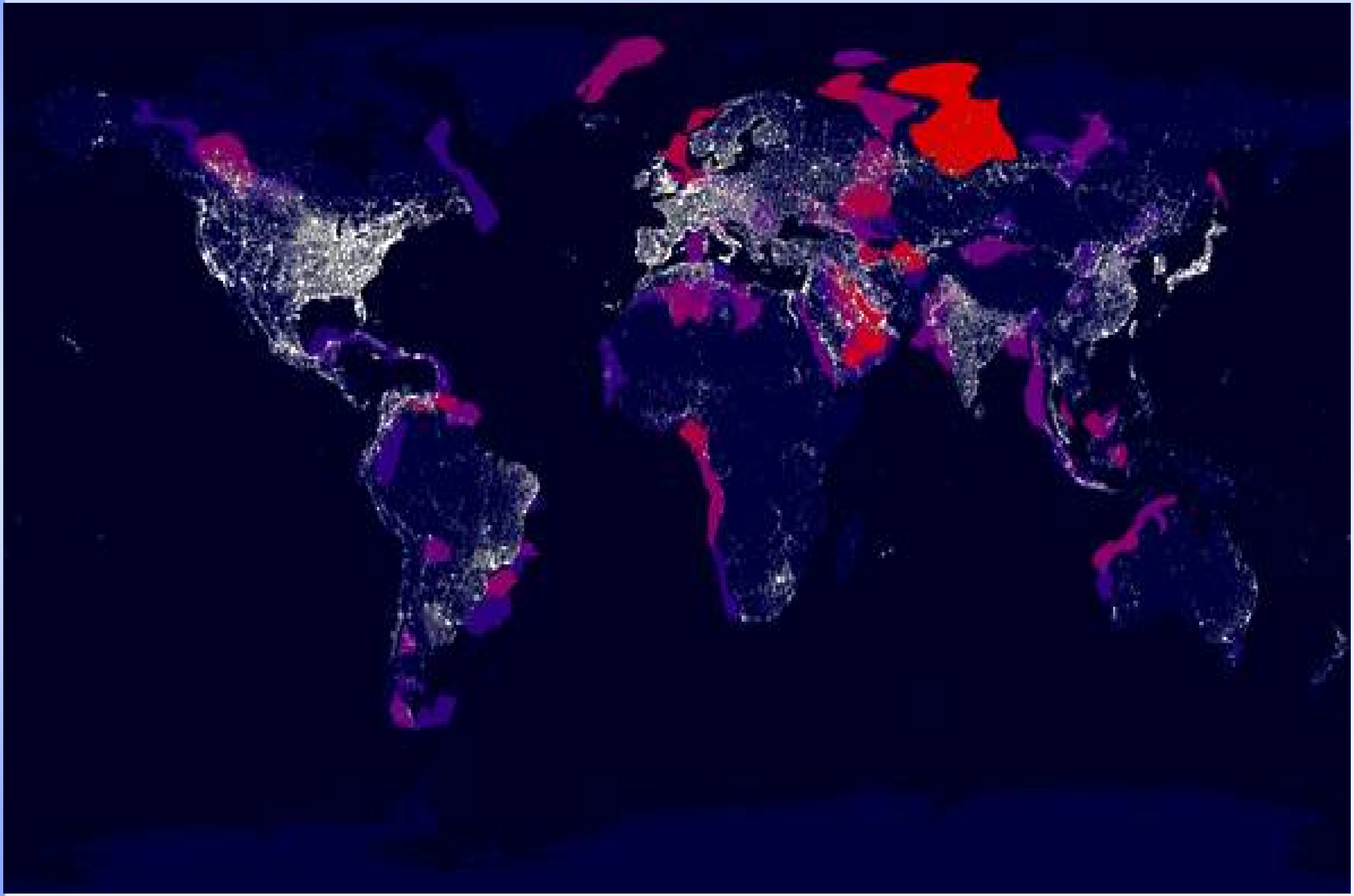
Technological change in mining



Linking supply with demand



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Representing transport networks

- The model examines a world market of expanding depth and geographical extent
- North American, European pipeline networks are now the main transport systems
  - LNG is only about 5% of world demand, but is important in Japan & Korea, and increasing elsewhere
- To allow calculations, supplies and demands are aggregated into discrete “nodes”, parallel pipes are aggregated into a single link, and minor distribution and gathering pipes are ignored
- Transport links are inherently discrete
  - We allow many potential pipeline links including ones that have been discussed and others that might appear profitable at prices calculated in initial iterations of the model
  - A hub and spoke representation is used for LNG to allow many potential trading partners
    - While bilateral contracts now dominate LNG trade, the market is becoming more flexible
    - Decreasing distances between suppliers and customers increases arbitrage opportunities
    - Contracts are financial arrangements that do not necessarily constrain physical trades
      - Contracts can be fulfilled by swap agreements as increased market depth increases trading options
- The 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

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Pipeline costs

- EIA published cost data for 52 pipeline projects
- Using this data, we estimated a regression relating specific capital cost (annual cost per unit of capacity) to project characteristics
  - Project cost is raised by:
    - Length of the pipeline
    - 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

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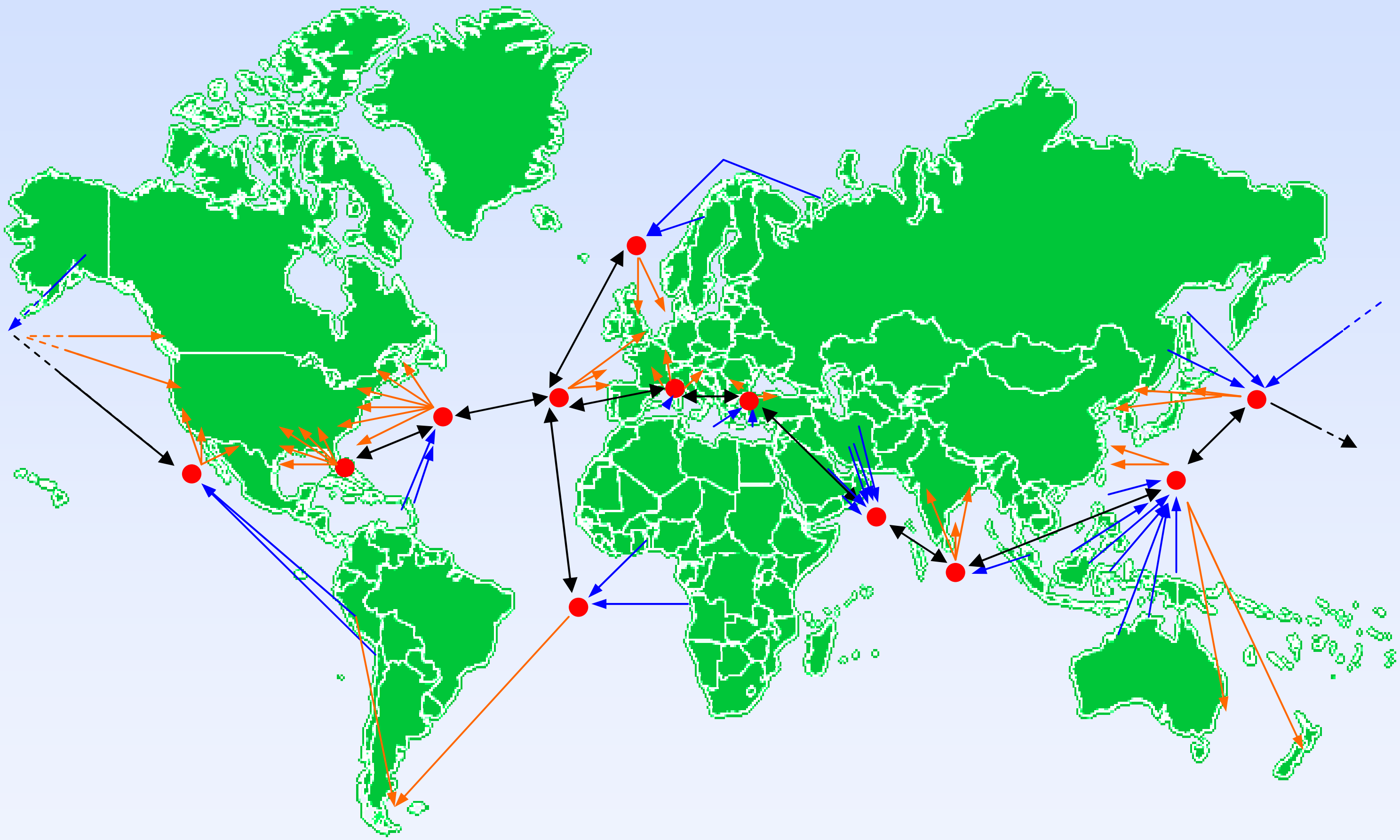
LNG transportation network



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LNG costs

- Consulted a variety of sources (including a 2003 EIA report 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 (model calculated)
- Regasification costs vary by location (primarily because land costs vary)

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Indicative LNG costs

Price required for expansion, including capital costs but excluding feed gas cost

Route	Liquefaction	Shipping	Regasification	Total
Trinidad to Boston	$ 0.82	$ 0.25	$ 0.69	$ 1.75
Trinidad to Lake Charles	$ 0.82	$ 0.32	$ 0.21	$ 1.35
Algeria to Boston	$ 0.82	$ 0.45	$ 0.69	$ 1.96
Algeria to Lake Charles	$ 0.82	$ 0.63	$ 0.22	$ 1.66
Nigeria to Lake Charles	$ 0.82	$ 0.77	$ 0.22	$ 1.81
Qatar to Lake Charles	$ 0.82	$ 1.17	$ 0.23	$ 2.22
Qatar to Baja	$ 0.82	$ 1.32	$ 0.28	$ 2.41
NW Shelf to Baja	$ 0.82	$ 0.99	$ 0.27	$ 2.07
Norway to Cove Point	$ 0.82	$ 0.57	$ 0.36	$ 1.74

Sources:

1. "The Global Liquefied Natural Gas Market: Status and Outlook" (December 2003), US Energy Information Administration

2. Various Industry Consultant Reports

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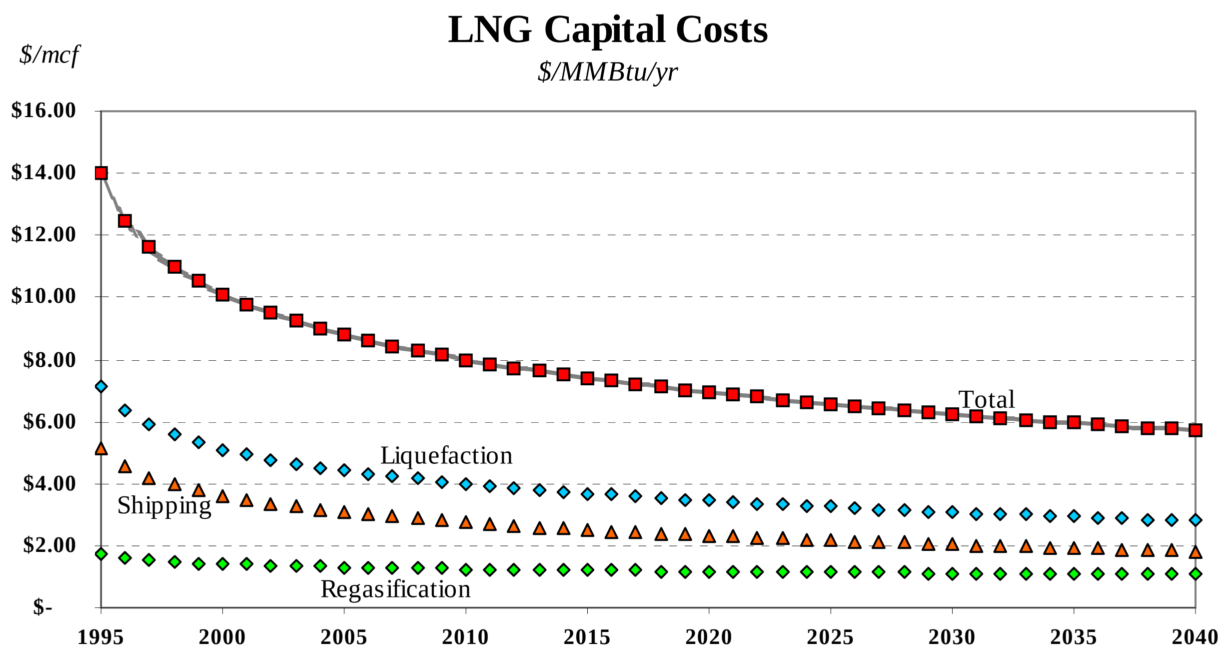
Technological change in LNG

- 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



Source: ***World Energy Investment Outlook, 2003*** **, International Energy Agency**

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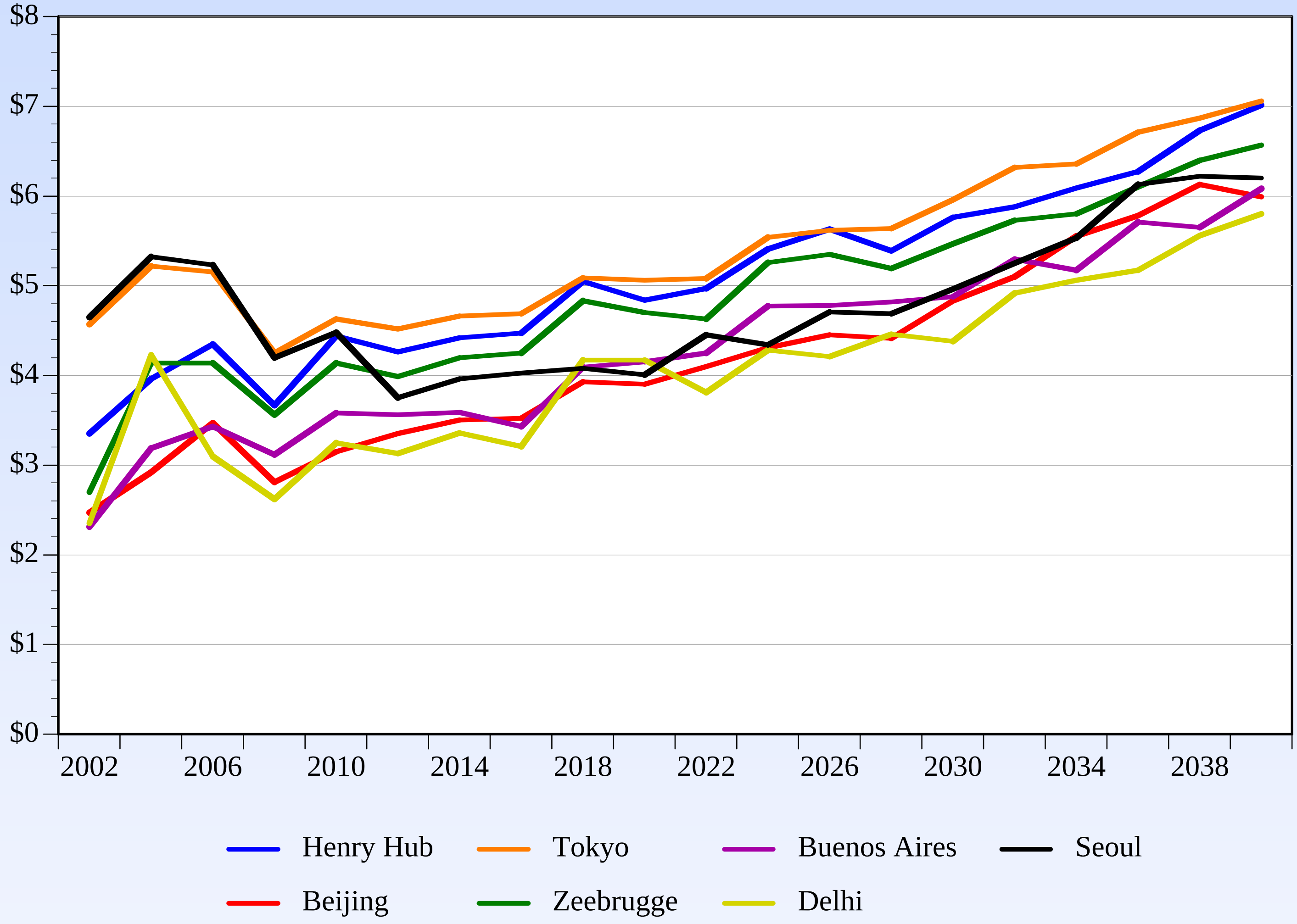
Selected price projections



Source: RWGTM, Hartley and Medlock (2005)

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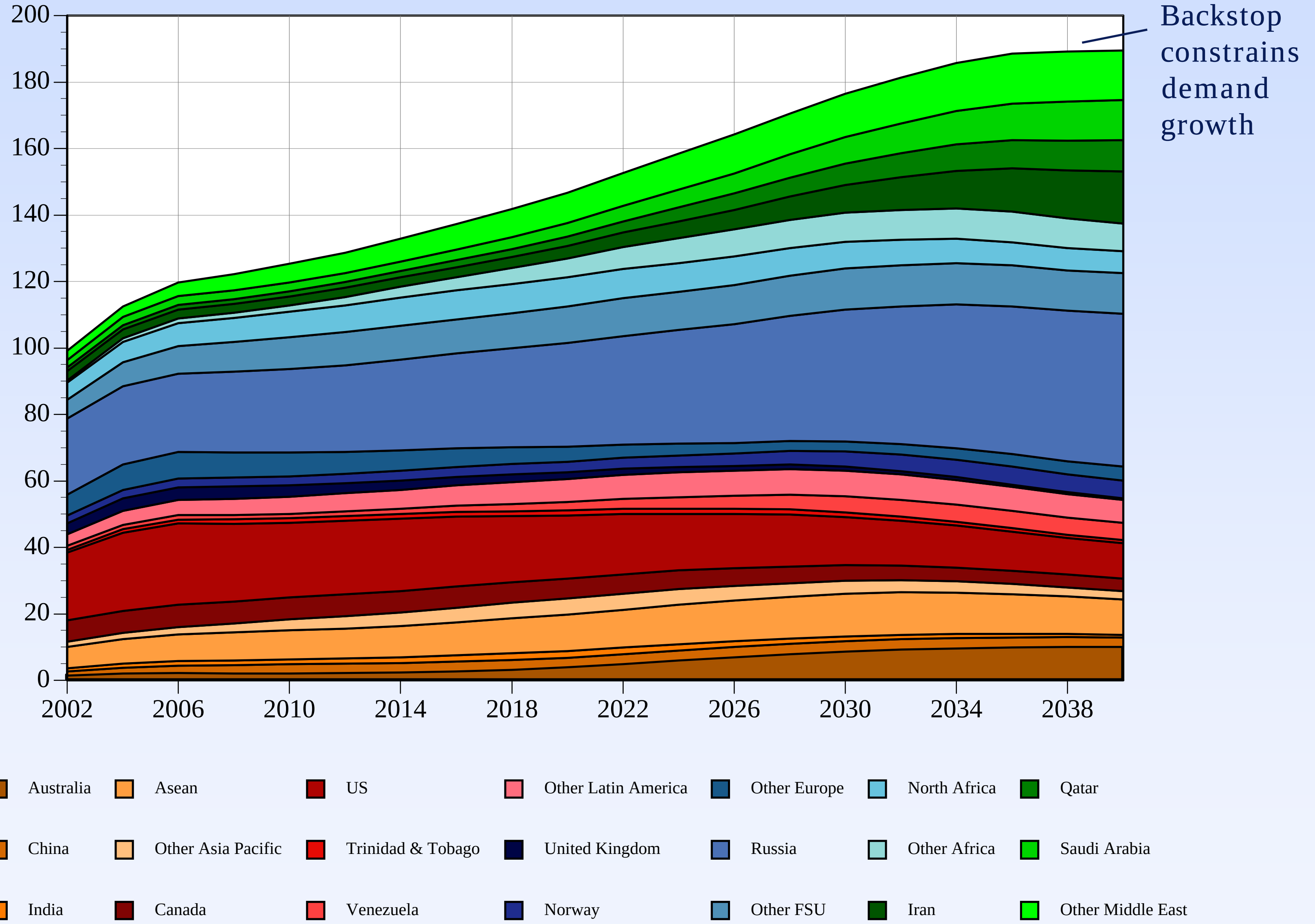
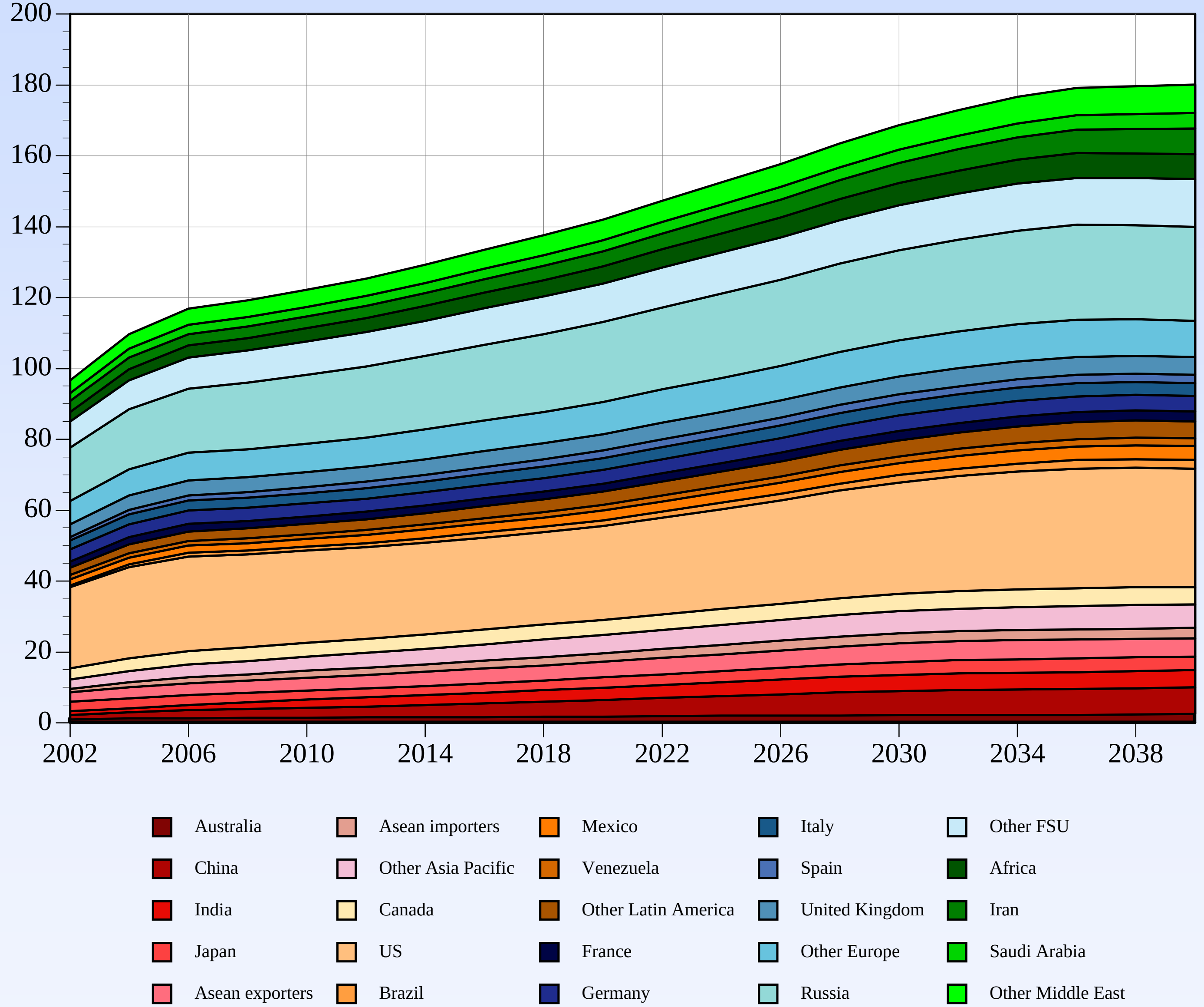
European and US supply shrinks, to be replaced by Russia and Middle East



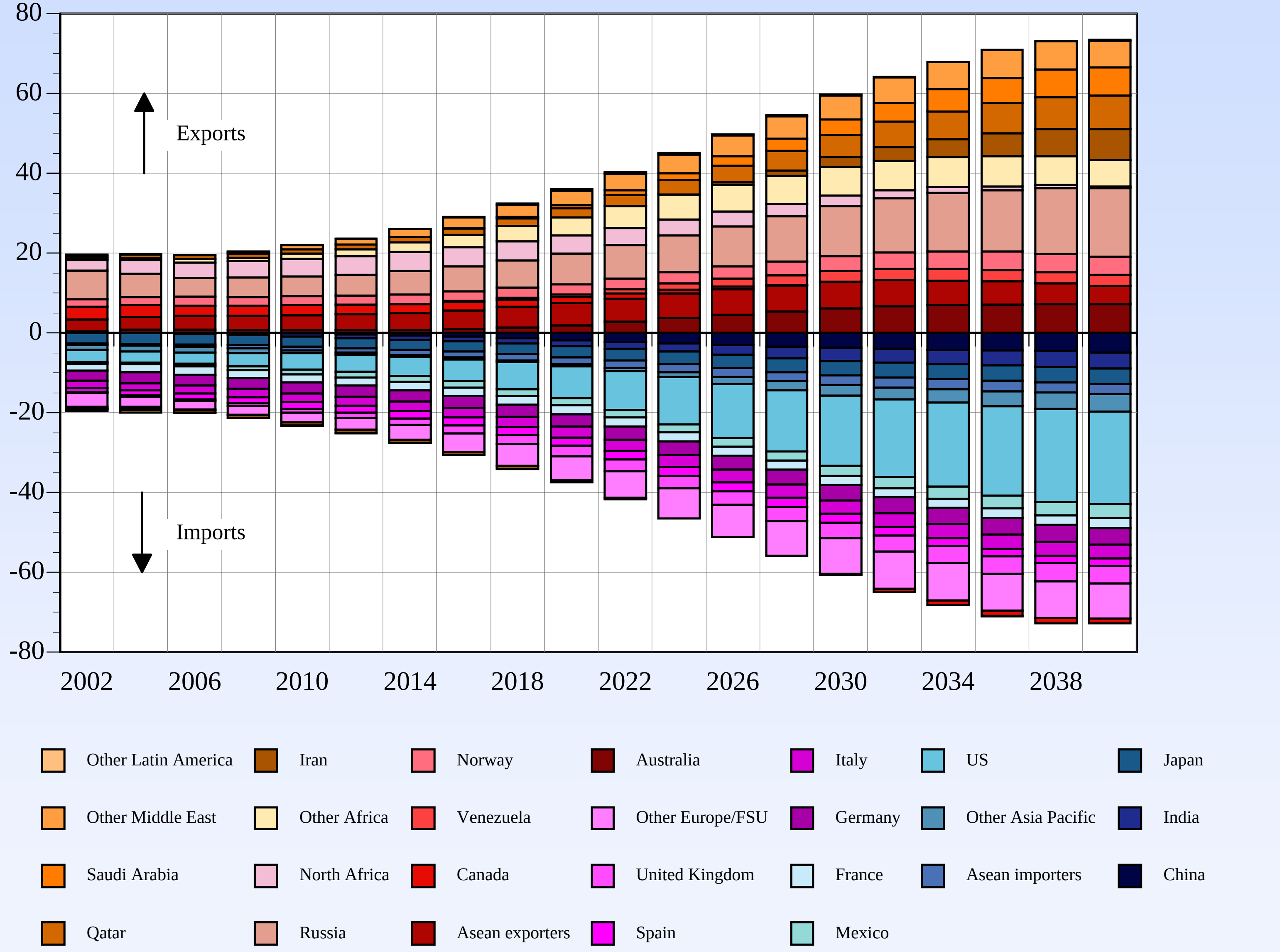
Source: RWGTM, Hartley and Medlock (2005)

Demand projections



Source: RWGTM, Hartley and Medlock (2005)

Natural gas trades



Source: RWGTM, Hartley and Medlock (2005)

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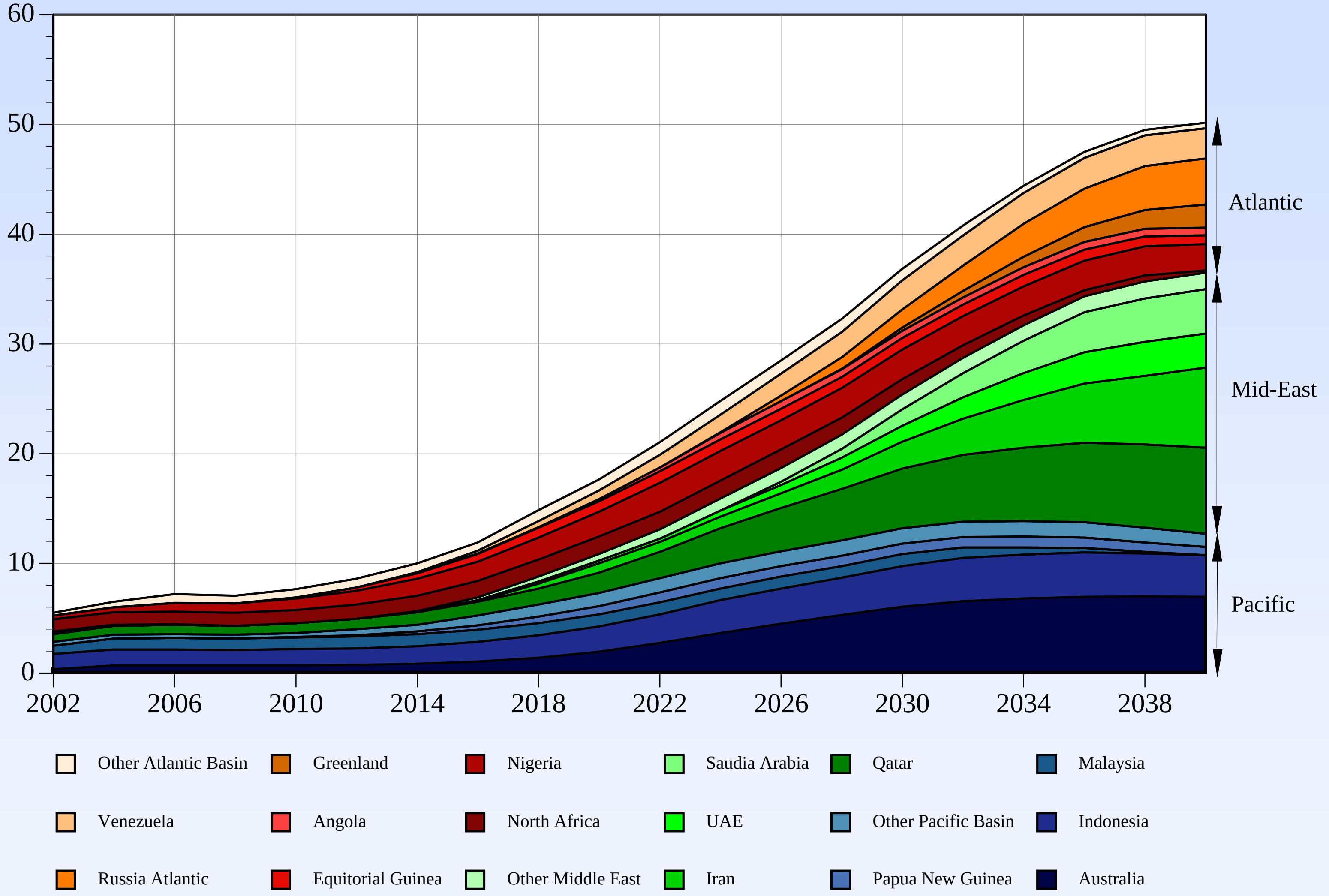
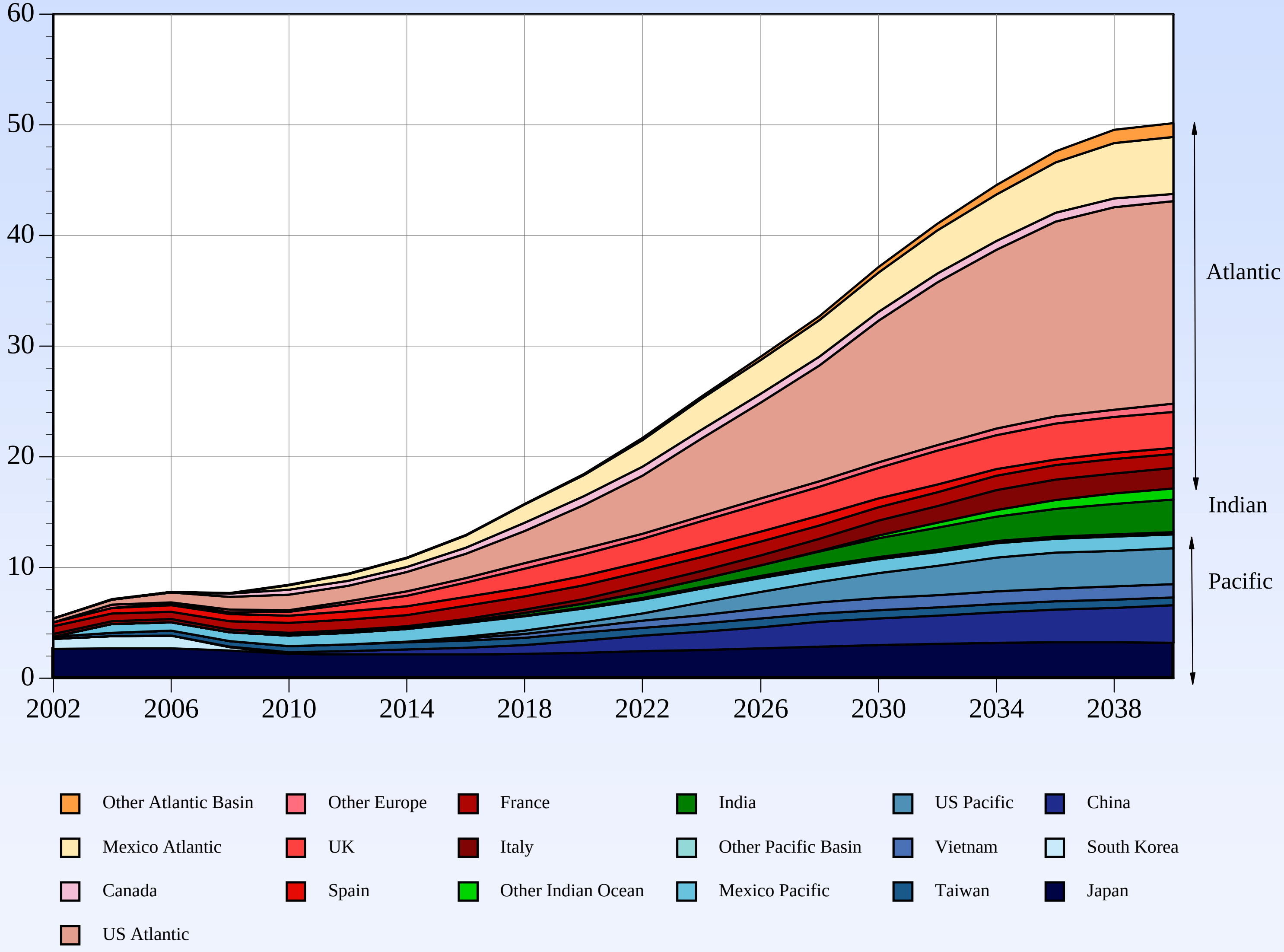
LNG exports to come from higher risk sources



Source: RWGTM, Hartley and Medlock (2005)

LNG imports to be dominated by Asia & North America



Source: RWGTM, Hartley and Medlock (2005)

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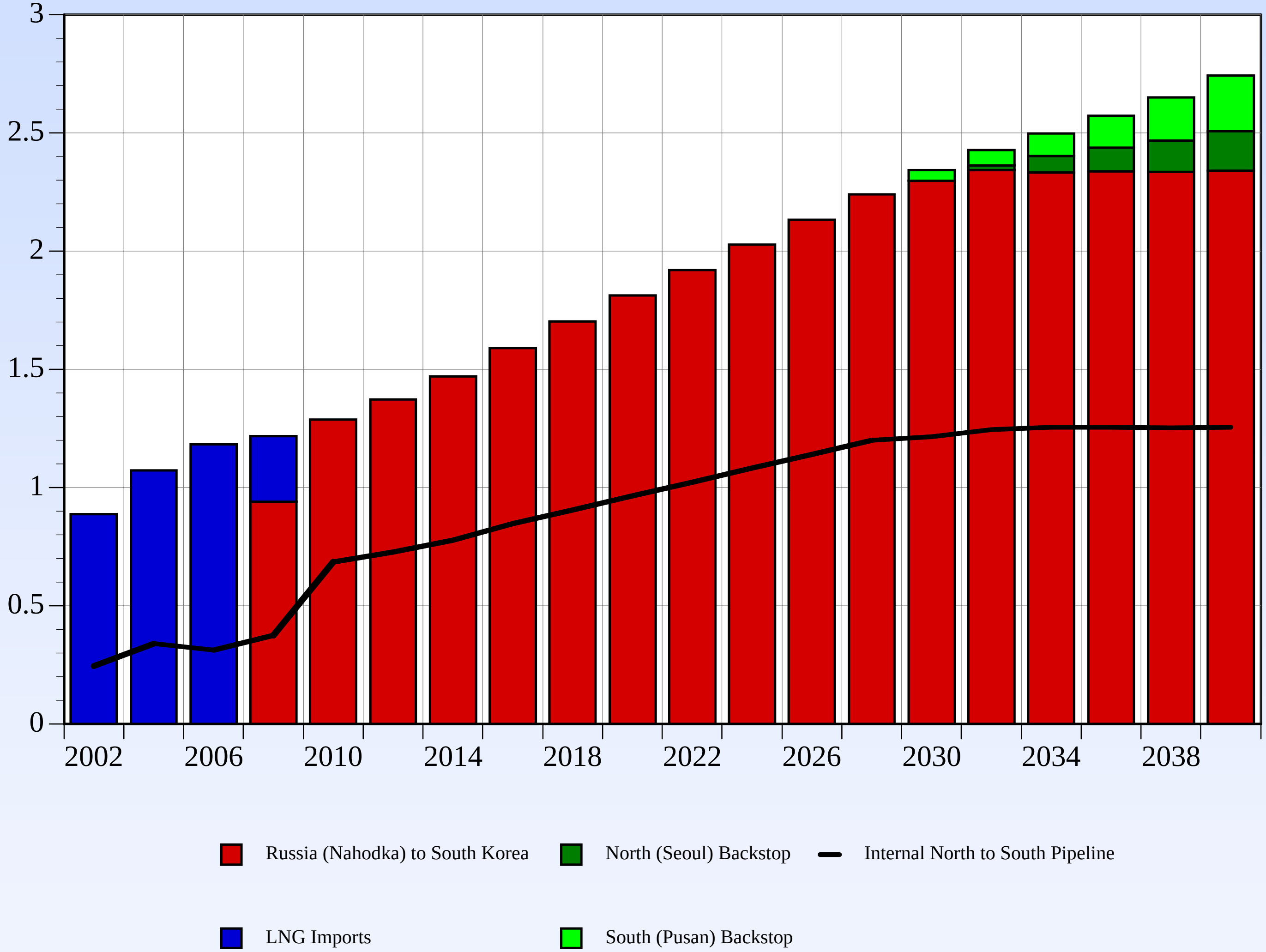
South Korea - pipeline gas displaces LNG in the Reference Case



Source: RWGTM, Hartley and Medlock (2005)

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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
    - Korea shifts to pipeline gas from Russia and stops importing LNG
    - In consequence, Seoul prices fall from approximating Tokyo prices to approximating Beijing prices
  - Russia also enters the LNG market possibly supplying the US
    - “Net-back” prices in Russia have to be equilibrated
- Over the period from 2002-2040 Australia, Qatar and Indonesia are the largest suppliers of LNG (>40% of total), but in 2040 Iran, Russia and Saudi Arabia join Australia and Qatar to supply more than 60% of LNG exports
- Russian pipeline gas exports to Europe and Asia make Russia the dominate exporter overall
- Other long-haul international pipelines are constructed
  - The trans-Saharan pipeline (Nigeria to Algeria) is constructed in 2012
  - India imports Iranian gas via pipeline from 2020
  - Europe also imports gas from the Middle East via Turkey in substantial amounts from 2020
  - A pipeline from West Siberia to East Siberia is constructed in the mid 2030’s to supply NE Asia
- 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, but Venezuela is significant later
  - Brazil imports Bolivian and Venezuelan supplies
  - Argentina imports Bolivian supplies and becomes an LNG importer
- A backstop technology is implemented almost everywhere by 2040, but is used most heavily in the US, western Europe and Japan

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Will Russia Continue to Increase its Oil and Gas Exports?

- Sustainable Russian export growth depends on removing major bottlenecks in
  - Eastern Siberia
  - Northern route to Barent's Sea for ocean bound movements by ultra large tankers
  - Bypass to Bosporus Strait

State control in pipeline sector unlikely to change

Problem of financing –state funds and higher tariffs unlikely to be enough

Outside investors?

State Stabilization Fund?

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Putin reasserting government control over Russia's natural resources

- Philosophy dates back to late 1990s
- Believes in a mixed system of state and private ownership in assets but state protecting the interests of the nation
  - Since early 2004, new appointments of like minded officials to cabinet, presidential administration and state oil and gas firms
    - Many have background that includes service in state security organs
- Sea change likely to affect business model for Russian industry
  - New round of redistribution of petroleum assets
  - Corporate responsibility a la Russe; need to follow "unwritten rules" to succeed in Russia
  - These rules involve limits to Western involvement and Western style management
  - Kremlin decides export routes

Geopolitical Trends

1. Russia actively being courted by U.S., China, Japan, Europe
   - Kremlin as a moderator of global prices?
2. Kremlin's plans for industry reorganization is dampening level of increase by disrupting speedy implementation of plans to remove infrastructure constraints or if it causes a slow down in capital expenditures and project development
3. Russia worried about fate of eastern regions
   - Emigration a demographic threat to Russia's sovereignty
   - Fears of splintering of oil-rich distant regions
   - Wants to use East Siberian resources to spur local economic develop; many in the Kremlin take a Russia first attitude towards energy resources
4. Energy as key plank to Russia's diplomacy in Asia
   - Russia wants to speed up integration process with Asia Pacific but pipeline routing remains an economic and diplomatic problem, but political/diplomatic problems surrounding the routing question remain to be tackled

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Two scenario analyses

1. Pipelines from Nahodka & NE China through North Korea are blocked
   - Political relations with North Korea prevent them
   - An undersea pipeline to South Korea from China can still be built
   - Connections between South Korea and Japan are also permitted, but these are too expensive to use
2. Russia to China pipelines also don't get built
   - Political difficulties may also prevent this development
   - We also rule out the pipeline from Uzbekistan to China
     - It otherwise provides an indirect route for gas sales from the Volga-Urals region in Russia to China
   - Sakhalin pipeline to Japan still is possible

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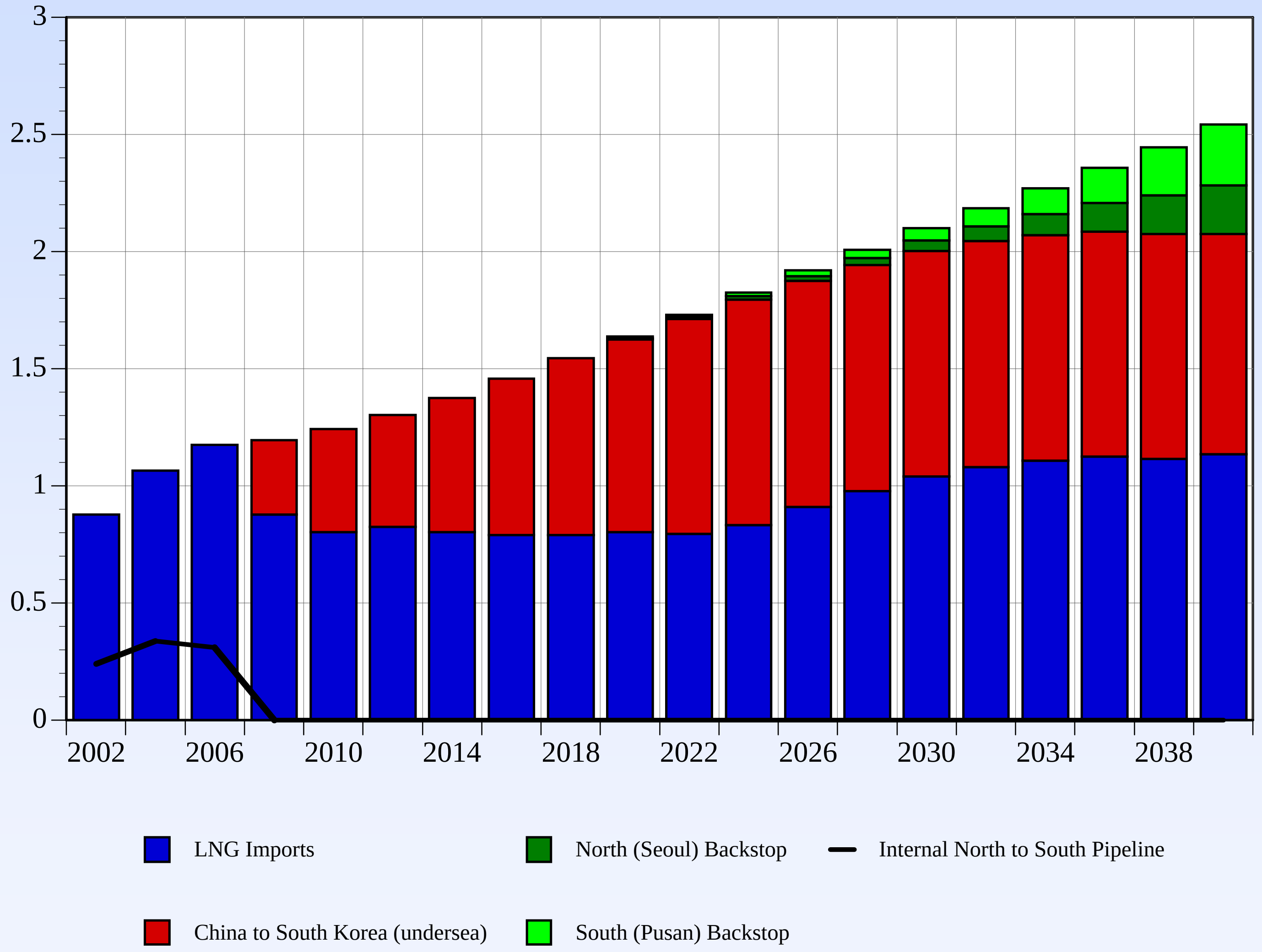
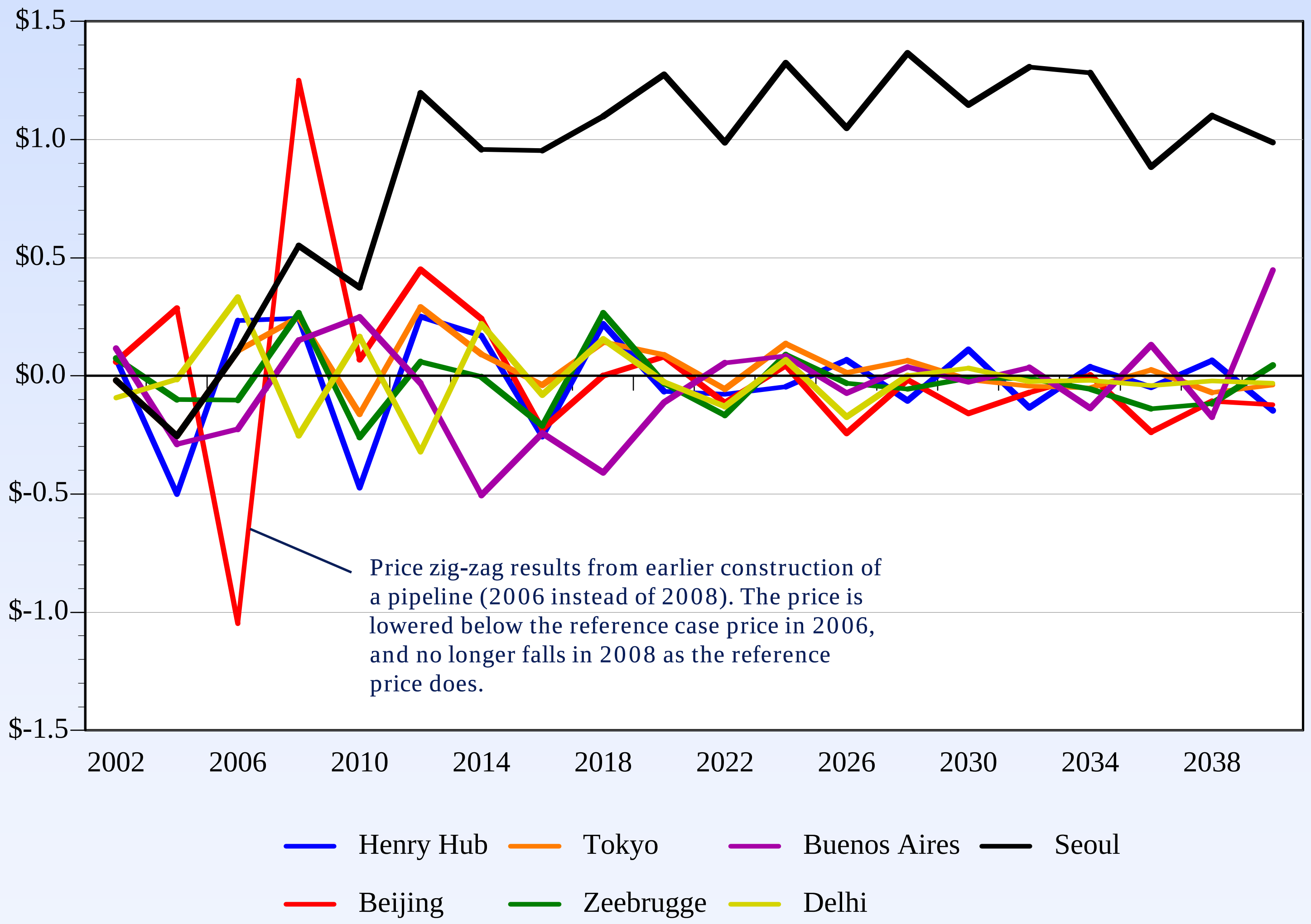
No North Korea pipes: LNG and China pipeline share South Korean market more equally



No North Korea pipes: Changes in Selected Prices



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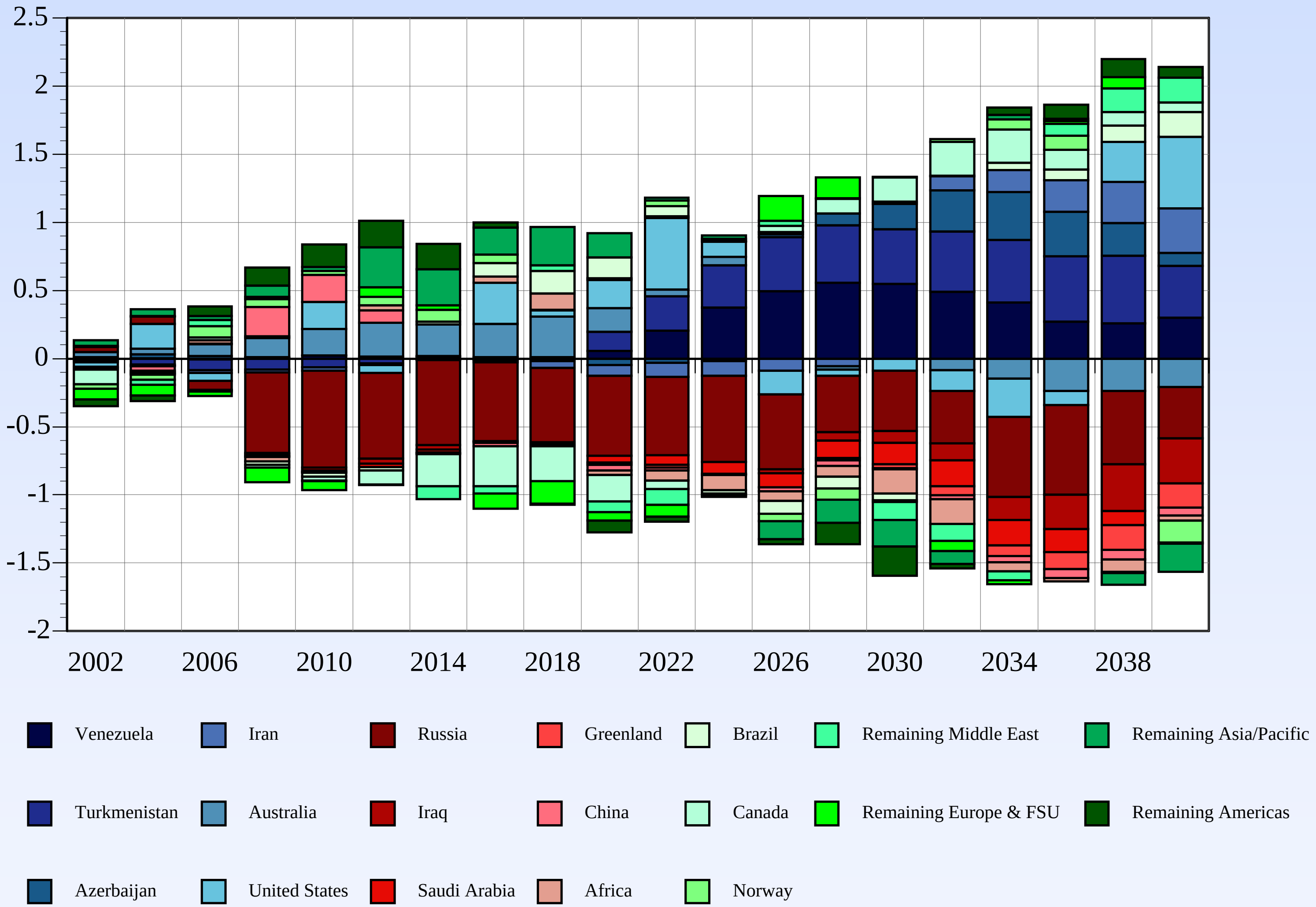
No North Korea pipes: Major Supply Changes

Russian output declines most, but effects are worldwide



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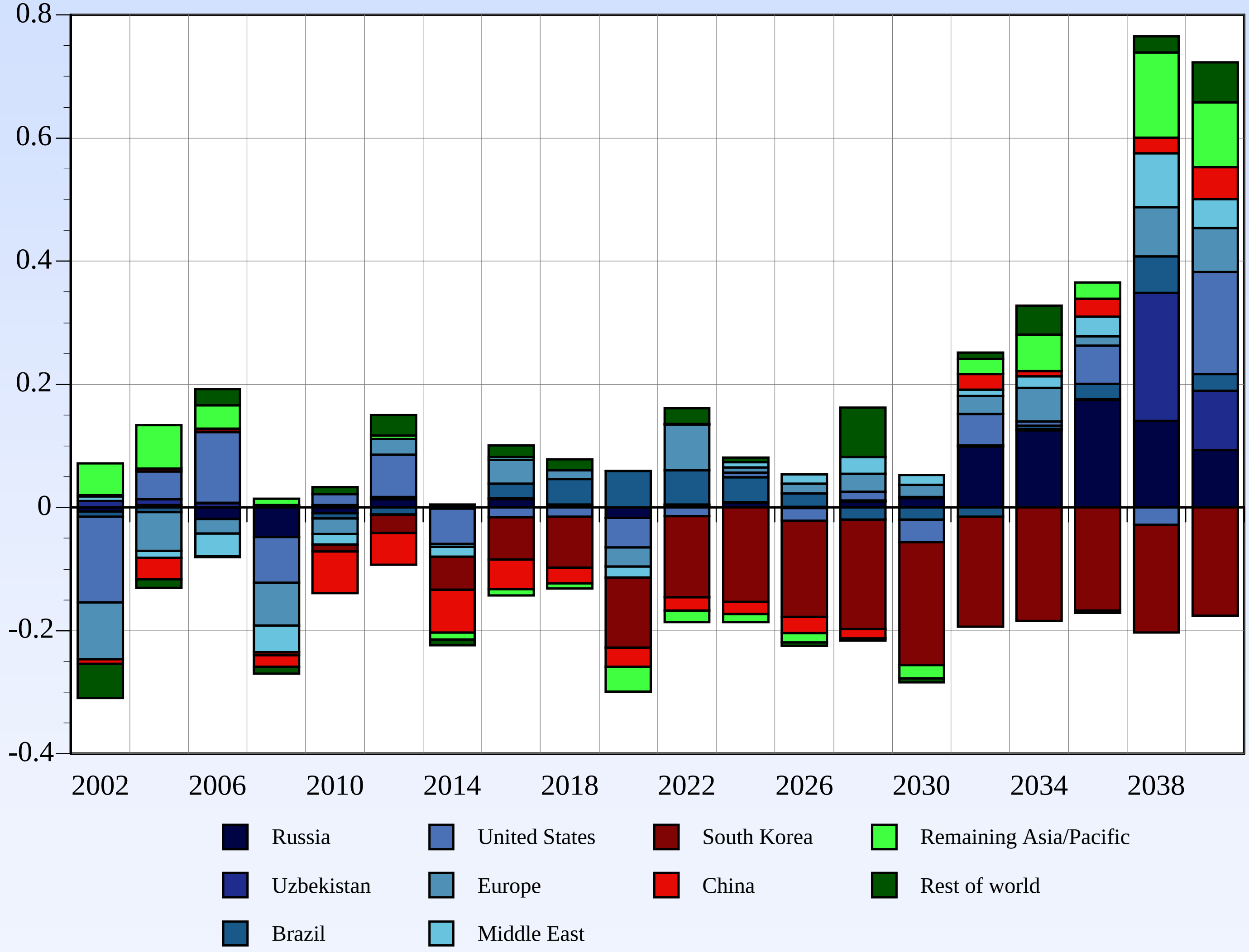
No North Korea pipes: Major Demand Changes

Higher prices stifle South Korean demand, and in general lower prices stimulate demand elsewhere



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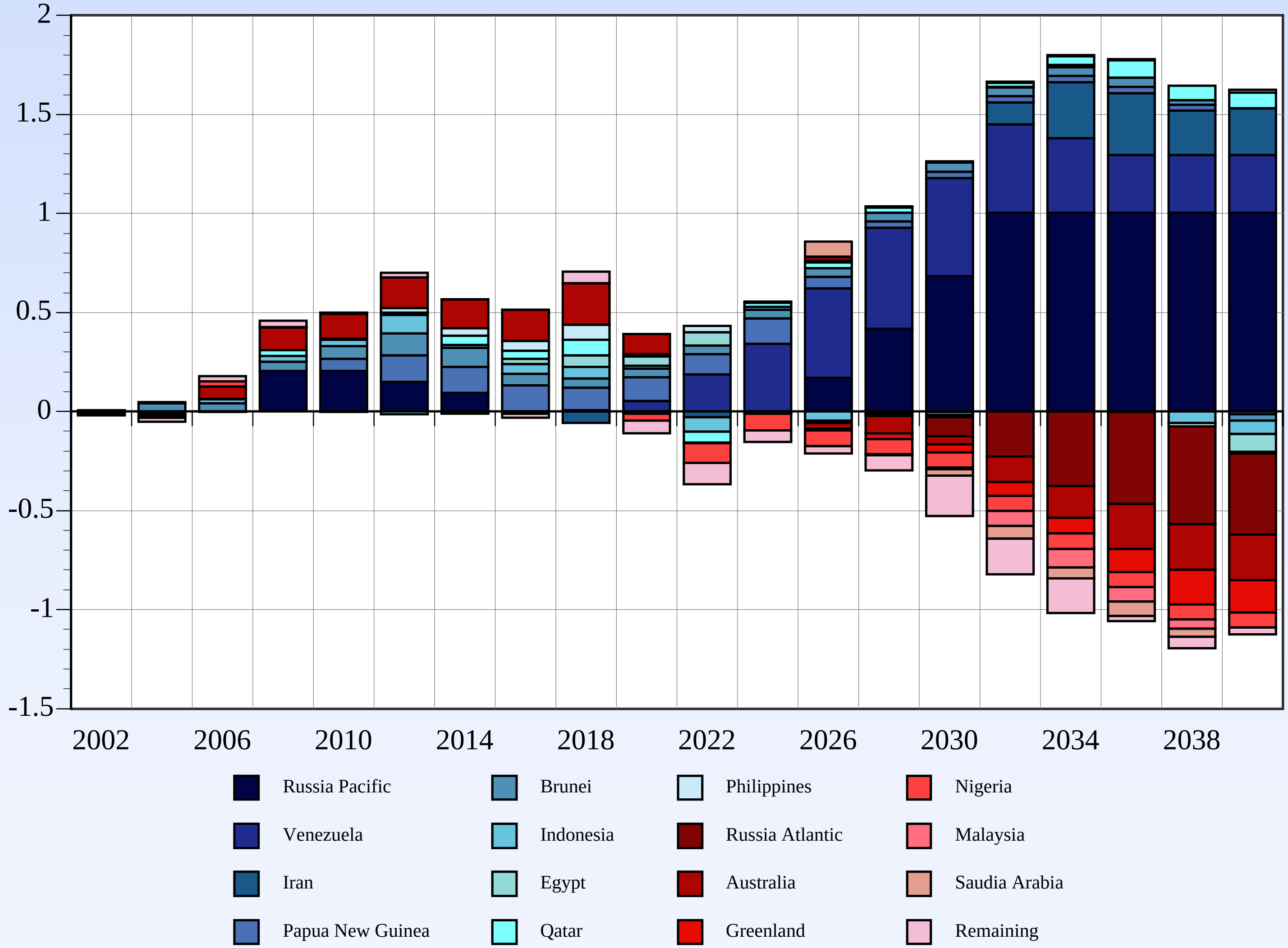
No North Korea pipes: Major Changes in LNG Supply

More Sakhalin gas is now exported as LNG, beating out other LNG from Australia and Saudi after 2030



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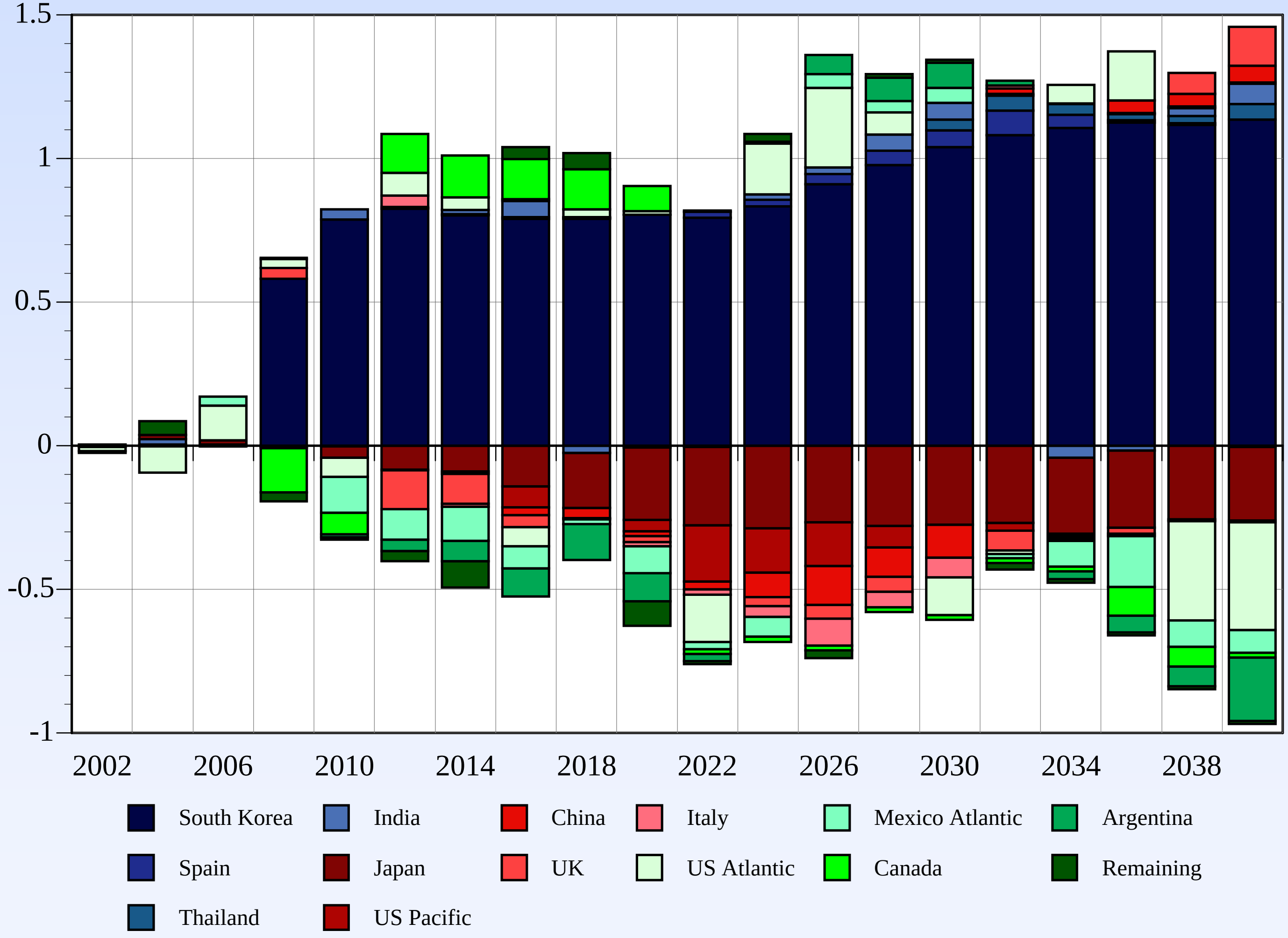
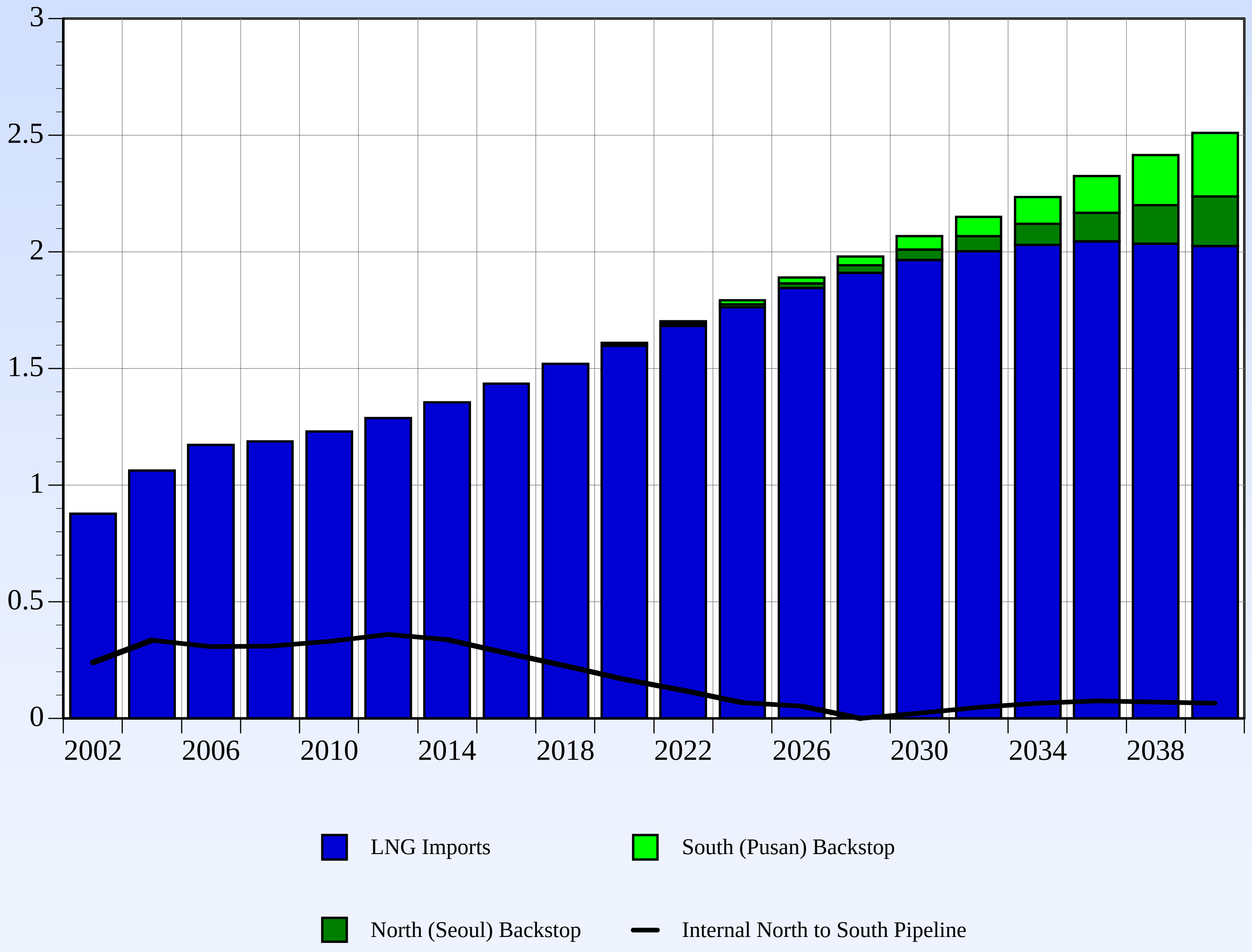
No North Korea pipes: Major Changes in LNG Demand

Higher Korean LNG demand reduces LNG consumption in other Pacific Basin importers, especially Japan



China & Korea pipes off: Effects on Korean Supplies
LNG beats a potential Sakhalin-Japan-Korea pipe



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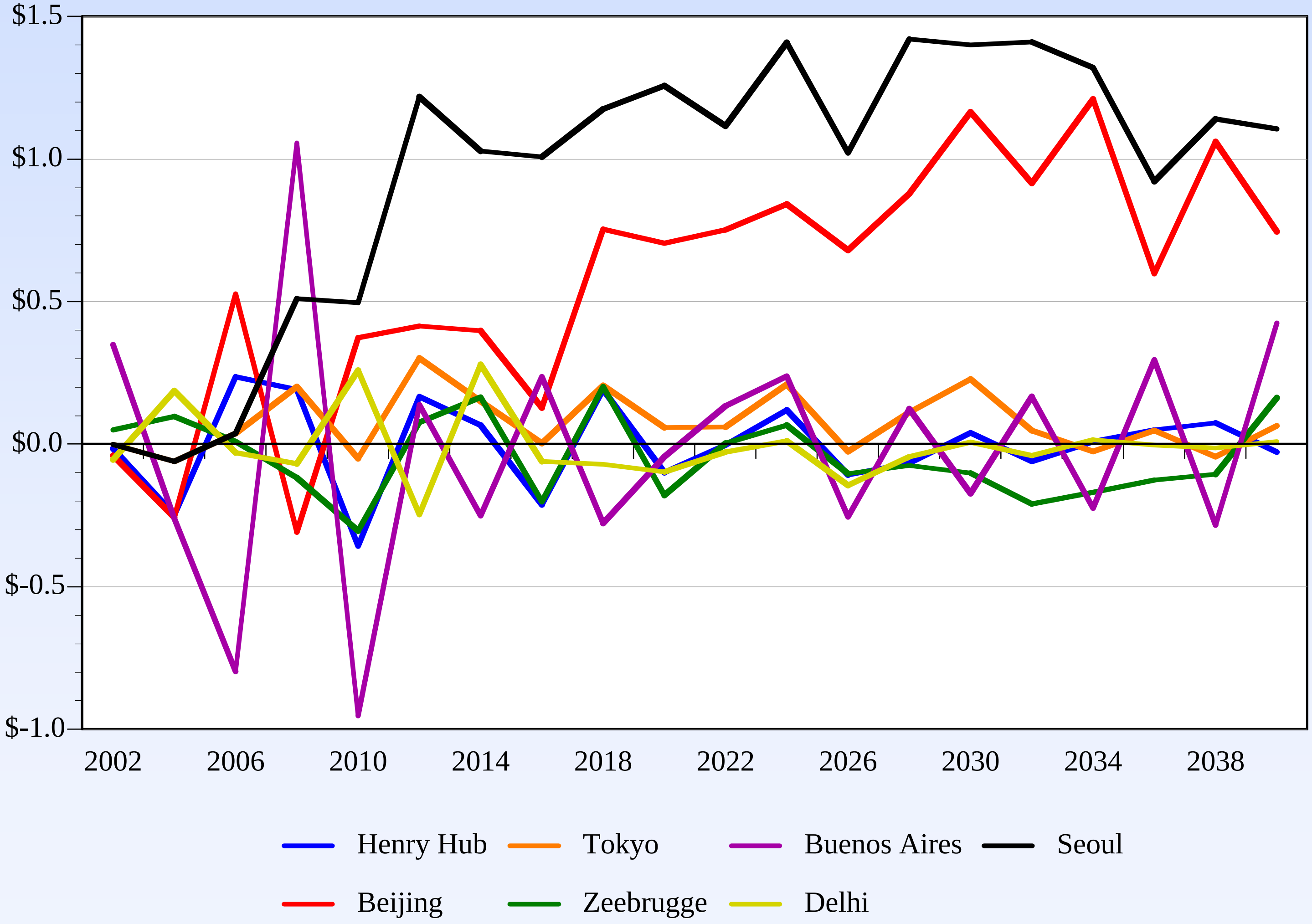
China & Korea pipes off: Changes in Selected Prices



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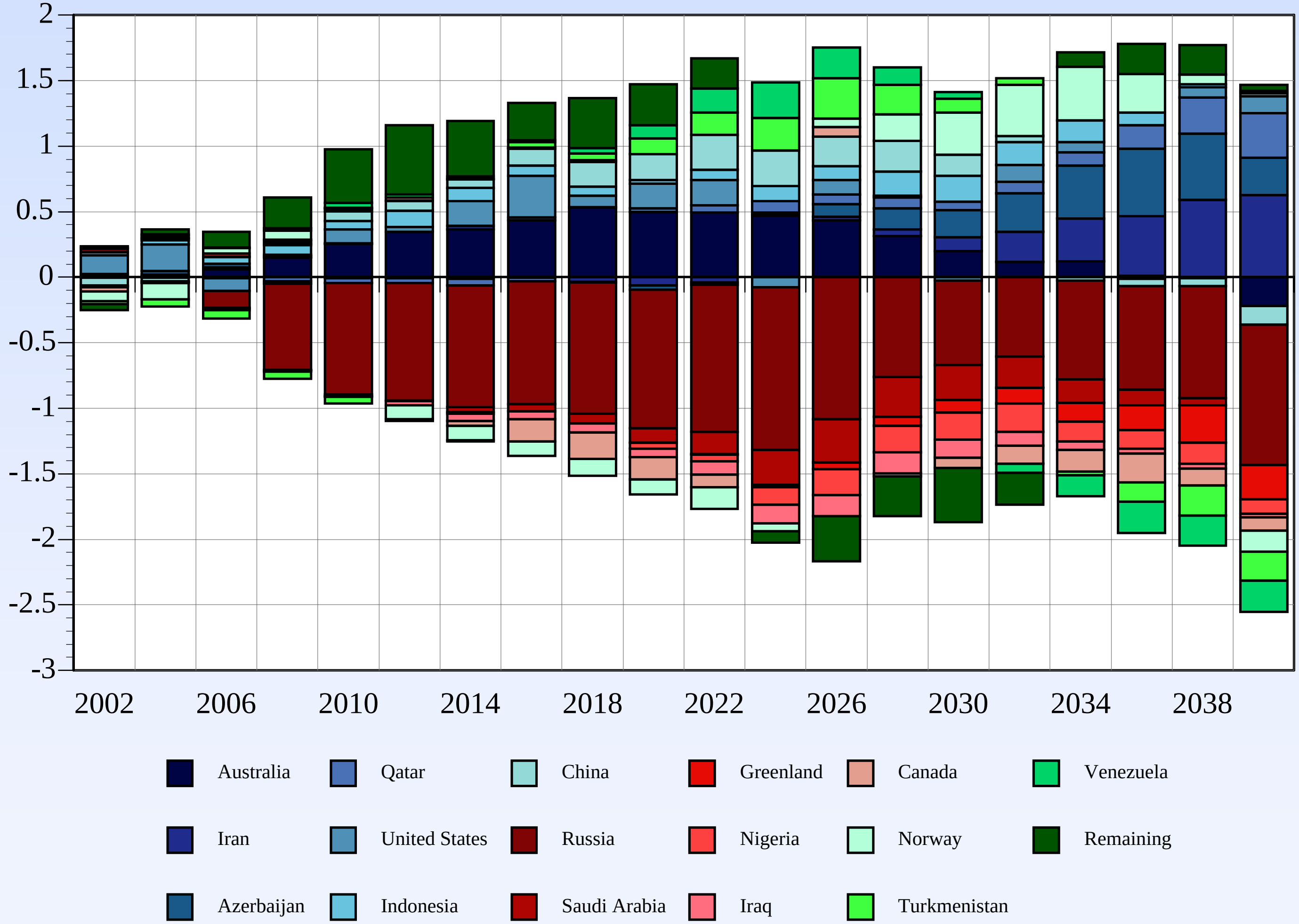
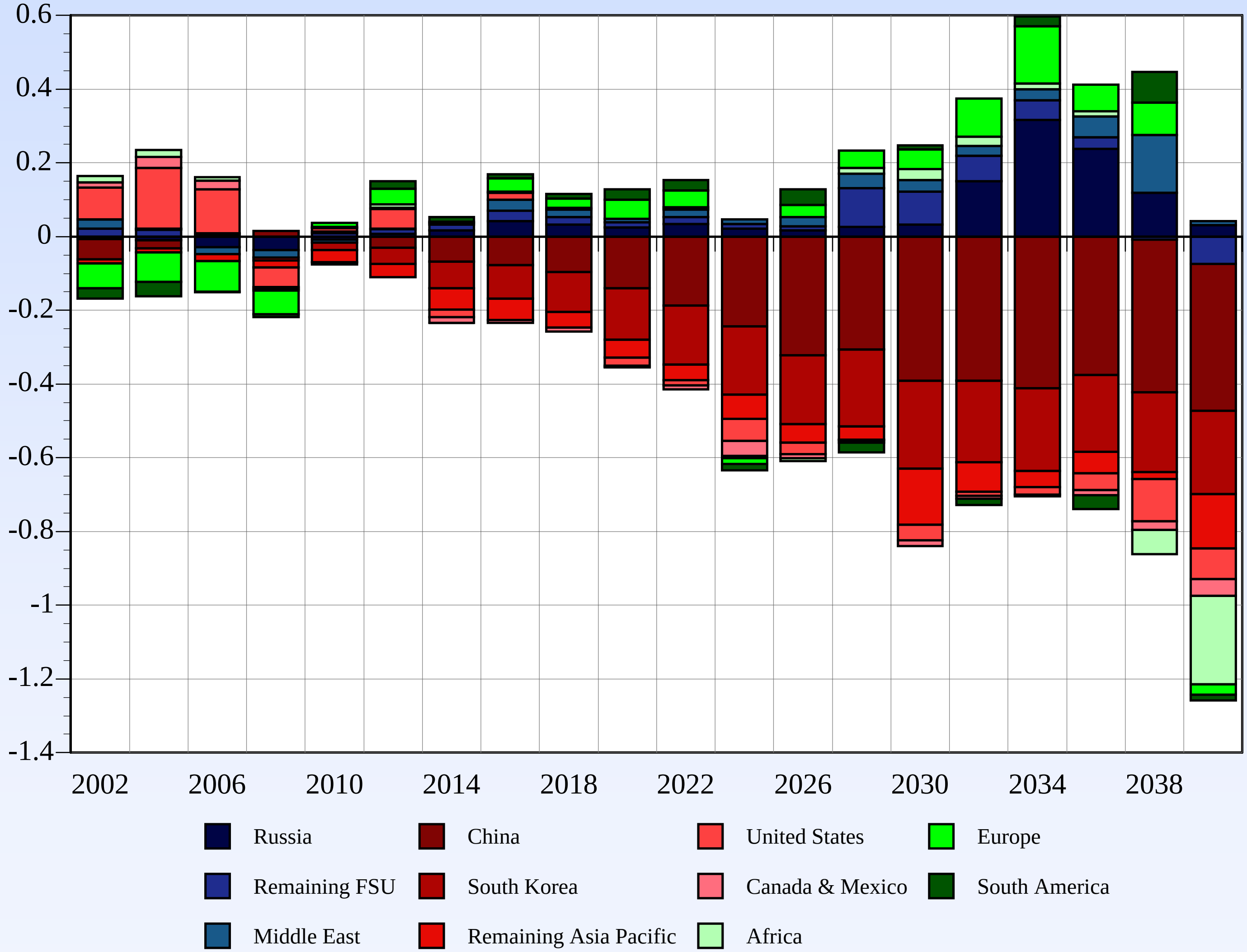
China & Korea pipes off: Major Supply Changes

Now higher overall LNG demand allows main LNG exporters (Australia, Iran, Qatar, Indonesia) to expand



China & Korea pipes off: Major Demand Changes

Now Chinese demand decline exceeds the Korean one; remaining Pacific Basin importers are again adversely affected



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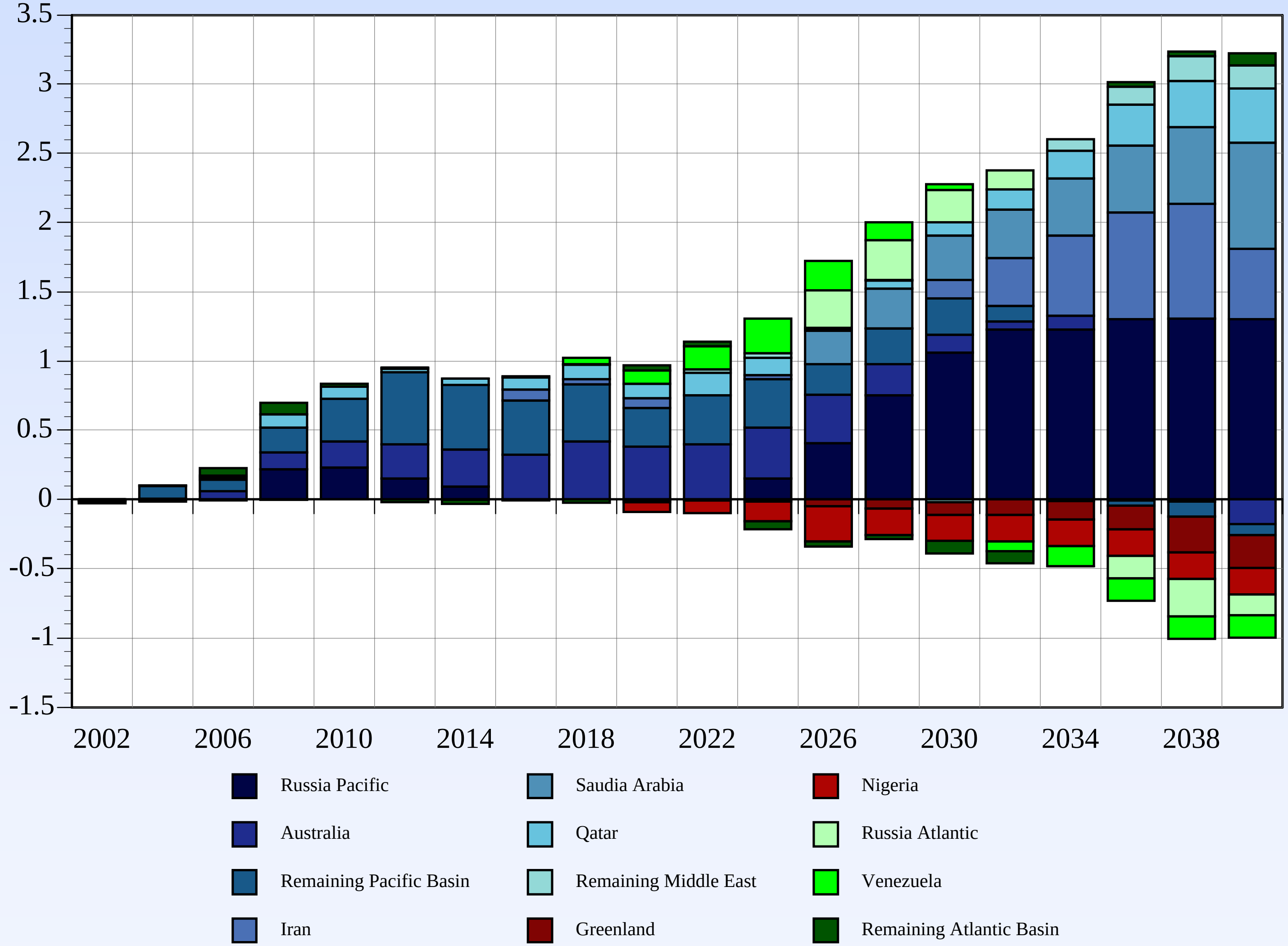
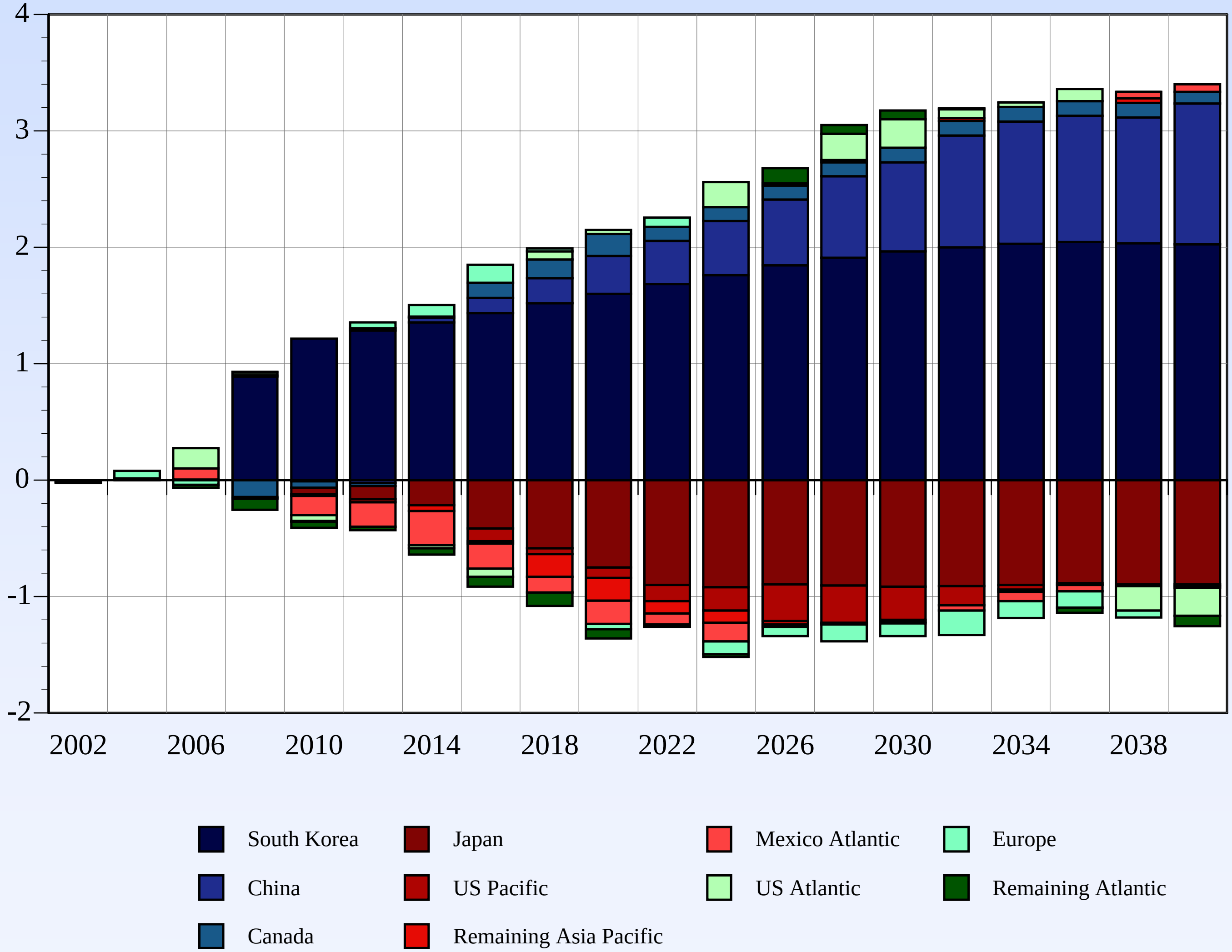
China & Korea pipes off: Major Changes in LNG Supply

Again Sakhalin LNG exports rise, but now the overall LNG market expands enough that few LNG exports decline



China & Korea pipes off: Major LNG Demand Changes

Increased LNG demand in Korea and China displaces demand in other Pacific Basin importers



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Some implications of the Results

- In the coming worldwide market for natural gas, political disturbances in one area have global effects
- The results illustrate the key role Russia will play in the future world gas market
  - Russia not only has a lot of gas
  - It also is strategically placed to ship gas either east or west and hence in a position to arbitrage between European and Asian markets
  - Toward the end of the horizon, Russia also becomes a significant exporter of LNG, thus helping to solidify the link between LNG prices and pipeline gas prices around the world
- North America and the Middle East also link Pacific and Atlantic gas markets
  - Middle East producers can export LNG east or west, and also can ship gas via pipeline to Europe or the Indian sub-continent
  - In North America, if Pacific Basin gas prices rise, more Atlantic Basin LNG is imported and the arbitrage point moves toward the west coast
- A final point more specific to the Korean experiments is that Japan is a close competitor to South Korea for Pacific Basin LNG and increased Korean demand raises Japanese prices

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References for further information

- Details on the construction of the model can be found in the paper:

  Hartley and Medlock (2005a), "The Baker Institute World Gas Trade Model", available at

  http://www.rice.edu/energy/publications/docs/GAS_BIWGTM_March2005.pdf

- Other scenarios are discussed in the companion paper:

  Hartley and Medlock (2005b), "Political and Economic Influences on the Future World Market for Natural Gas", available at

  http://www.rice.edu/energy/publications/docs/GAS_PoliticalEconomicInfluences.pdf

- The model of economic development and energy demand is explained further in:

  Medlock and Soligo (2001), "The Composition and Growth in Energy Demand in China", available at

  http://www.rice.edu/energy/publications/docs/AsianEnergySecurity_CompositionGrowthEnergyDemandChina.pdf