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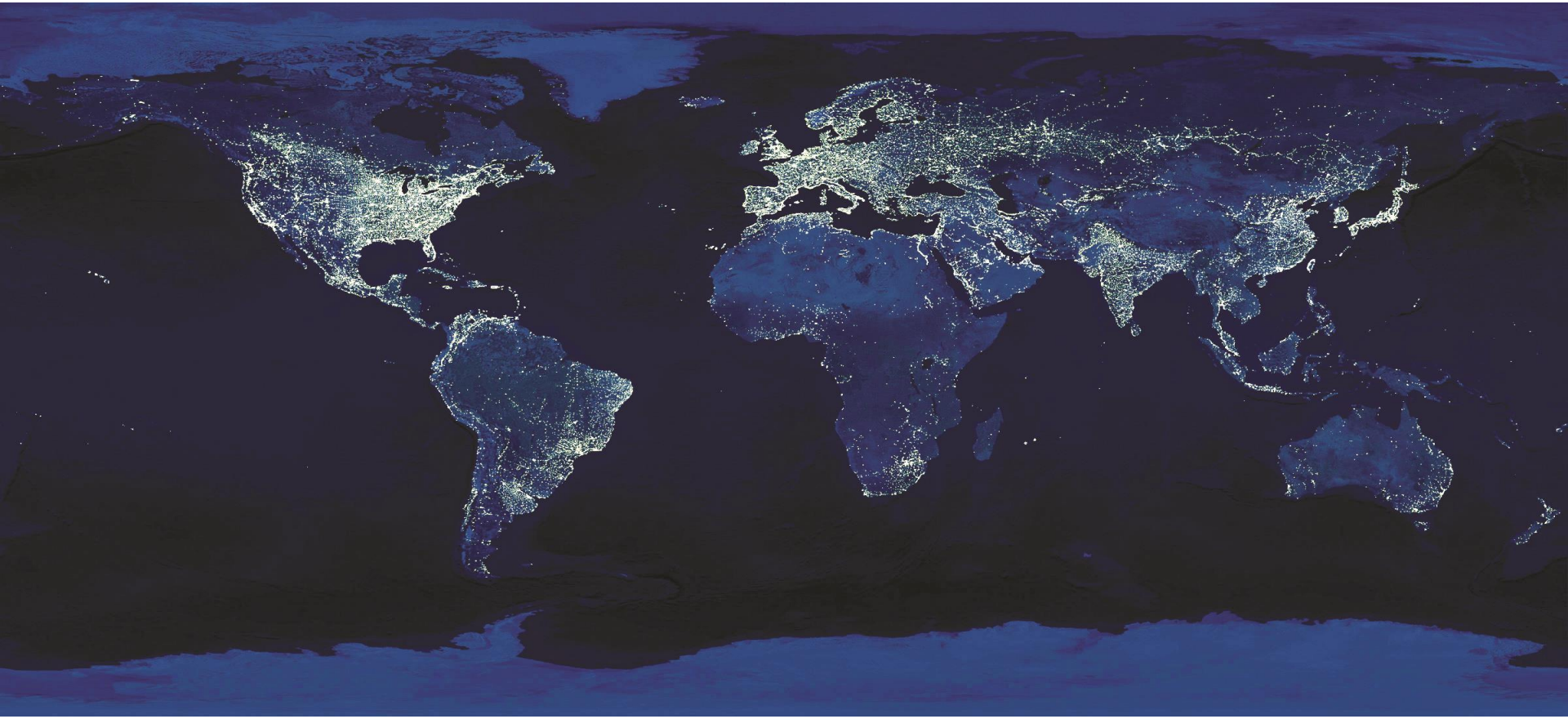
Brazil's Role in an Evolving Global Gas Market



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Rice University's Baker Institute

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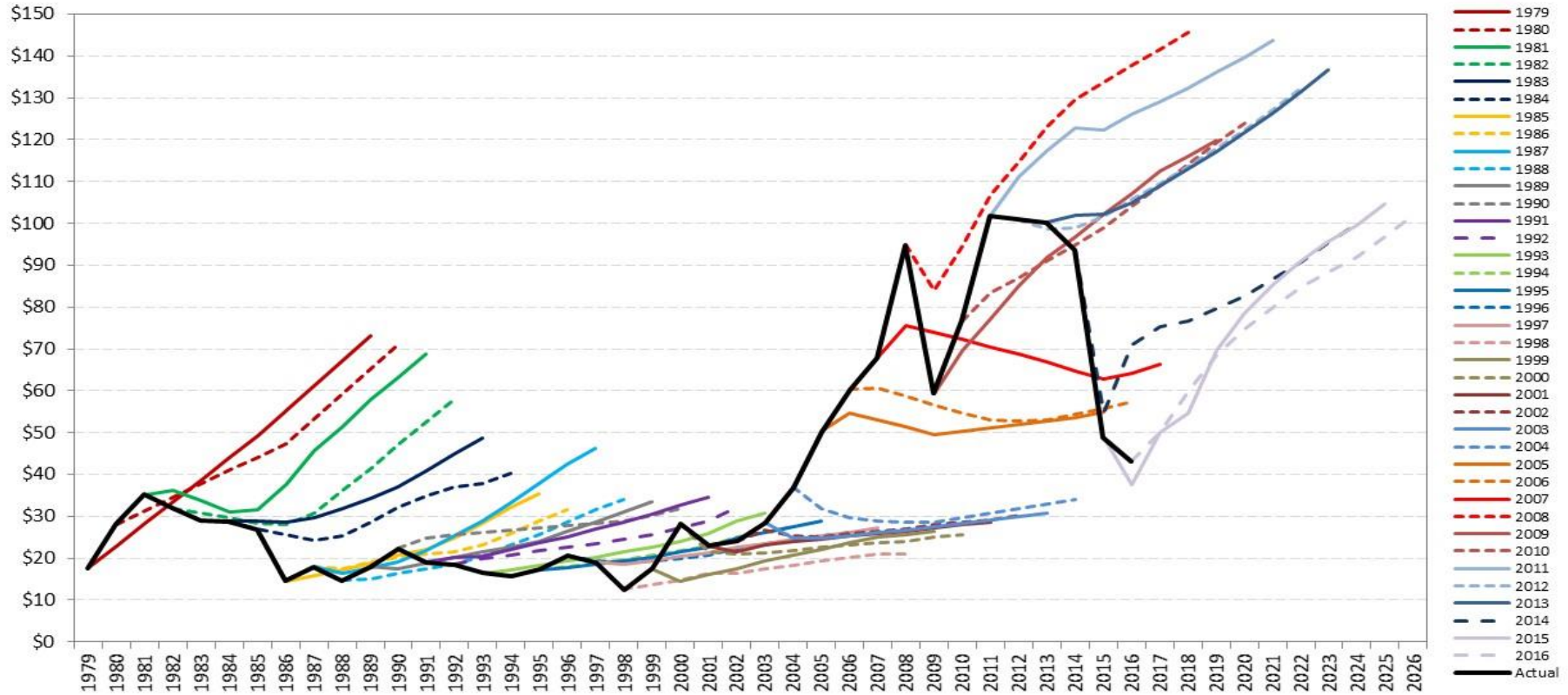
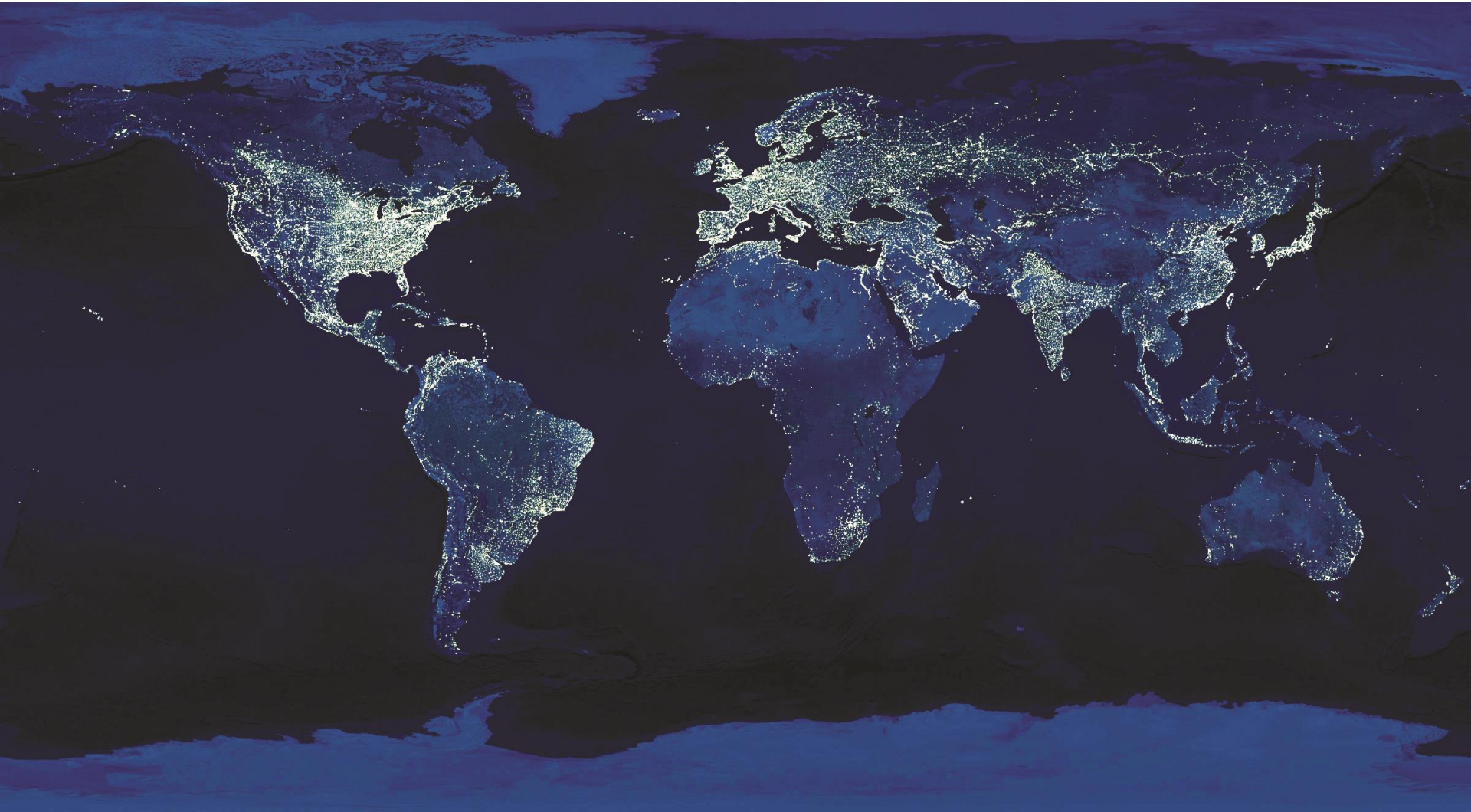
Forecasting 101 – Precision is Folly!

- Long term price projections are rarely accurate, and appear adaptive.
- Too much emphasis on the recent past, can ignore long run fundamentals.
- "The best cure for high (low) prices is high (low) prices"



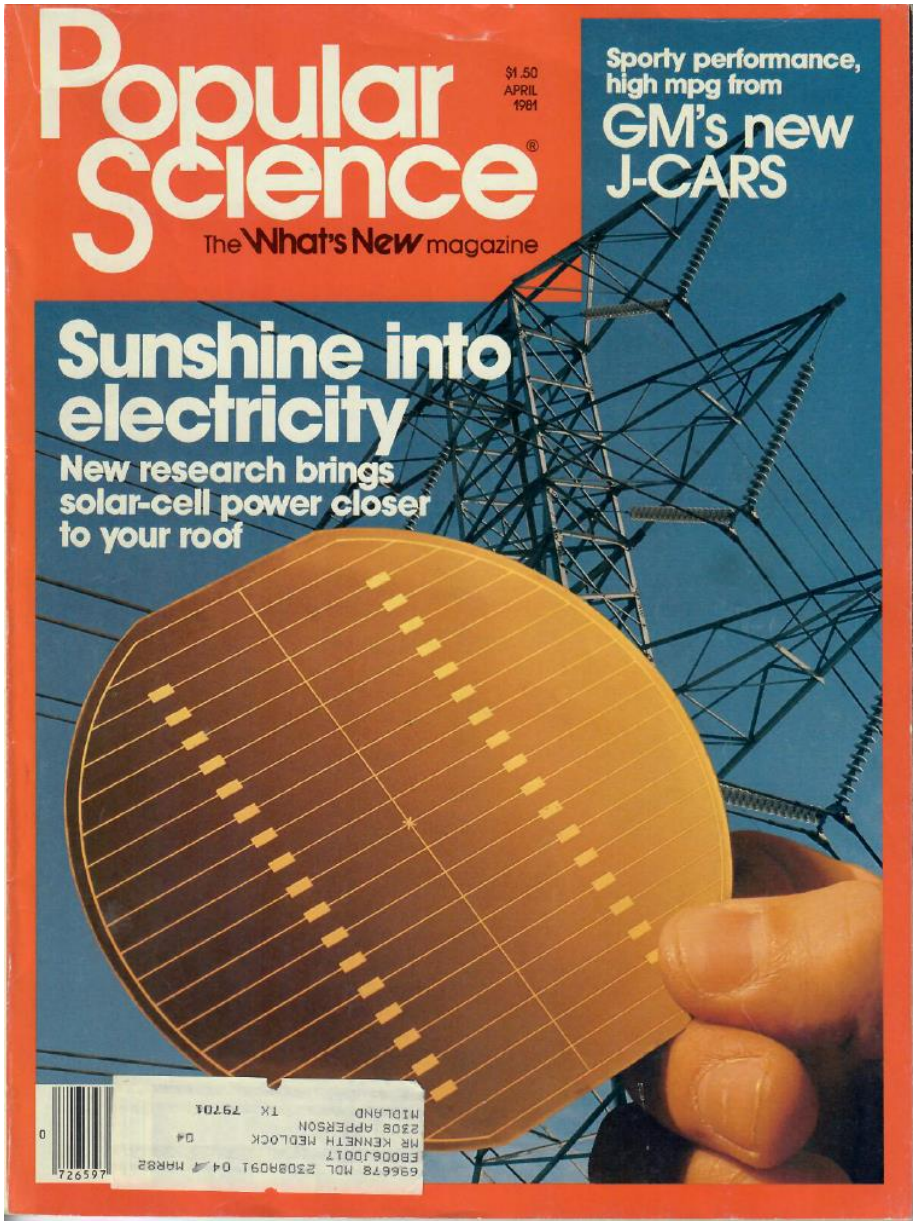
Source: US EIA

The past, present and future of energy?
The story is the picture, but the devil is in the details…



Does history repeat itself?

- The early 1980s was a period of robust promise for renewable energy and distributed generation. Why?
  - High oil prices and energy security.
  - Natural gas supply concerns.
- What happened?
  - Incumbent fuel costs fell and efficiency increased.
  - Fixed costs of adoption matter.
  - Coal expanded.
- How is the present different?
  - Costs are lower and coal is encumbered, each aided by policy.
  - Energy *and* environmental security.
  - Natural gas supply is robust.
- Are recent developments lasting?

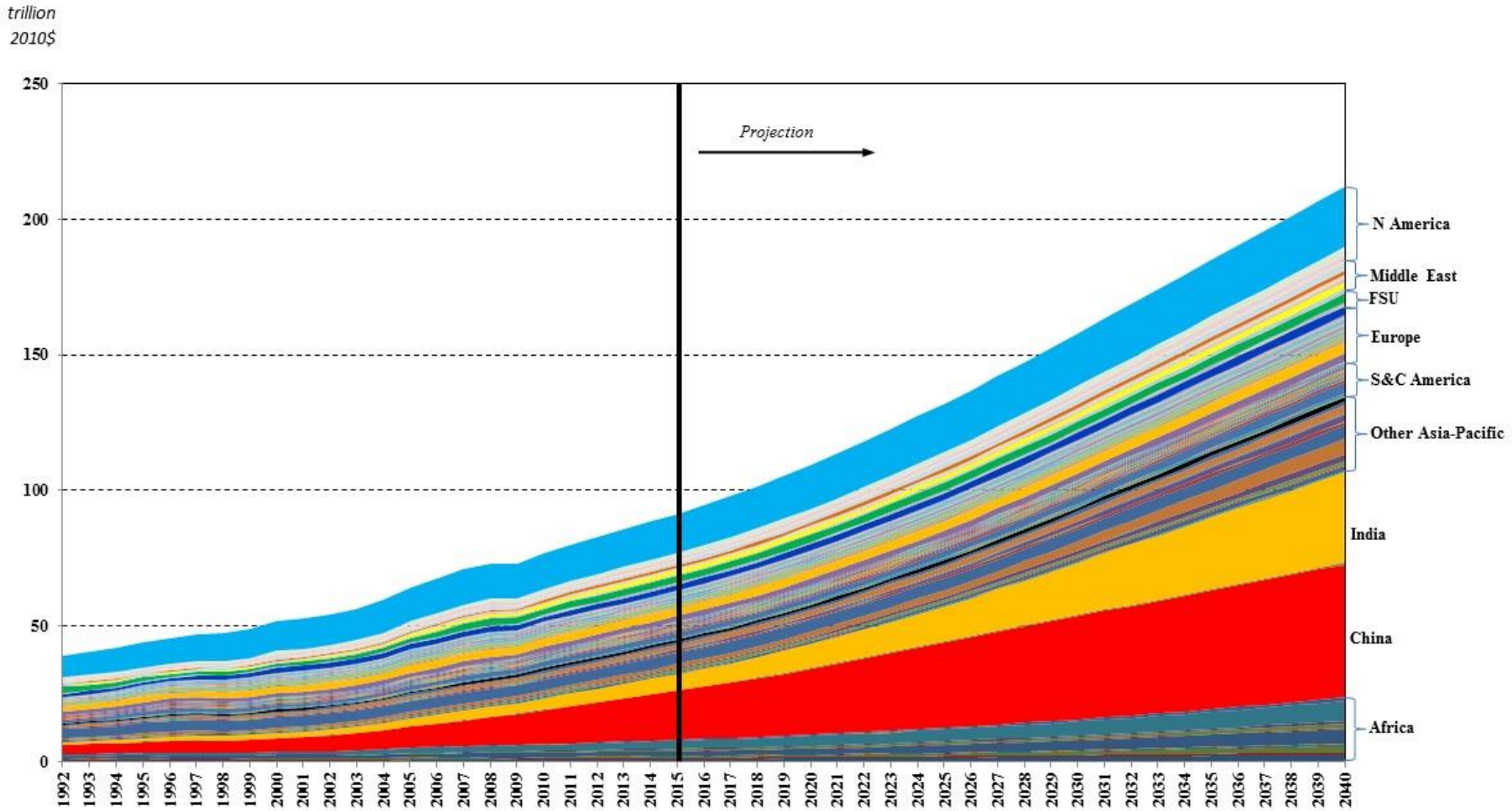


This is a *long run* story…

- Economic growth and population drive energy demand. As such, developing nations, not developed nations, will dictate future energy demand growth as well as composition, or the "energy mix".
- Technology, scale and legacy are each important factors.
  - Technology signals how fuels will ultimately compete. This can work in multiple, sometimes competing, directions by raising the efficiency of use of existing fuels *and* by introducing new competitive energy sources.
  - Scale matters because energy systems must accommodate expanding access.
  - Legacy of infrastructure and fuel delivery systems is the footprint for change.
- Scale and legacy affect the diffusion of new technology.
- Economics matter. The cost-benefit must be favorable for sustainable diffusion of new technologies because, in the long run, fundamentals win.
- Finally, policy and geopolitics shape, and are shaped, by all of the above.

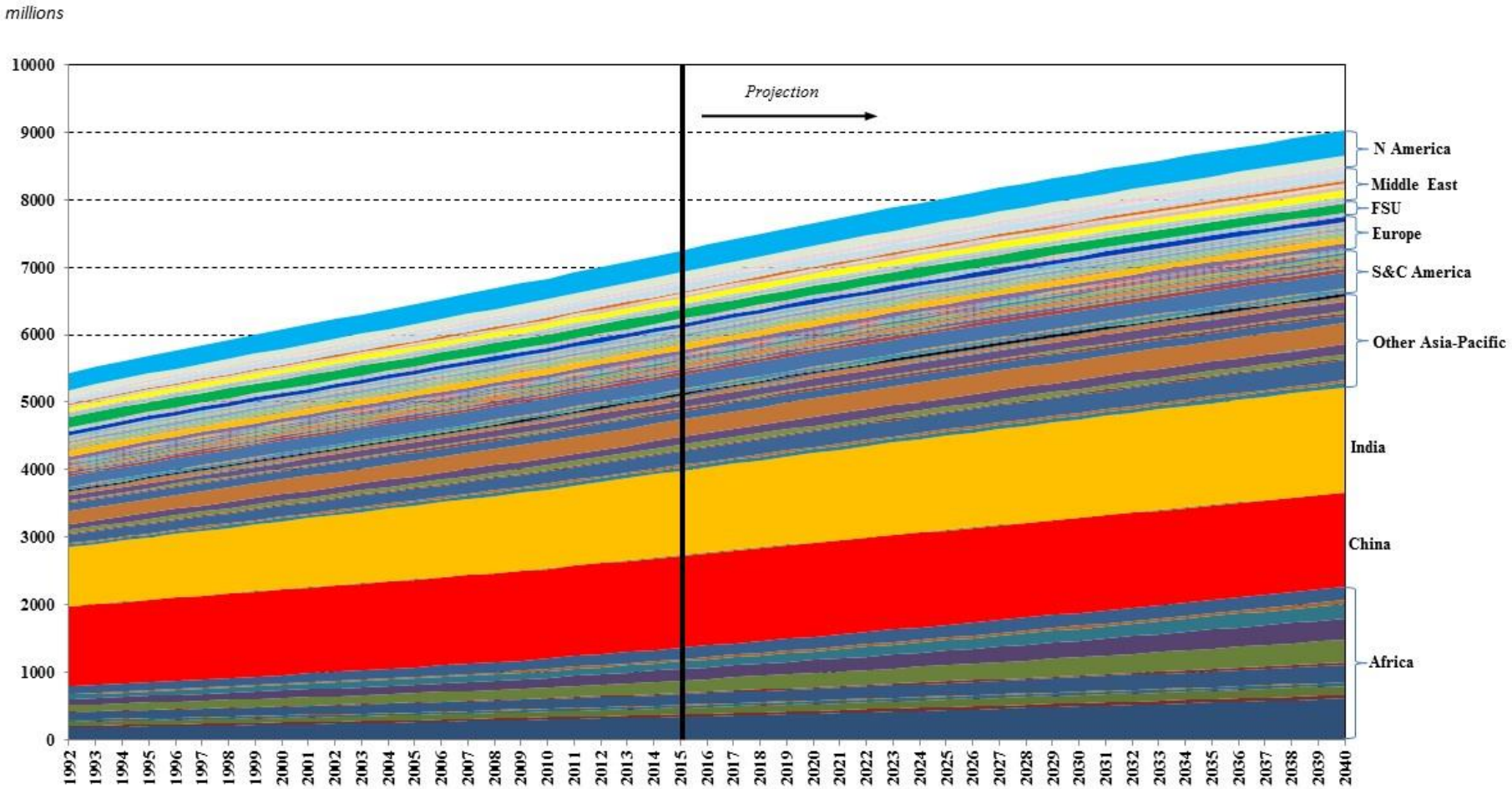
Long Run Fundamental Drivers of Energy Demand

Global GDP by Country



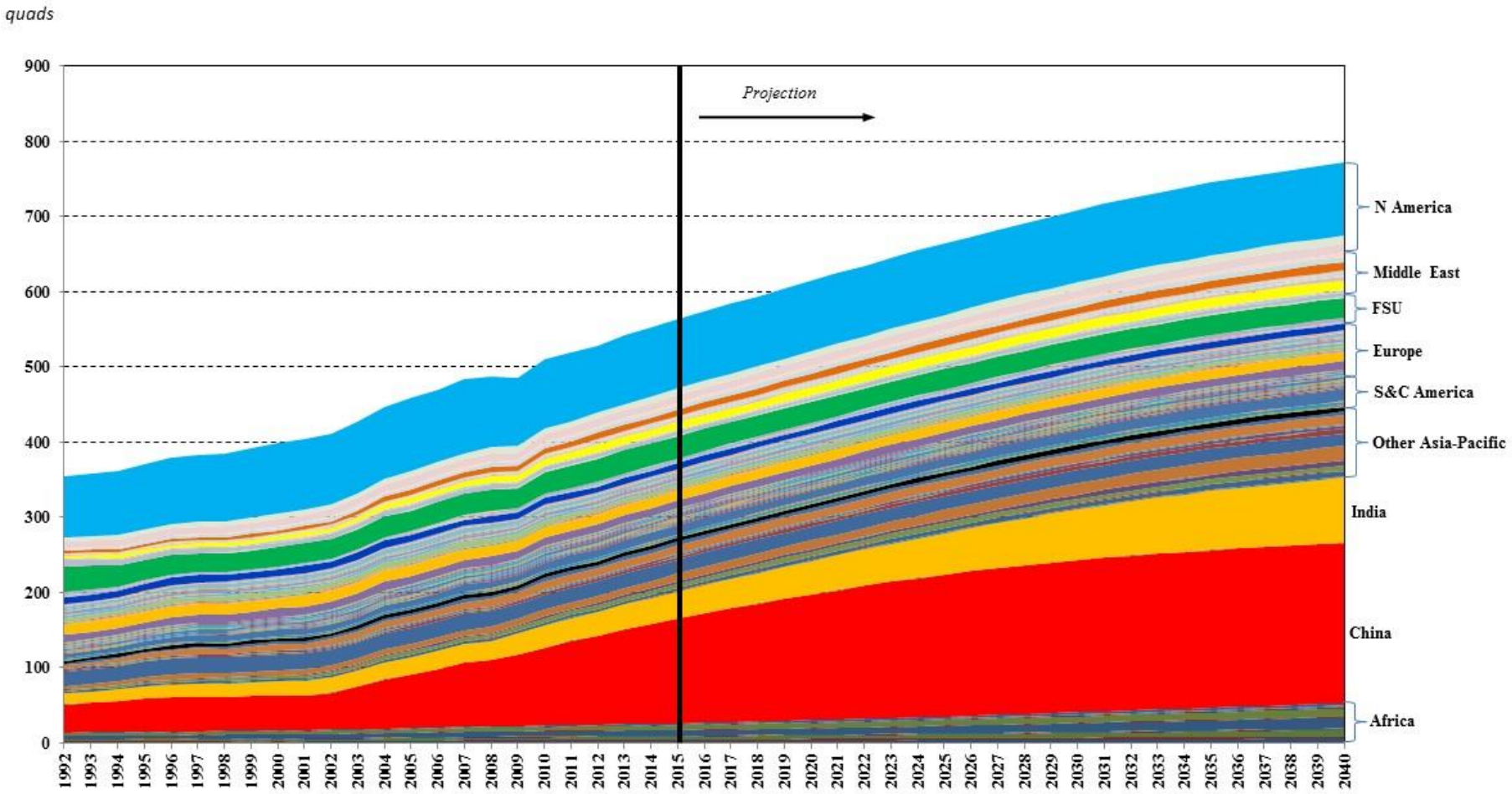
Data Sources: World Bank, PWT, IMF, BIPP CES

Global Population by Country



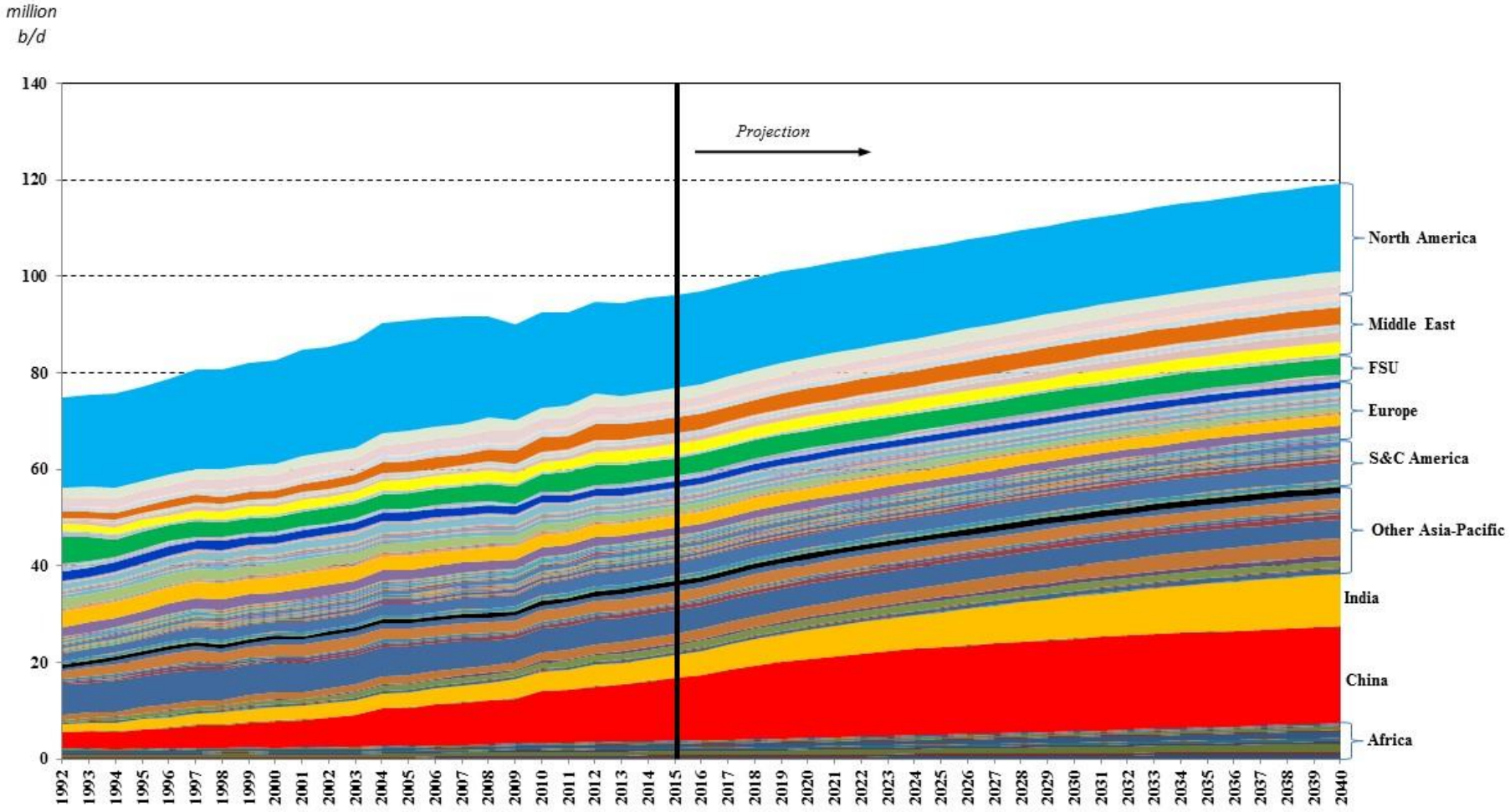
Data Sources: World Bank, UN

Total Primary Energy Requirement by Country



Data Sources: IEA, BIPP CES

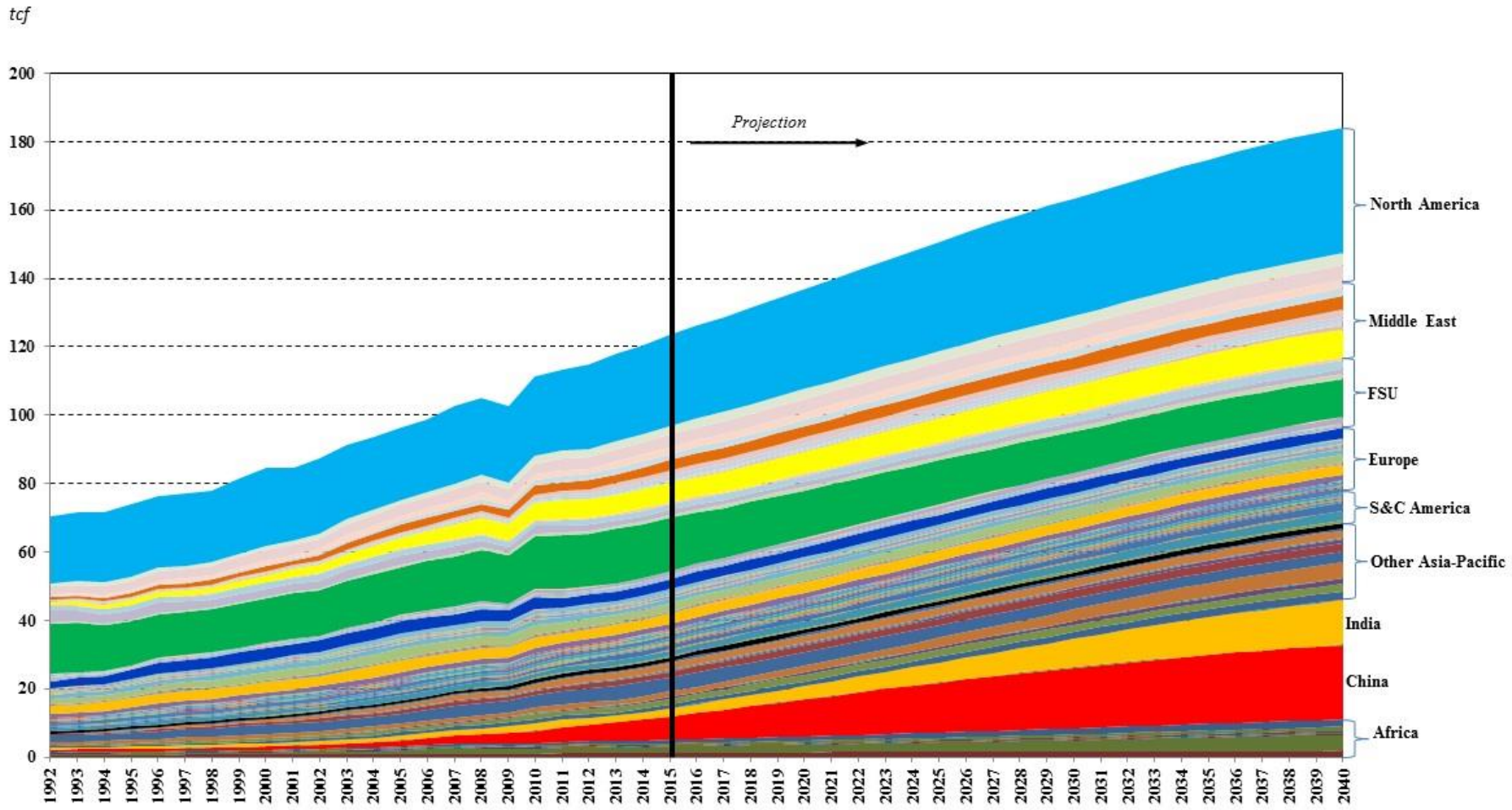
Oil Demand by Country



Note: The reference case assumes EVs are 5% and 15% of all new sales by 2023 and 2030, respectively, up from 1% today → displacement of 2.1 million b/d by 2030.

Data Sources: IEA, BIPP CES

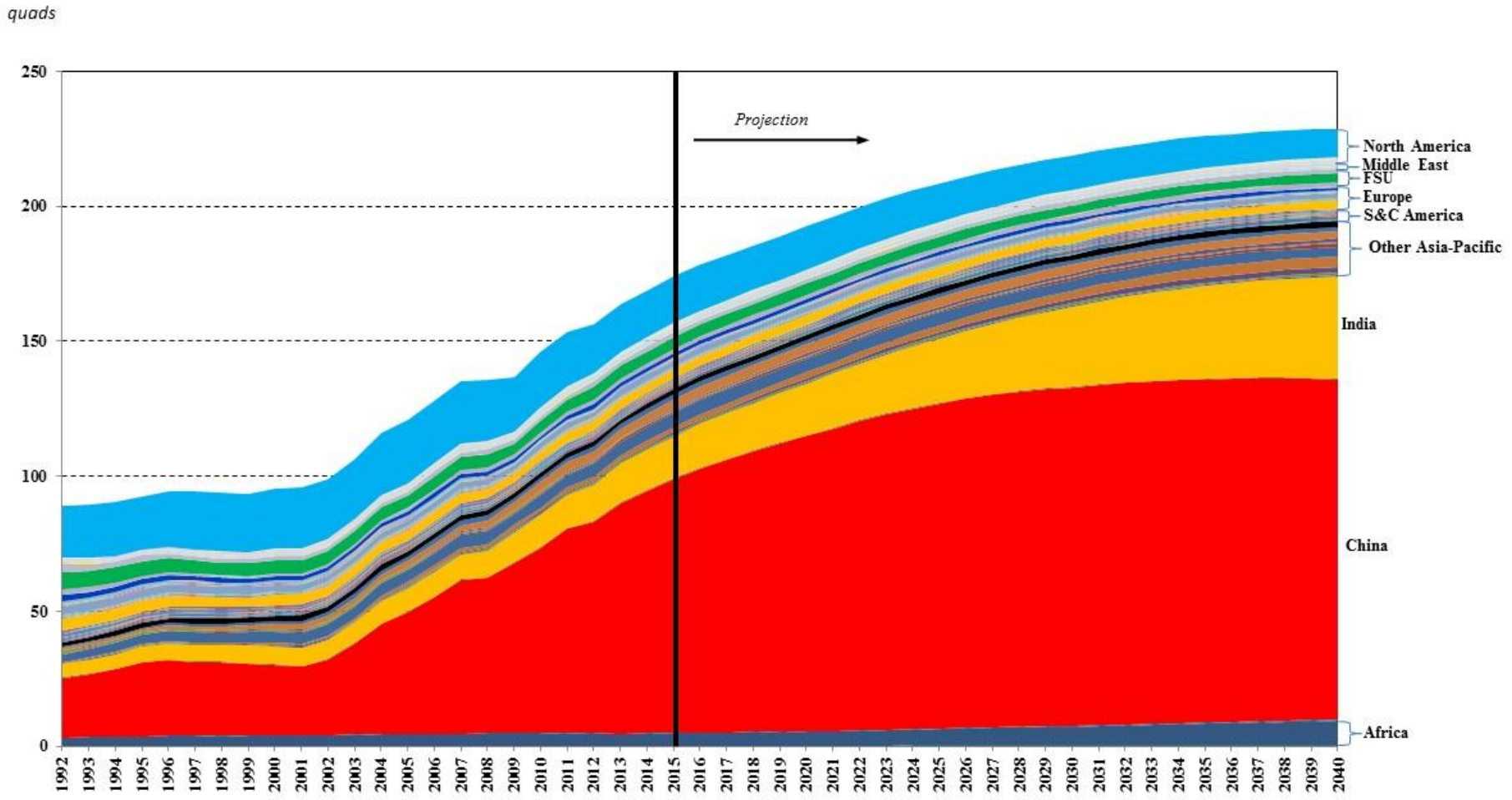
Natural Gas Demand by Country



Note: Natural gas demand growth is driven primarily by growth in power generation and reinforced by shifting market structure → different impact in developing nations vs OECD.

Data Sources: IEA, BIPP CES

Coal Demand by Country



Coal use slows in China, rises in India and some ASEAN nations, but declines in the OECD → Economic growth versus new sources.

Data Sources: IEA, BIPP CES

Regardless of the view of global energy markets, natural gas will be a significant proportion of the global energy mix for the next few decades. How is this demand to be met?

Much of the projected demand growth will be in developing Asia, where there is a paucity of domestic resource. So, it is very probable that LNG will play a critical role. A deepening global gas market will lower the perception of supply risks and support expansion of natural gas demand.

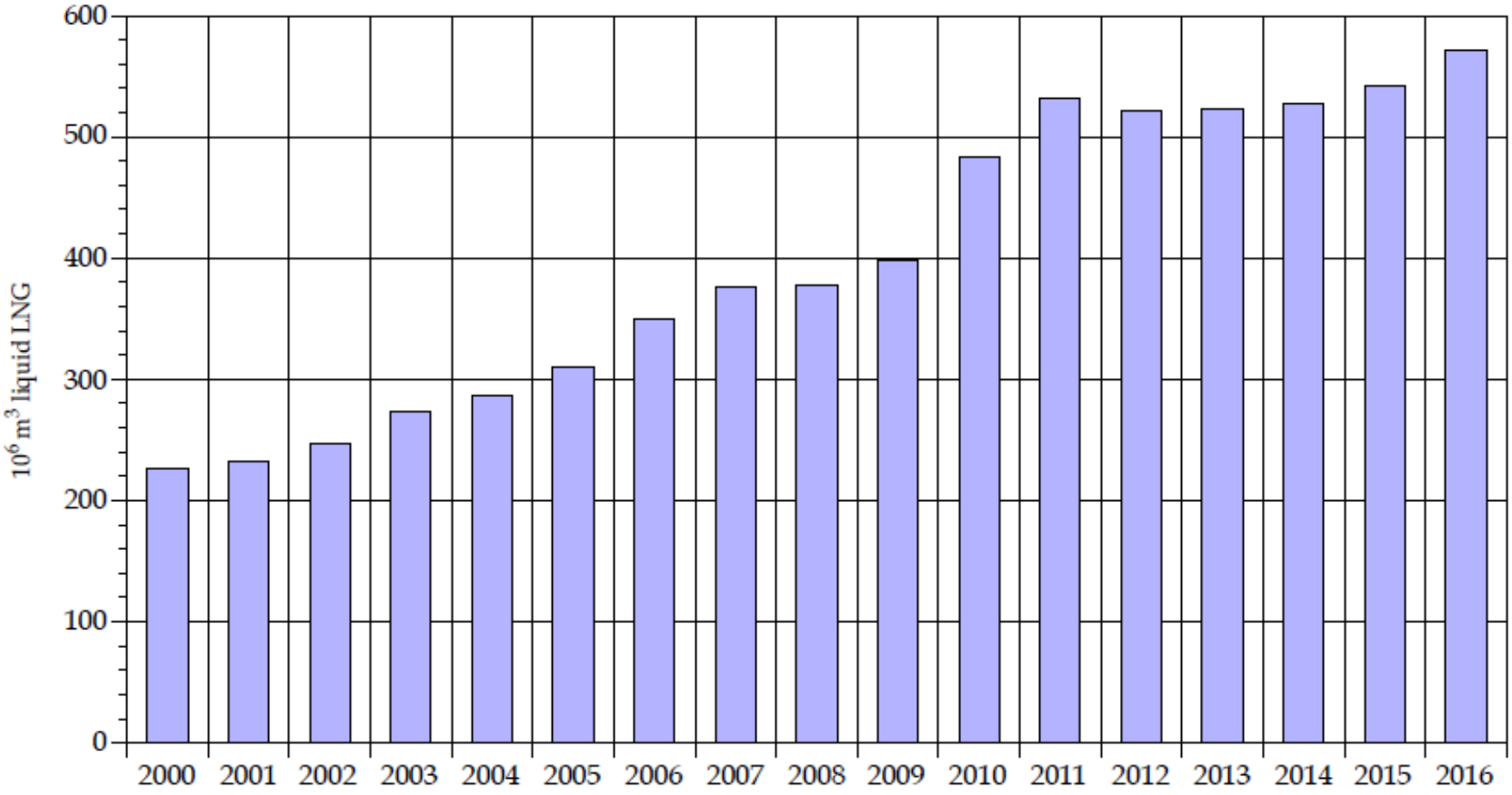
Shale has been paradigm shifting for both natural gas and crude oil markets, but it has been a US-centric development. Questions remain regarding the opportunities for shale and other frontier resources outside the US, but there is a potentially important and expanding role for energy in the Western Hemisphere.

Energy efficiency will be a major part of any environmentally-driven path forward. But, natural gas will gain in favor.

Natural Gas and LNG:
Market Evolution and the Self-reinforcing Impact of Investment, Trade and Fungibility

How have LNG Markets Evolved?

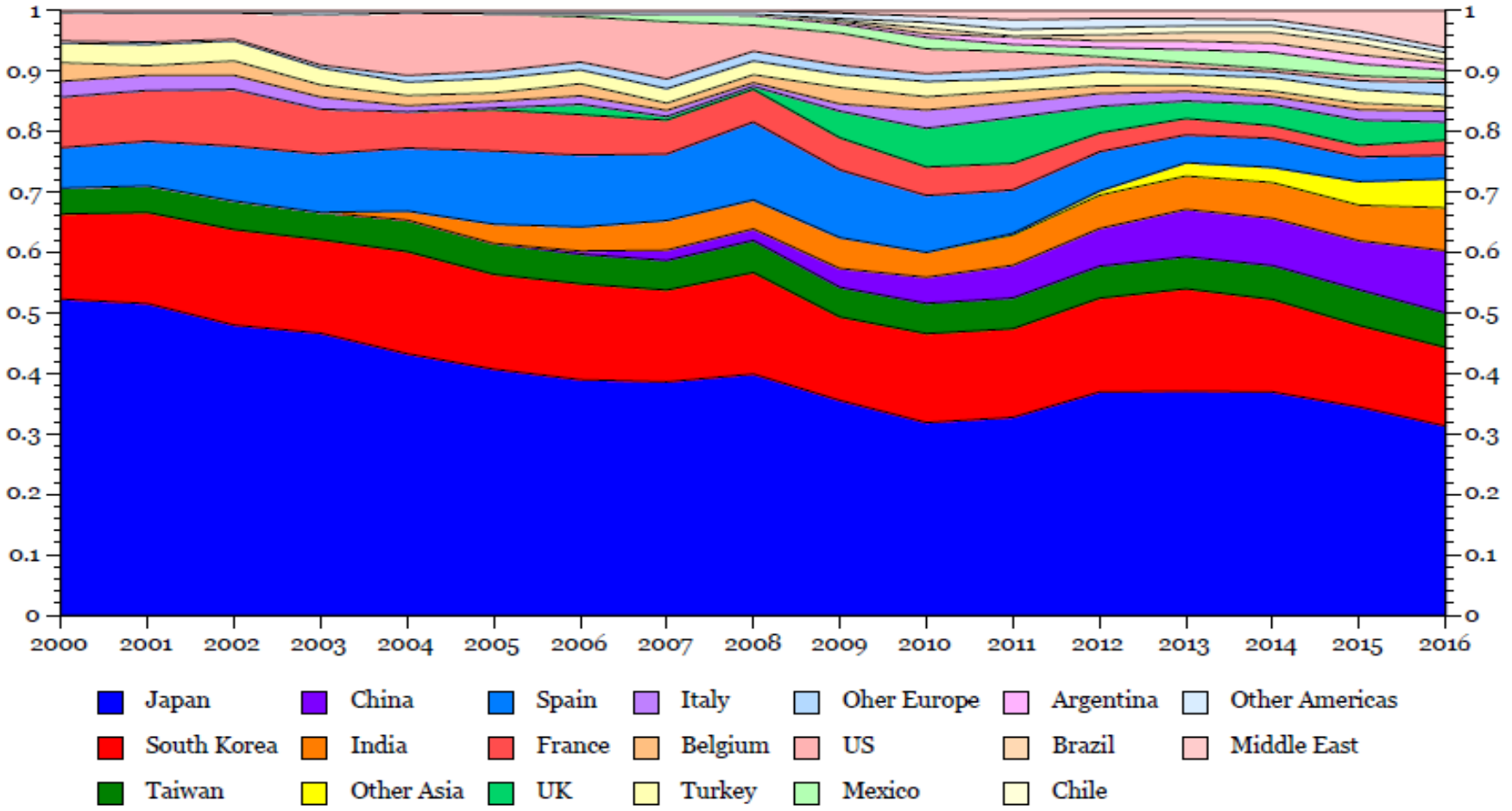
- LNG trade has more than doubled in the last 15 years.



Source: GIIGNL

Who is Buying?

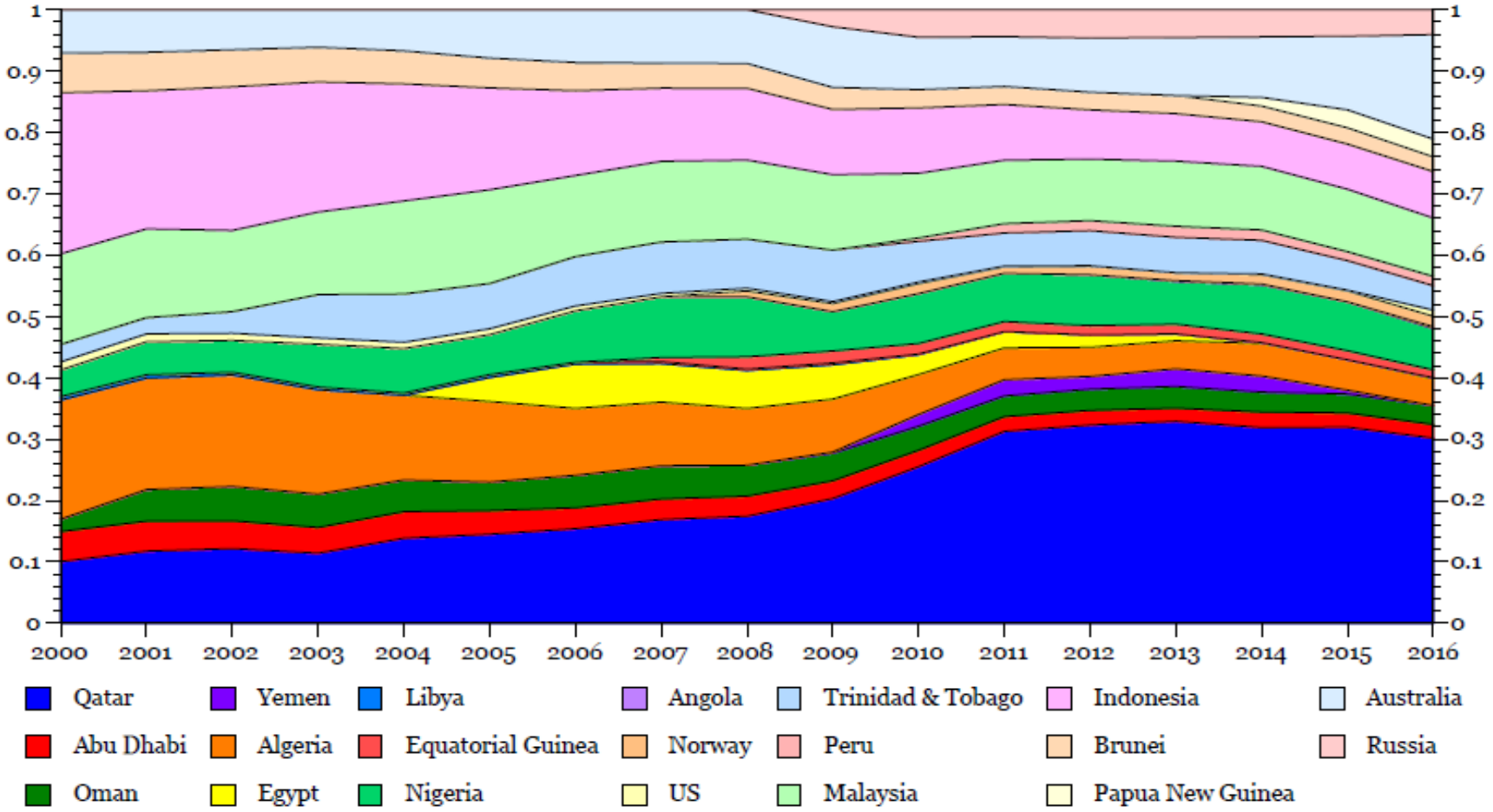
- The composition of LNG importers has changed significantly.



Source: GIIGNL

Who is Selling?

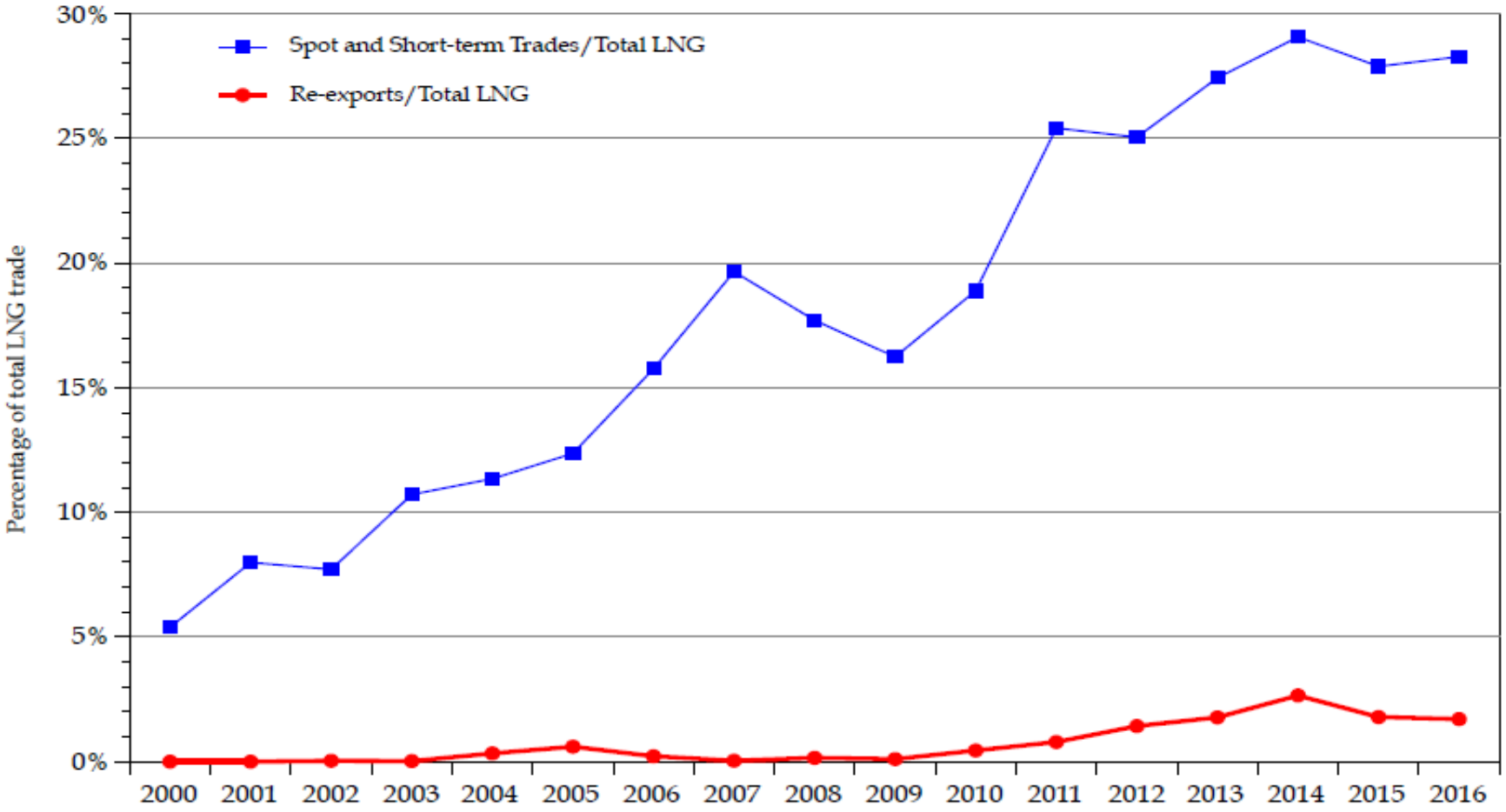
- The composition of LNG exporters has also changed significantly.



Source: GIIGNL

Trade is Deepening, and Evolving…

- Spot and short term trade as a fraction of all trade has more than quintupled.



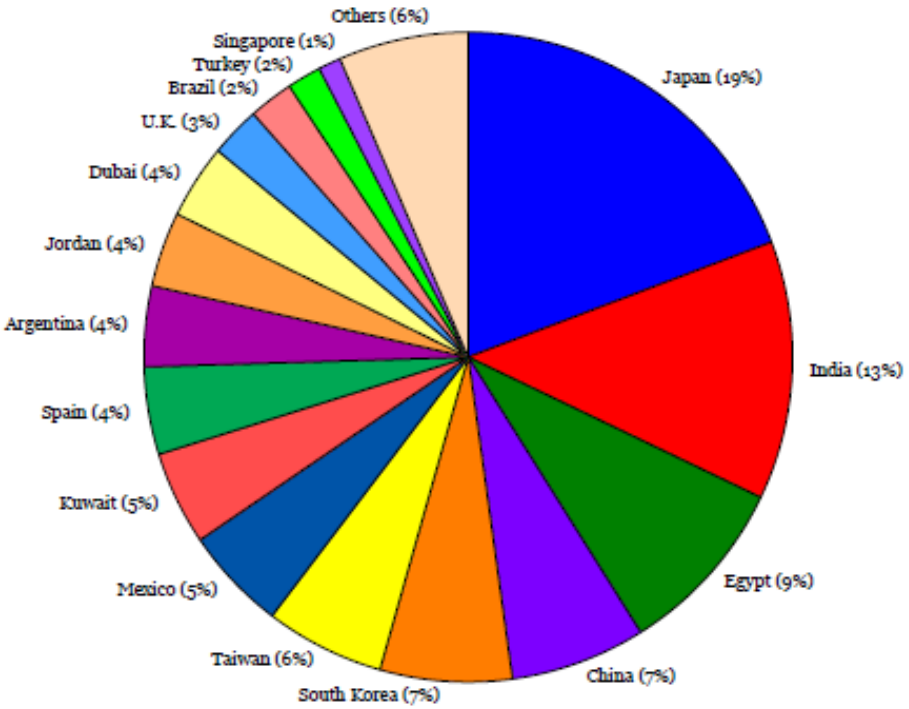
Source: GIIGNL

… with a Diverse set of Actors…

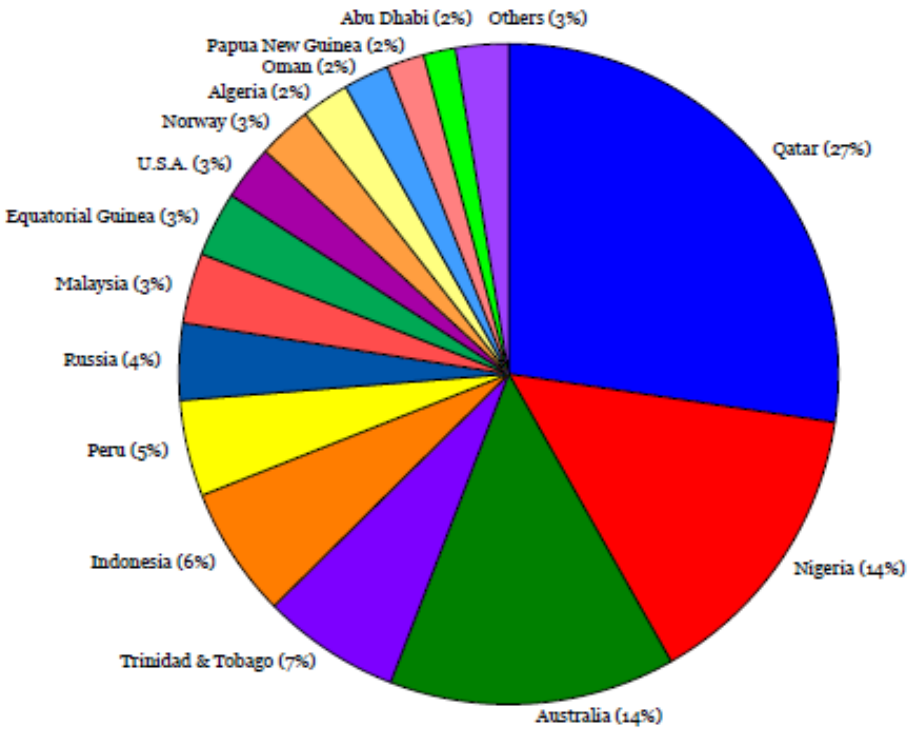
- Shares of spot and short term trades indicate a diverse set of importers and exporters participating in deliveries **not** dictated by long term contracts.

2016

Importing countries



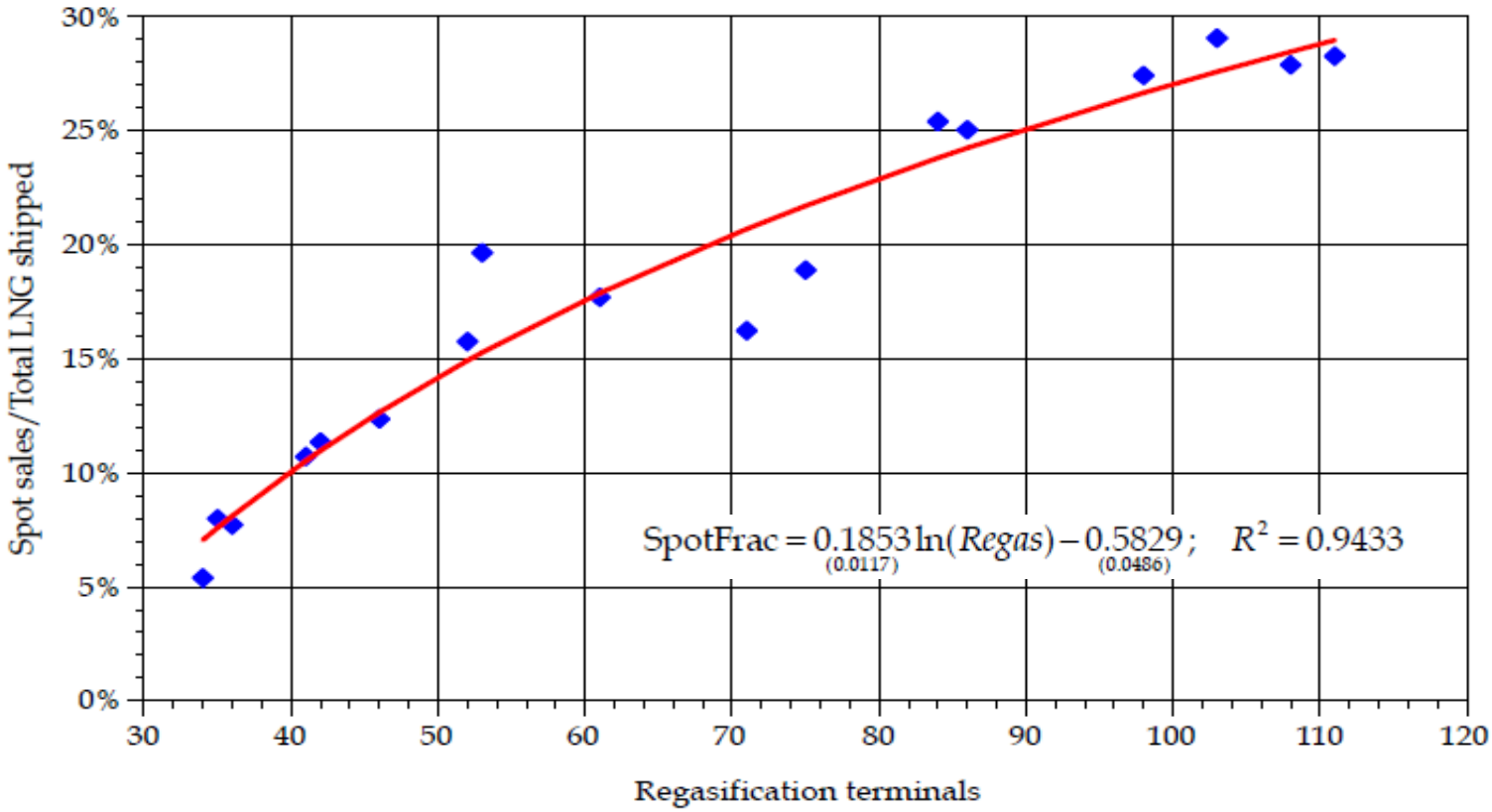
Exporting countries



Source: GIIGNL

… and Spot Trading is Related to the Number of LNG Market Outlets

- As markets deepen, spot transactions grow. This is consistent with economic theory and indicates a rapidly evolving global LNG market.

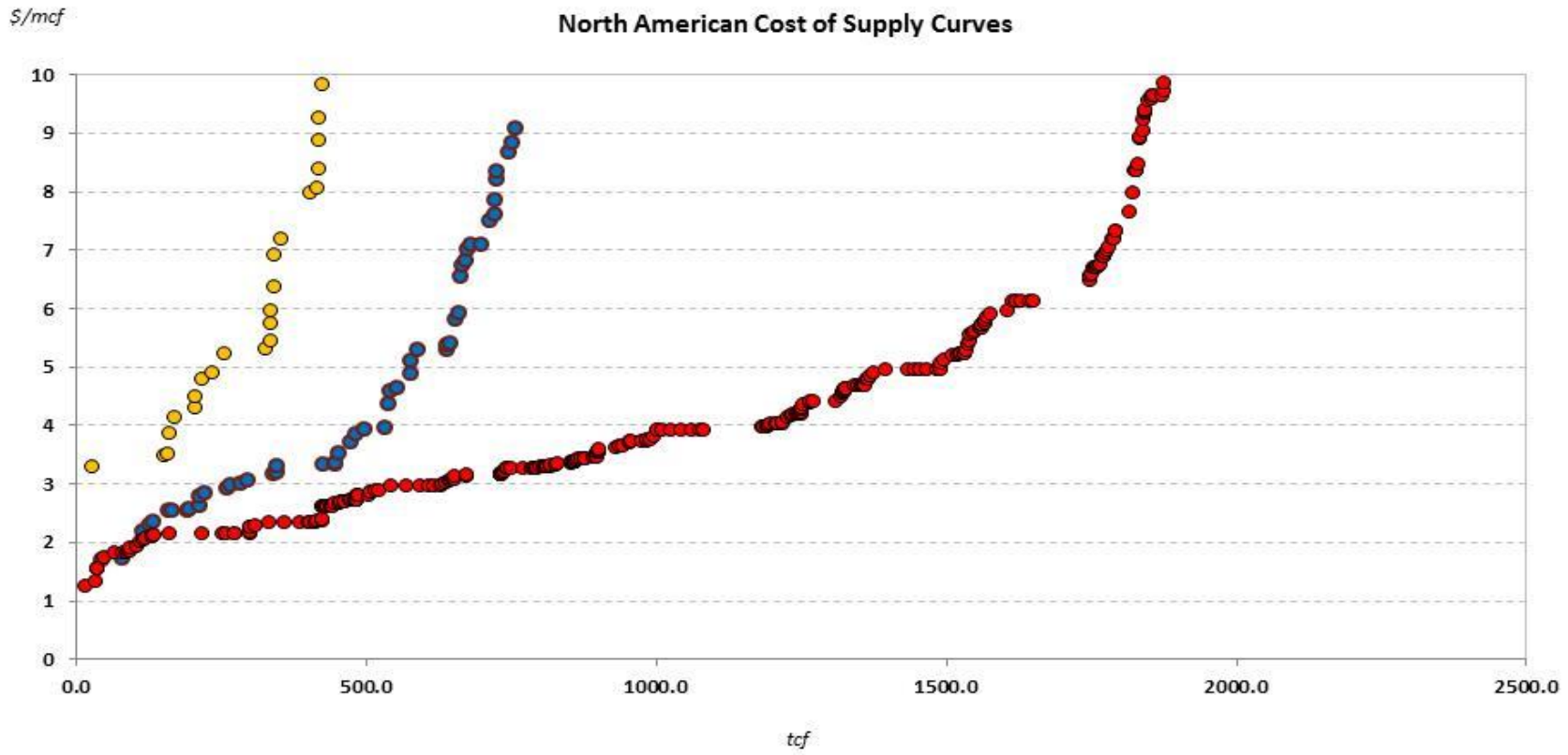


Sources: Data from GIIGNL and Analysis by Peter Hartley, "Recent Developments in LNG Markets and Possible Implications for the Future"

North America and the Path Forward

North American Natural Gas Supply

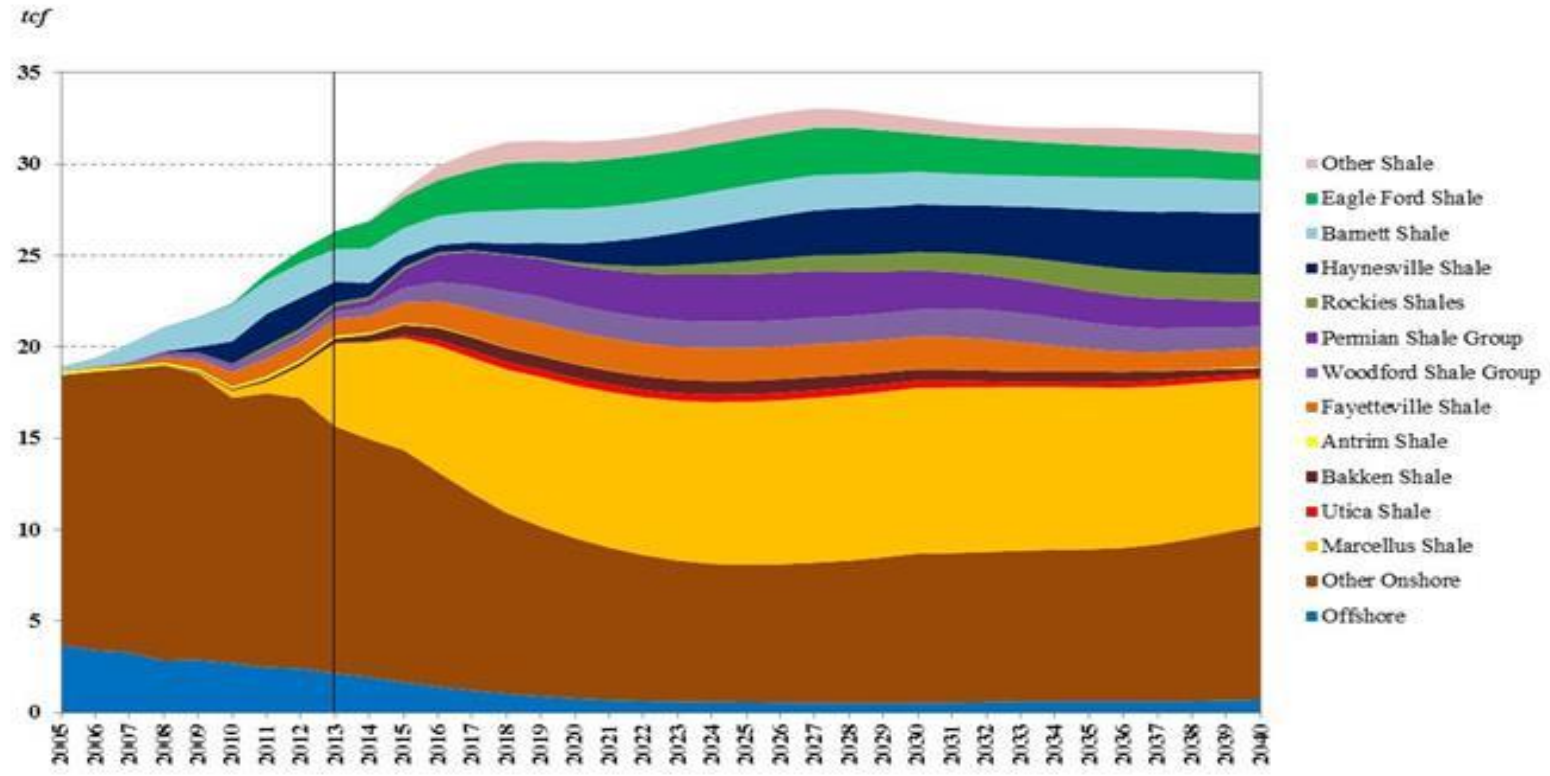
- Including all gas resources, there is about 2,500 tcf available at wellhead prices below $6, and 1,700 tcf at well head prices below $4. So, North America is likely to be a driver of global gas market developments.



Source: Baker Institute CES Research

US Natural Gas Production*

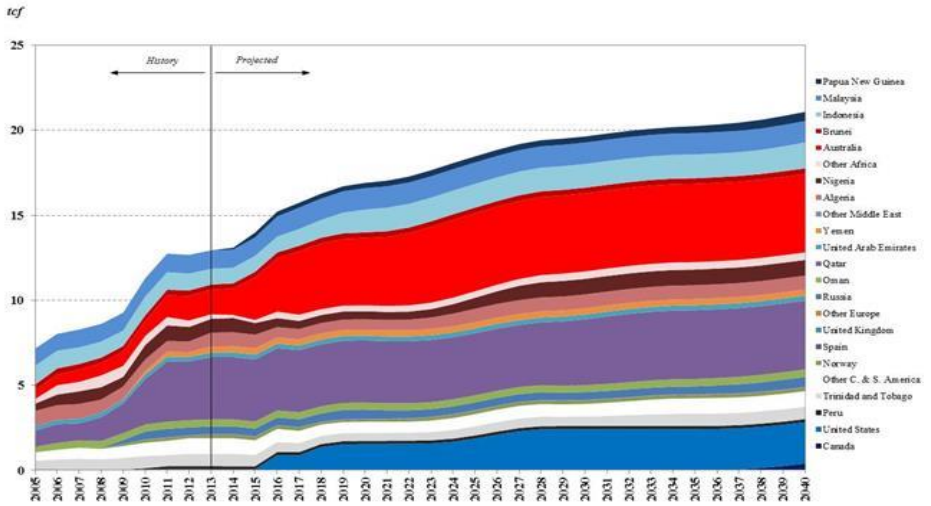
- A shale dominated picture emerges, highlighting a need for infrastructure development as well as opportunities for deeper North American integrations.



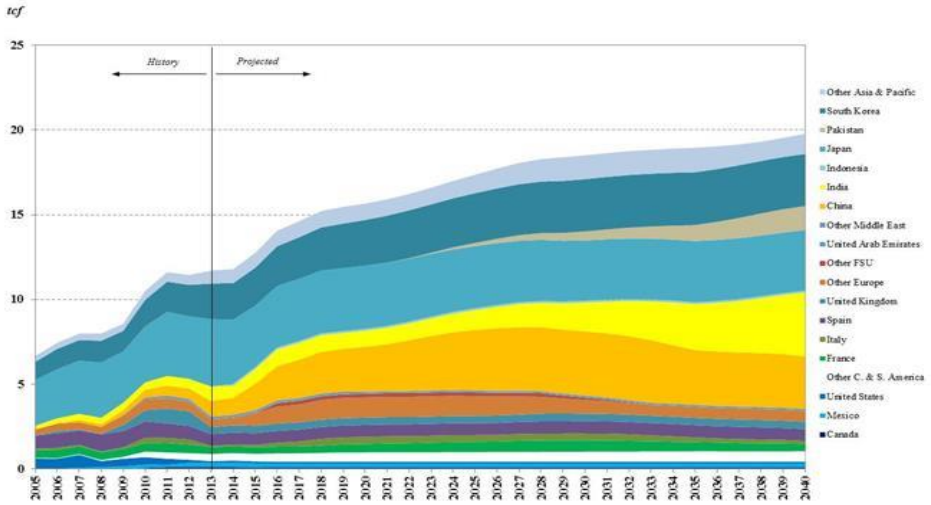
* The results are from the Rice World Gas Trade Model (RWGTM). The RWGTM was developed by Kenneth B Medlock III and Peter Hartley at Rice University using the MarketBuilder software platform provided through a research license with Deloitte MarketPoint, Inc. The architecture of the RWGTM, the data inputs, and modeled political dimensions are distinct to Rice and its researchers. Data depicted are from the recent CES/Oxford study completed for the US DOE, "The Macroeconomic Impacts of Increased US LNG Exports."

LNG Trade*

- LNG exports increase in multiple locations, with the US emerging as the 3rd largest LNG exporter in the world behind Australia and Qatar, and…



- … new consumers enter the market as global demands increase. The market continues to deepen, altering trading paradigms.

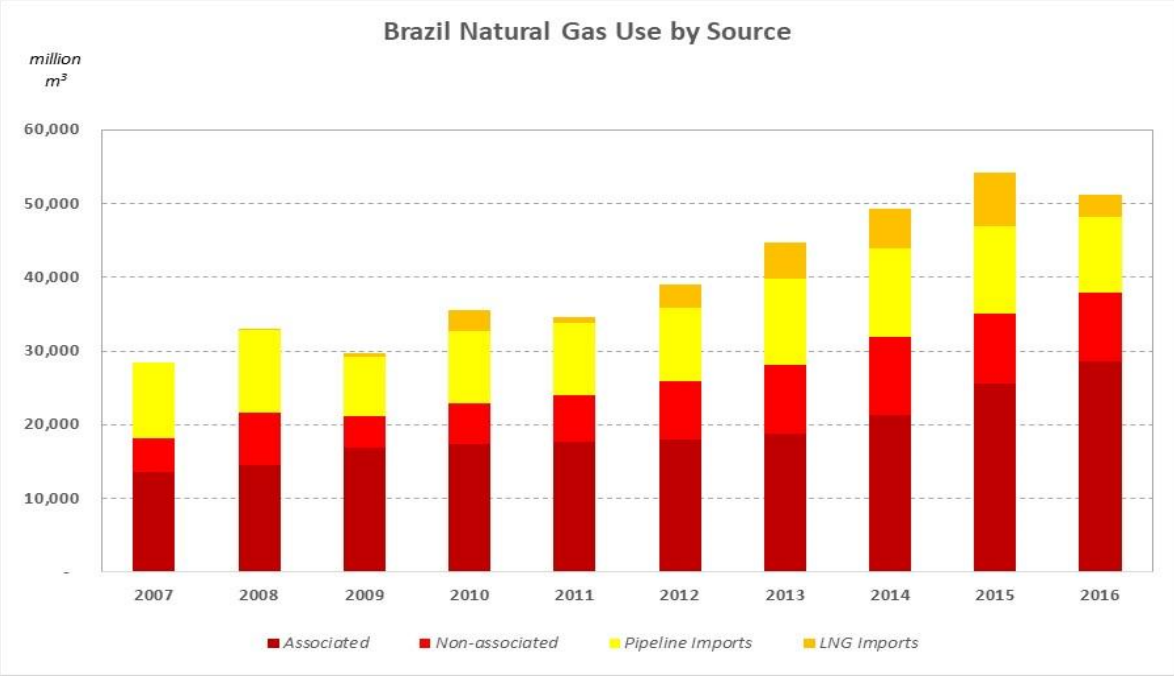


* Data depicted are from the recent CES/Oxford study completed for the US DOE, "The Macroeconomic Impacts of Increased US LNG Exports."

Brazil's Place in It All…

Brazil in the Global Natural Gas Market

- Third largest producer of oil in the Western Hemisphere. As oil production grows, so does associated gas output.
- It's implications for Brazil are significant, and regulatory guidance and market structure will be critical.
- The domestic power sector will be intimately intertwined with natural gas.



Closing Remarks

- Non-OECD nations comprise over 6.2 billion people compared to about 1.3 billion in the OECD. The non-OECD will dictate the future of energy.
- New technologies will play a critical role, but scale-up can be a challenge.
  - Rapid EV diffusion requires infrastructure overhaul, rapid build-up of vehicle production capacity, and assurances of no supply chain constraints.
  - Renewables will capture market share, but they face supply chain challenges, some of which have yet to be realized.
  - When considering the entry of new technology, one cannot forget that price response is dynamic, so no one extreme change can occur without a reaction that re-establishes competitive margins.
  - Energy efficiency play a major role in setting the economic viability of energy sources by establishing the "cost of service" for energy-intensive activities.
- Natural gas is clean and can leverage existing infrastructure and technology.
- Market structure is its largest hurdle. Brazil, given its size in South America, could define the path forward for the entire region.
- "Frontier" resources will have significant bearing on markets for 20+ years.

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