Shale Gas and LNG - Effects on Global Markets

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THE ROLE OF NATURAL GAS IN THE FUTURE ENERGY SYSTEM

THE NEED FOR FLEXIBILITY

NTNU ENERGY TRANSITION WORKSHOP

NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY

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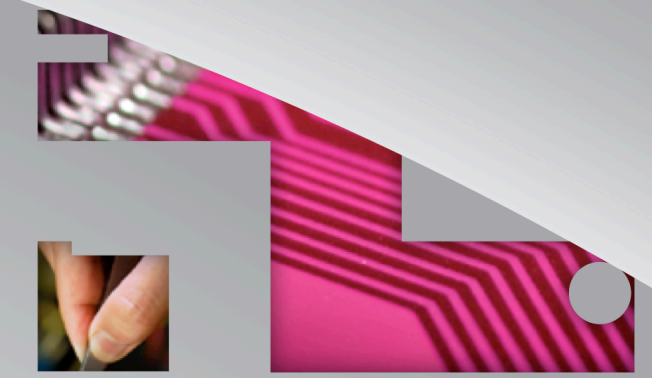

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Outline

1. Global Natural Gas Markets
    1. Consumption, Production Forecasts
    2. LNG and Shale Gas Aspects
2. Prospects for Flexibility and Research Topics

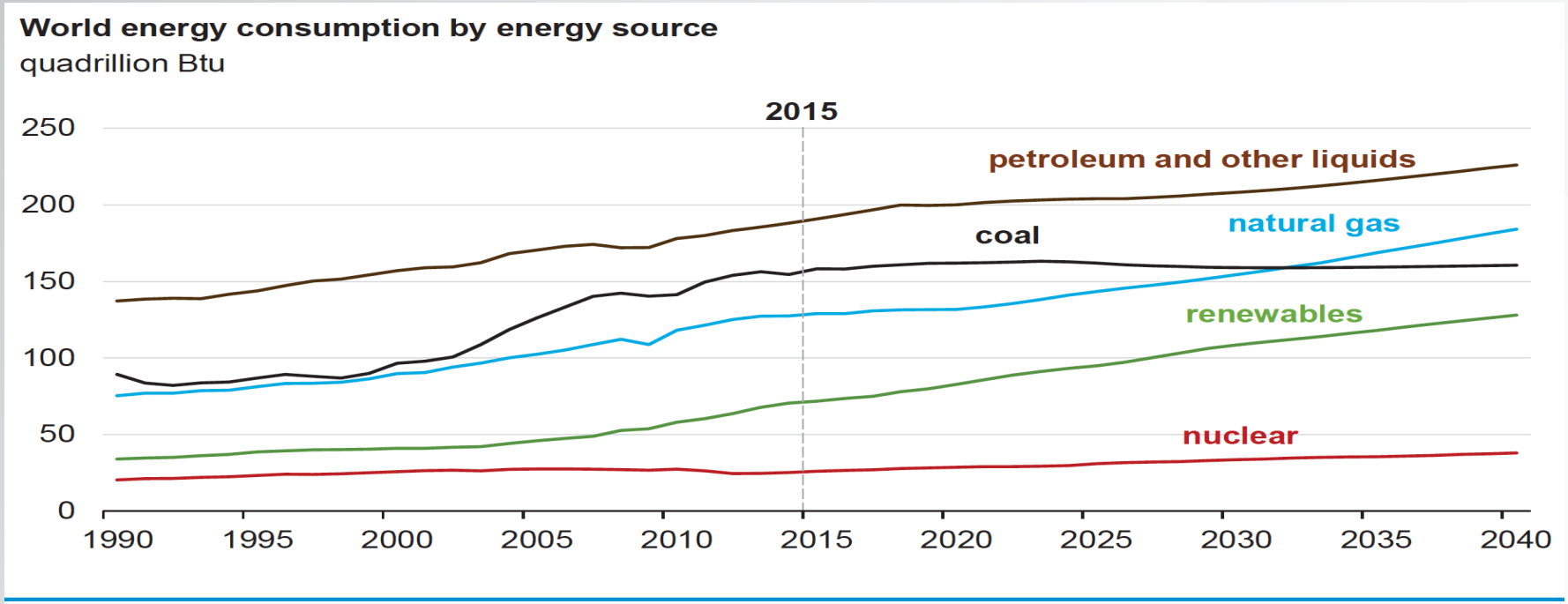
Main Sources

- *World Energy Outlook 2017* (WEO2017), International Energy Agency (IEA)
- *International Energy Outlook 2017* (IEO2017), U.S. Department of Energy, Energy Information Administration (EIA)
- Resources for the Future, Washington, DC

Global Gas Consumption

Energy Consumption Forecasts (IEO2017)

- The demand for all fuels except coal are predicted to grow (Reference case) through 2040
- Natural gas: the fastest growing fossil fuel, increasing by 1.4%/year
- Demand for gas surpassing coal between 2030 and 2035

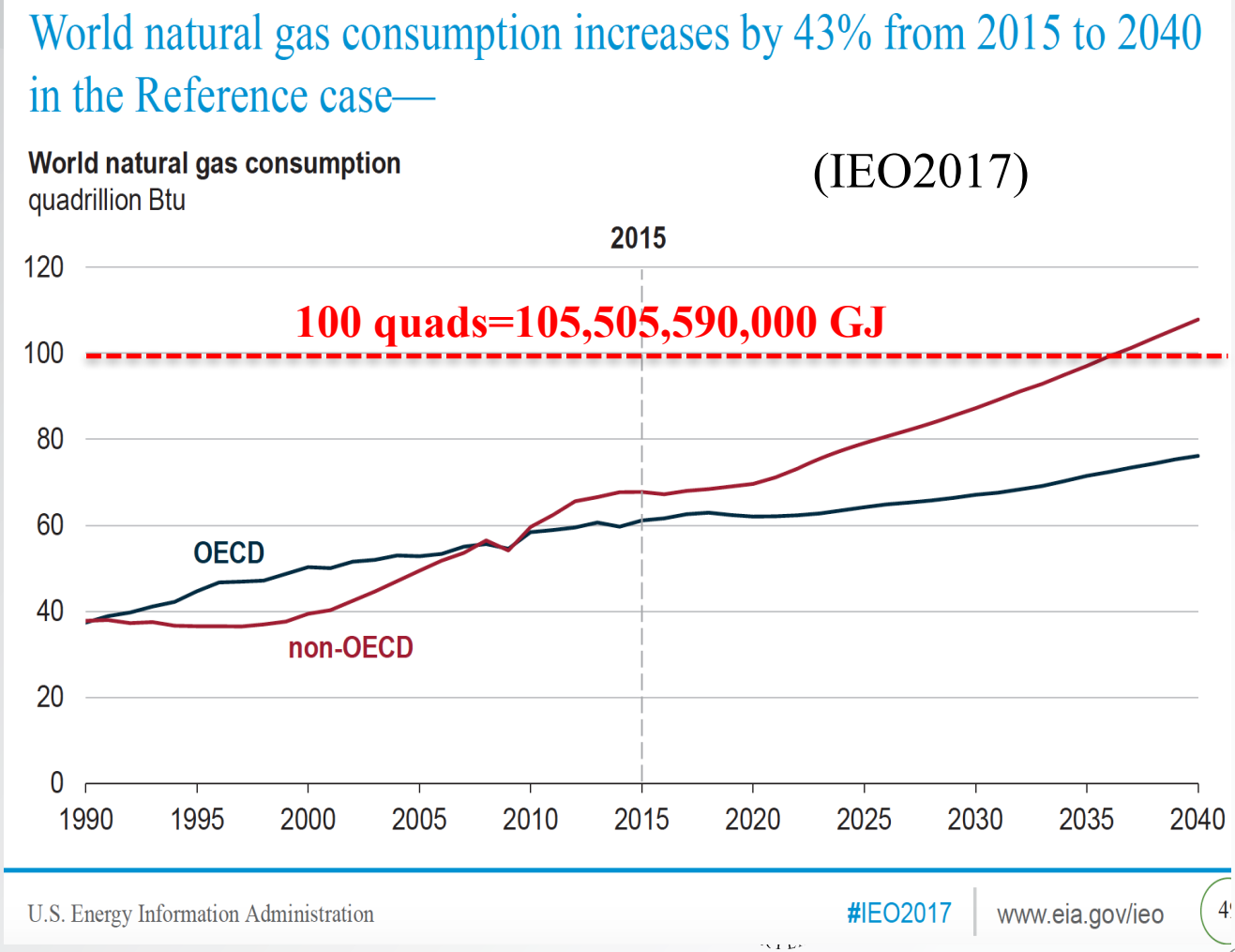


Major Predictions for Global Gas Markets (WEO2017)

- Different from the past 25 years worldwide energy needs to be met by (in New Policies Scenario):
  - Natural gas (cleanest fossil fuel, thermal back-up for renewables, etc.), needs to minimize methane leaks though
  - Renewables (40% of total power generation by 2040)
  - Energy efficiency

Large Consumption Increases for Natural Gas

- Natural gas use increases by 45% to 2040 (some in power sector, largest in industrial sector) (WEO2017)
- Natural gas to account for a quarter of global energy demand by 2040 (New Policies Scenario) (WEO2017)



Major Predictions for Global Gas Markets (WEO2017)

- Vast majority of this growth in gas demand (80%) to be in developing economies (e.g., China and India)
- A lot of this gas in developing countries needs to be imported
- Transportation costs are significant, role of LNG important
- Gas transportation infrastructure (e.g., pipelines, LNG) not often in place yet– room for flexibility in building the right amount of infrastructure and where to put it
- Gas has to compete with coal, renewables for investments and in some countries
- Renewables cheaper than gas by the mid 2020's

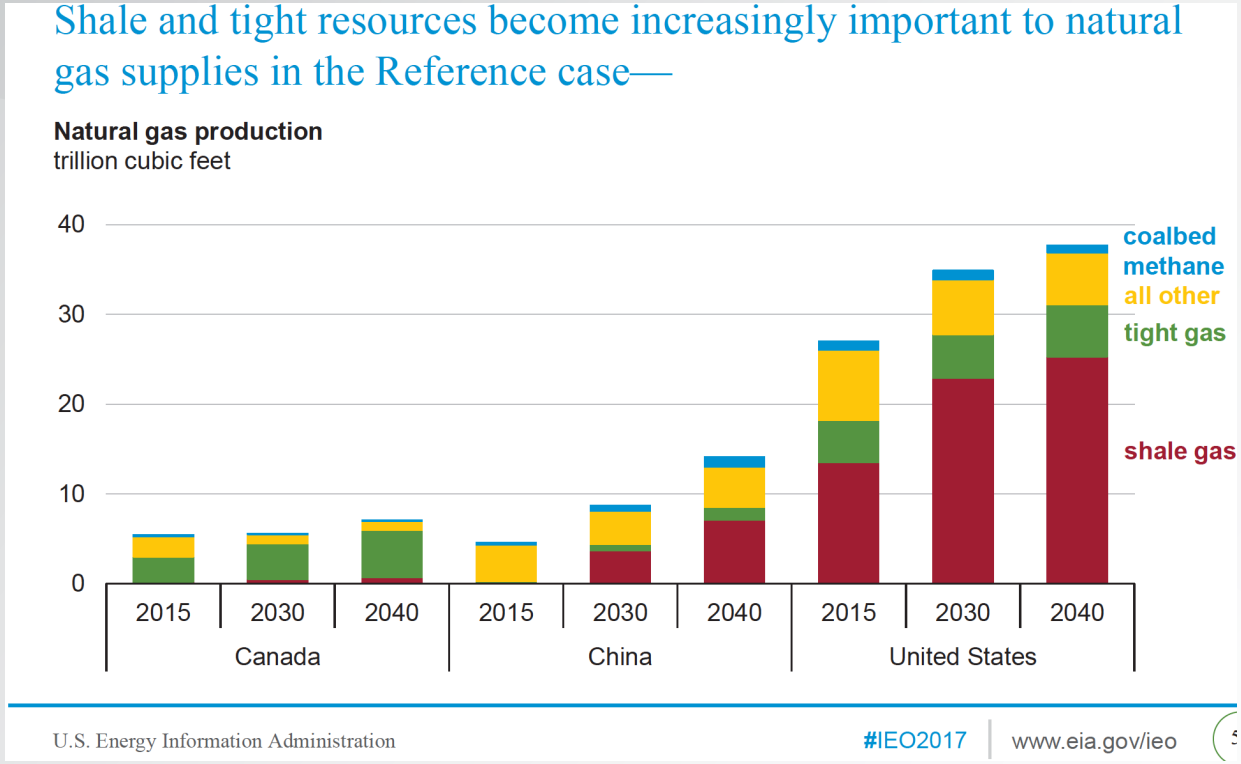
Gas Production and Shale Gas

Gas Production (IEO 2017)

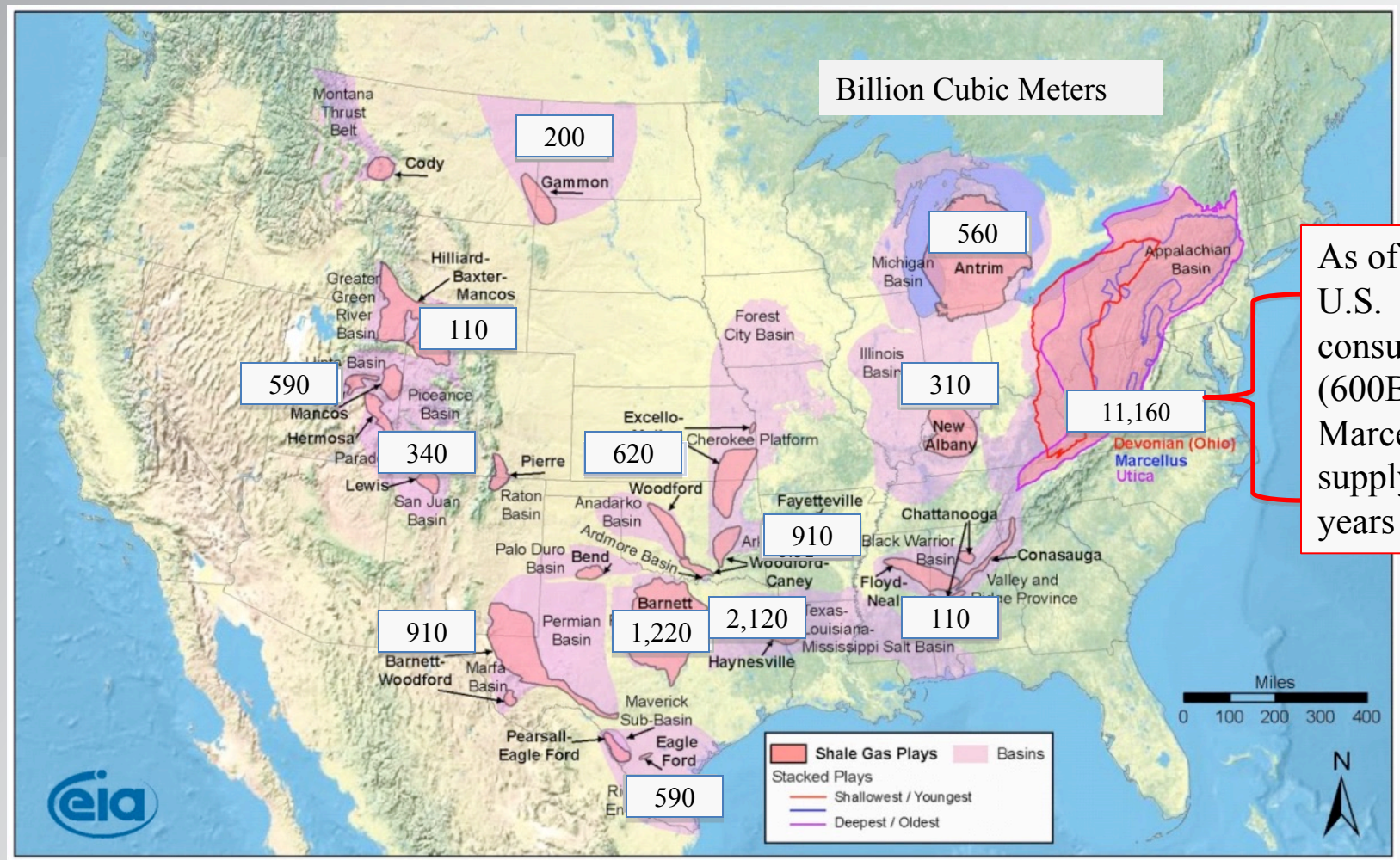
- Largest gas production increases (Reference case) 2015-2040 happen in:
    - The Middle East (about 340 BCM)
    - United States (about 311 BCM)
    - China (about 270 BCM)
- For the U.S. and China, these increases to mainly come from development of shale resources
- Russia projected to have an increase of natural gas production of about 140 BCM, supported by increased development of production from their Arctic and Eastern regions

Importance of Shale Gas Production: U.S., China, Canada (IEO 2017)

- Shale resource development for the U.S. 50% of gas production (2015) rising to almost 70% in 2040
- For China: 50% of gas production by 2040
- For Canada: future natural gas production projected from tight resources (British Columbia and Alberta)



US Shale Gas Plays, Lower 48 States



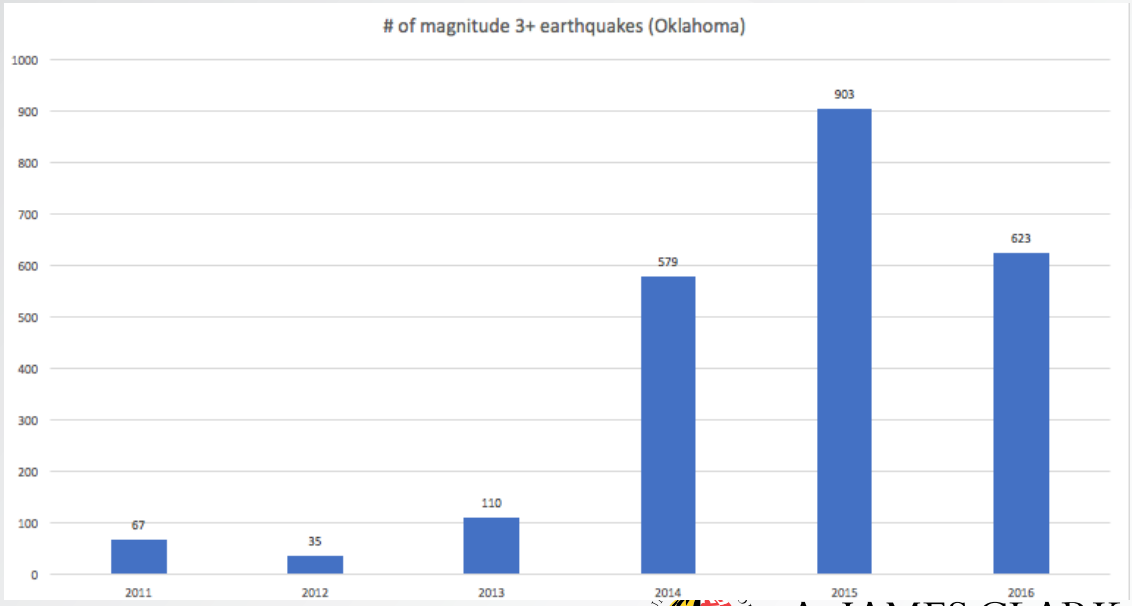
Source: Energy Information Administration based on data from various published studies
Updated: May 28, 2009

As of 2010 U.S. consumption (600BCM*), Marcellus can supply for 20 years

*BP Statistical Review, 2011

Earthquakes from Wells? Summary

- "The Oklahoma Geological Survey has determined that the majority of recent earthquakes in central and north-central Oklahoma are very likely triggered by the injection of produced water in disposal wells."
- Magnitude 3+ Earthquakes
  - 2016: 623
  - 2015: 903
  - 2014: 579
  - 2013: 110
  - 2012: 35
  - 2011: 67
  - 2010: 41



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https://earthquakes.ok.gov/what-we-know/

Daniel Raimi, Resources for the Future

(http://www.rff.org/blog/2018/facts-fracking-podcast-daniel-raimi)

The Fracking Debate (book)

- Is shale gas good or bad? It is both. Boom-and-bust aspects
- Substantial economic benefits but water contamination
- Lots of documented cases with oil and gas shale fracking , only one or two cases with contamination (defect in equipment)
- Pollution occurs, but fairly rarely
- Water contamination, in Pennsylvania, shale wells
  - Before 2010: roughly 1% of wells drilled
  - After 2010 (2014): 0.23%, (2015): 0%
- U.S. National/international level: Saved lots of money
- Regional level: 271 new jobs in Ellis County, Oklahoma (rural county) 258 were oil and gas, rather have an economic boom than nothing
- Boom (in rural areas), influx of industry people (+/-), e.g., 2014 most expensive rental housing market in the U.S. was Williston, North Dakota

Daniel Raimi, Resources for the Future

(http://www.rff.org/blog/2018/facts-fracking-podcast-daniel-raimi)

The Fracking Debate (book)

- Natural gas: transition from coal to natural gas, U.S. coal share dropped considerably and natural gas increased, in 2016 CO2 emissions (power sector) were at 1989 levels (25% below peak at 2007)
- Methane emissions: are not large enough to remove the GHG benefit of gas vs. coal
- If > 4% of natural gas from the U.S. emitted as methane (not burned), climate benefits go away after 20 years
- Still some uncertainty but many in-depth studies/evidence suggest leakage rages 1.5 to 3.0 %
- Policy implications:
  - Low-cost gas supply not so helpful in the long-term though, low-cost gas competes with renewables, nuclear, etc.
  - Over 20 years the GHG advantage may be a wash
  - Interesting research opportunities to see worldwide benefit of shale gas

Liquefied Natural Gas (LNG)

Major Predictions for Worldwide LNG Trade (IEO2017)

- Projected to triple from about 340 BCM to about 878 BCM between 2015 and 2040
- Nevertheless, pipeline flows to account for 48% of interregional gas flows in 2040 (further pipeline infrastructure development)
- Europe: remain largely dependent on Russian pipeline gas
- Asia: projected to important lots of traded LNG
- North America: major exporter of natural gas by 2020

Flexibility in Gas Markets (WEO2017-IEA)

- U.S. LNG speeds up a move towards a more flexible, liquid global market
- Price formation: competition-based rather than indexed to oil
- Destination flexibility, hub-based pricing, spot markets, U.S. LNG key
- Research areas: impact of changing contract indexation, hub-based pricing, role of U.S. LNG
- Flexibility in LNG important to compensate for reduced options elsewhere (e.g., lower fuel-switching in some places due to drop in coal-fired generation)
- Research areas: Also, could we use gas pipelines for hydrogen transport, benefits of doing this especially to the transportation sector? (see Katrina Groth's talk)

Market Liberalization in Key Countries/LNG Markets Much More Active (WEO2017-IEA)

- Market liberalization in Japan and other Asian countries
- Rise of portfolio players (large companies with a variety of supply assets)
- LNG-importing countries 15 (in 2005) 40 (today)
- Number of liquefaction sites worldwide doubles to 2040
    - Biggest ones: United States, Australia
    - Smaller ones: Russia, Qatar, Mozambique, Canada

Large Role in Global Gas Markets/LNG for United States (WEO2017-IEA)

- U.S. becomes the biggest oil and gas producer worldwide even at lower prices due to shale gas and tight oil
- U.S. oil and gas output jumps to a level 50% higher than ”any country has ever managed”
- U.S. already a net exporter of natural gas, in late 2020’s becomes a net exporter of oil
- By mid 2020’s, U.S. becomes the world’s largest LNG exporter
- Large share of gas-fired power generation through to 2040 (even without U.S. policy to phase out/slow down coal)
- LNG has a huge role in long-distance gas trade to 2040 (90%), is more flexible than pipelines
- Some exceptions: route between Russia and China

U.S. LNG Export Status as of March 1, 2017
Total of All Applications Received

	Total (per day)	Total (per year)
FTA application	54.72 Bcf/day or 1.54 BCM/day	19.97 Tcf/year or 565 BCM/year
Non-FTA application	51.13 Bcf/day or 1.45 BCM/day	18.74 Tcf/year or 530 BCM/year

FTA with the U.S. requires national treatment for trade in natural gas, including Australia, Bahrain, Canada, Chile, Colombia, Dominican Republic, El Salvador, Guatemala, Honduras, Jordan, Mexico, Morocco, Nicaragua, Oman, Peru, Republic of Korea and Singapore

Source: https://energy.gov/sites/prod/files/2017/03/f34/Summary%20of%20LNG%20Export%20Applications.pdf

China and India, Huge Drivers of Energy Infrastructure Investment (WEO2017-IEA)

By 2040 China:

- Add today's equivalent of U.S. power system infrastructure
- Per-capita energy consumption > European Union
- Energy policy emphasis on: natural gas, cleaner, high-efficiency and digital technologies
- Responsible for quarter of projected increase in global gas demand (projected imports of 280 BCM second to EU), very important for global gas trade

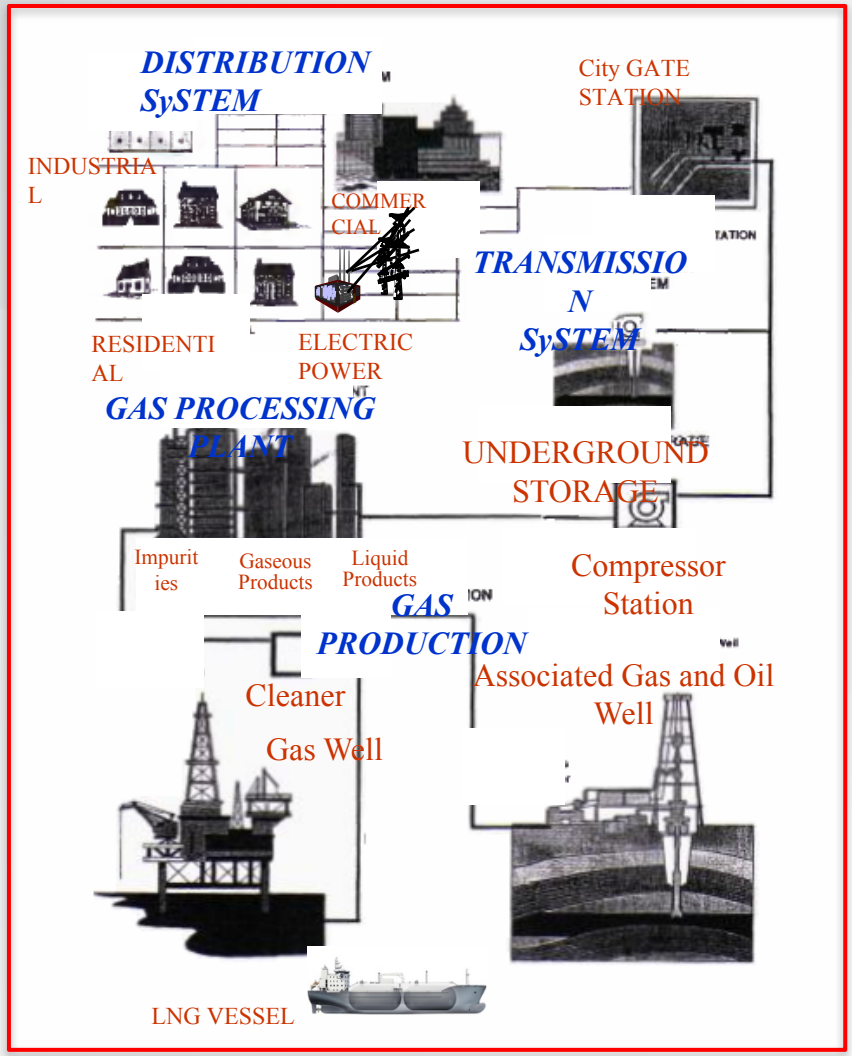
By 2040 India:

- Add today's equivalent of European Union power system infrastructure by 2040

The World Gas Model

- Production/Consumption Nodes: 41 (Groups of countries, countries, regions)
- Covers over 95% of worldwide consumption
- 10 periods: 2005-2050, calibration year 2010
- Typical decision variables
  - Operating levels (e.g., production, storage injection)
  - Investment levels (e.g., pipeline, liquefaction capacity)
- Other
  - Market power aspects (traders)
  - LNG contracts database
  - Seasonality of demand: low and high demand
  - Environmental policy consideration: Carbon costs for supply chains
- Computational aspects
  - Large-scale complementarity problem (KKT optimality conditions for all players + market-clearing conditions)
  - ~78,000 vars. Solves in ~240 mins (8GB, 3.0 GHz)
  - MCPs are examples of non-convex problems (via the complementarity constraints)
  - Improved WGM, S. Moryadee Ph.D. thesis 2015

Natural gas supply chain



The World Gas Model (WGM)
(S. Moryadee, S.A. Gabriel, 2015)

Market players with separate optimization problems	**Aspects of Current World Gas Model (University of Maryland)**	Producers Traders Pipeline operator Storage operator Marketers Liquefier Regasifiers LNG shipping operator Canal operators
LNG shipping cost		Endogenous
Investment for producers		Endogenous
Investment for LNG tanker		Yes
Limitation on LNG shipping		Constraint on LNG Shipping operator
LNG routes		Flexible up to 3 routes
Number of variables		~ 110,000 vars

Selected Research Questions

For the energy transition, given the move towards more intermittent renewables such as wind, solar with a strong reliance on relatively clean natural gas as a thermal back-up:

1. How to measure the value of flexibility (LNG vs. pipeline gas) and compare with other costs of the energy transition programme?
2. Can gas pipelines be used to carry hydrogen and then shift to LNG to achieve further emissions improvements in the transportation and other sectors?
3. Counter-factual analysis of how the gas industry flows, investments will change given competitive rather than oil-indexed contracts?
4. How will the environmental negative externalities (e.g., induced earthquakes, clean water) of shale gas be overcome in a socially and economically beneficial way?
5. Should natural gas from other, non-traditional less disruptive sources also be considered? (e.g., gas from wastewater, waste in general) and what would the effects be on the food-energy-water nexus?