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The Impact of Shale Gas Development on the Geopolitical and Macroeconomic Landscape

Rice Energy Finance Summit

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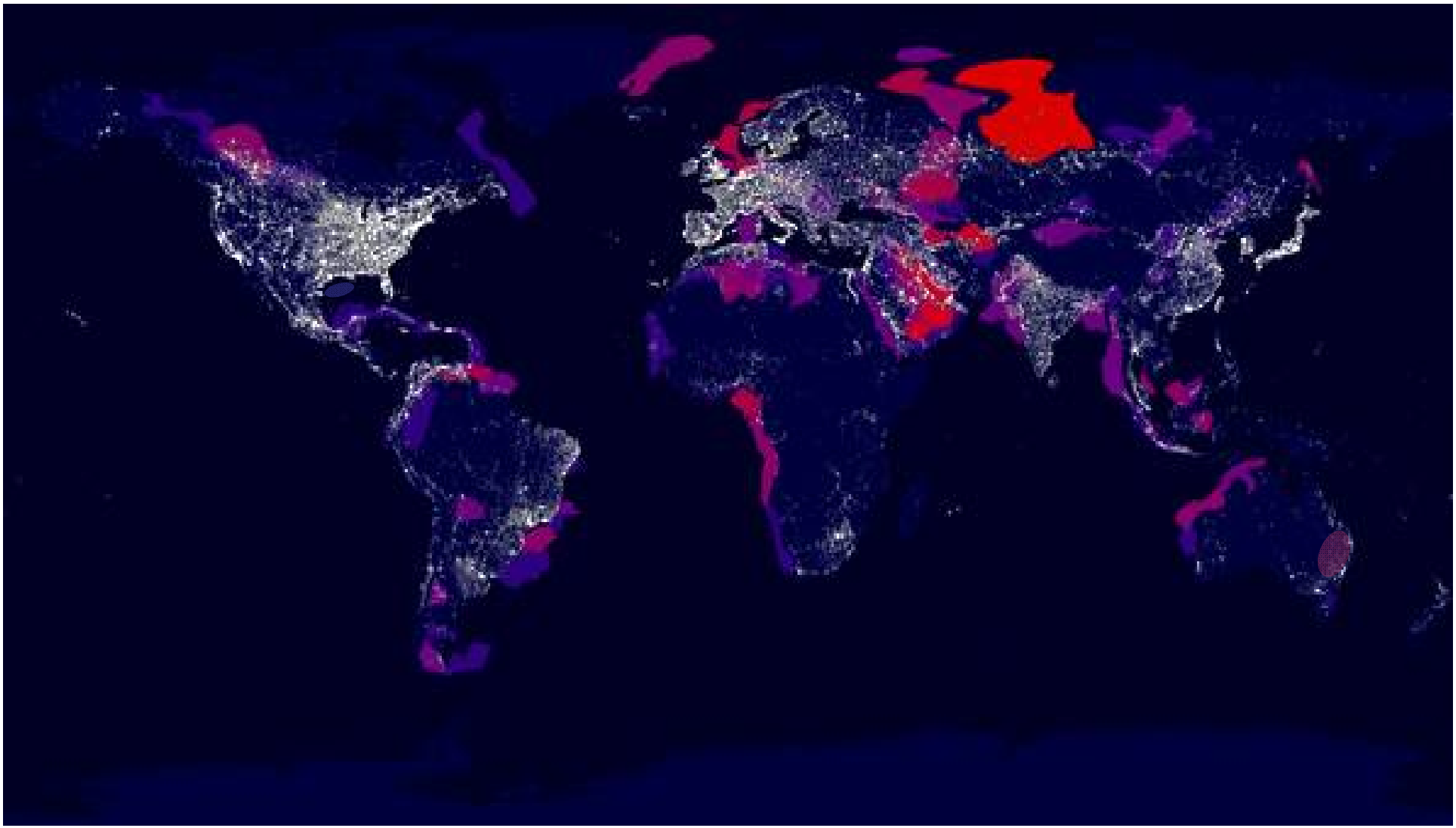
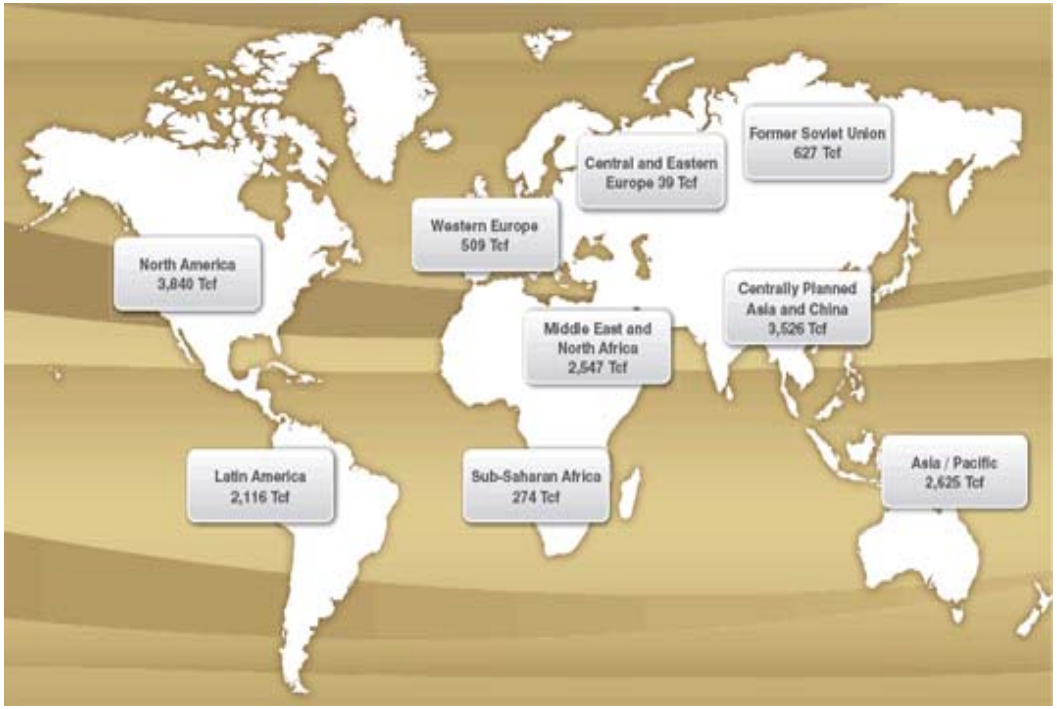
What has the “shale revolution” meant?

The "50,000 Foot" Natural Gas View in 2000: LNG is coming to North America



The Global Shale Gas Resource

- Knowledge of the shale resource is not new
  - Rogner (1997) estimated over 16,000 tcf of shale gas resource in-place globally
  - Only a very small fraction (<10%) of this was deemed to be technically recoverable and even less so economically.



Region	Resource In-Place (tcf)	Resource In-Place (tcm)
North America	3,842	109
Latin America	2,117	60
Europe	549	15
Former USSR	627	18
China and India	3,528	100
Australasia	2,313	66
MENA	2,548	72
Other	588	17
Total	**16,112**	**457**

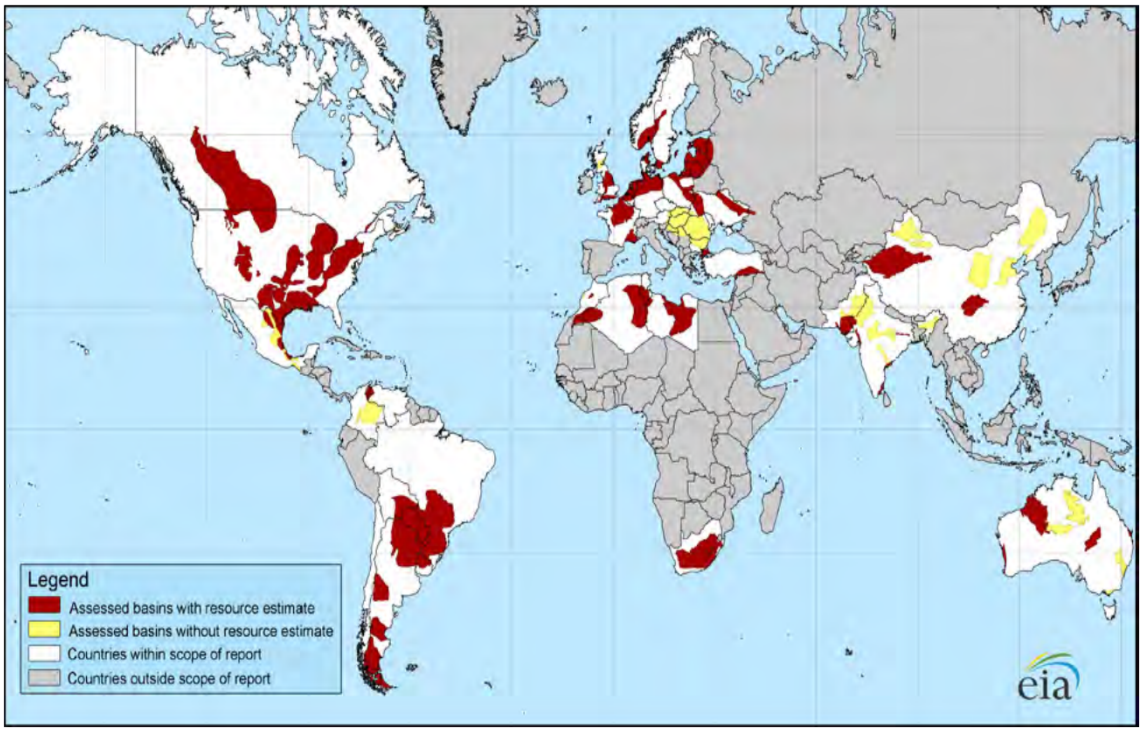
Source: Rogner (1997)

The Global Shale Gas Resource (cont.)

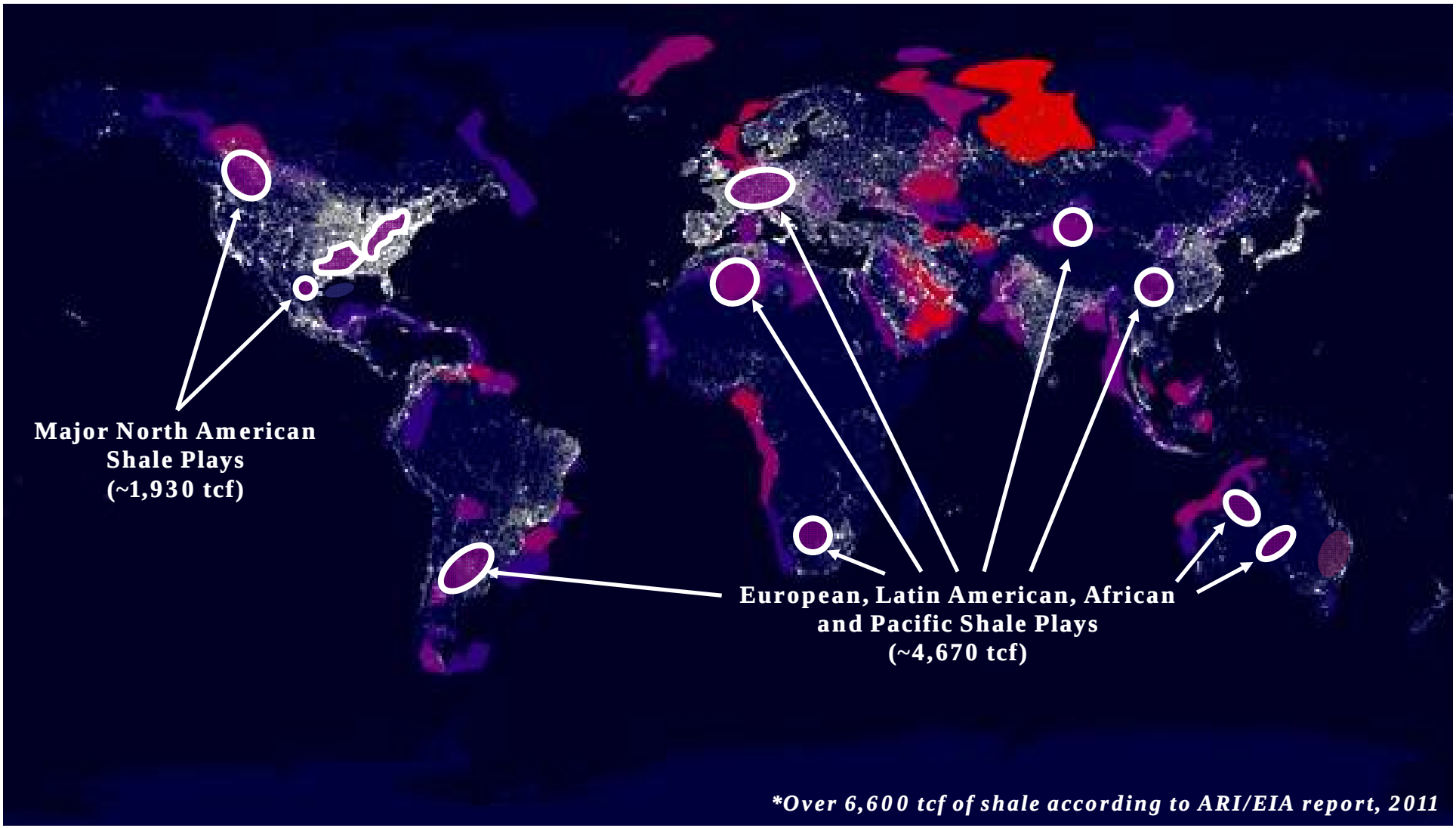
- Recently, however, innovations made the shale resource accessible
  - Shale developments have been focused largely in North America where high prices have encouraged cost-reducing innovations.
  - IEA recently estimated about 40% of the estimates resource in-place by Rogner (1997) will ultimately be technically recoverable.
  - A very recent assessment by Advanced Resources International (2011) assesses a larger resource in-place, and estimates a total technically recoverable resource of 6,600 tcf.

Region	Technically Recoverable Resource (tcf)
North America	1,931
Latin America	1,225
Europe	639
Former USSR	---
China and India	1,338
Australasia	396
Africa	1,043
Middle East	---
Other	51
Total	**6,622**

Source: ARI/EIA (2011)



The "50,000 Foot" Natural Gas View in 2011: Over 6,600 tcf of technically recoverable shale*



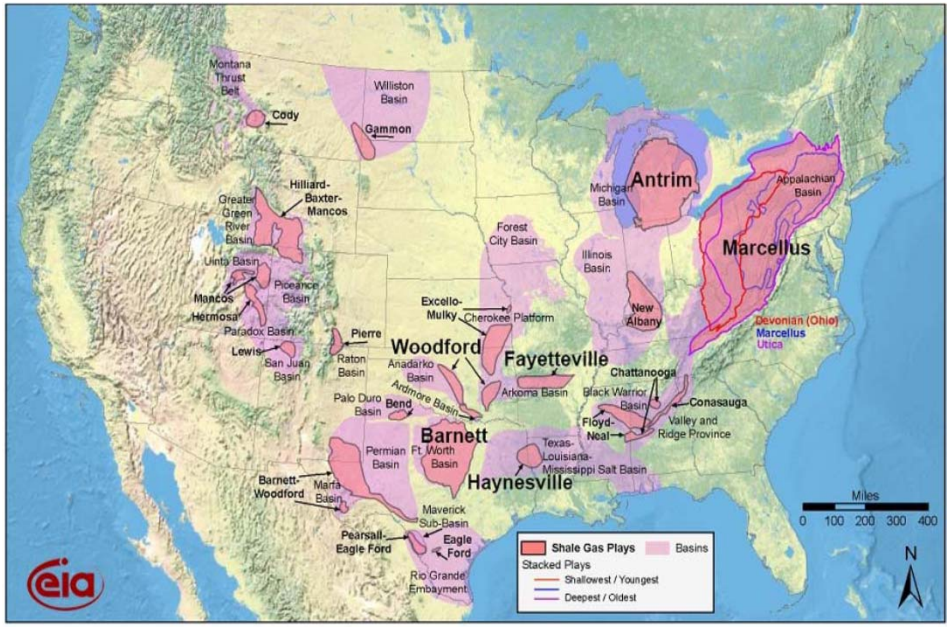
*Over 6,600 tcf of shale according to ARI/EIA report, 2011

Shale in The United States: An Evolving State of Knowledge

- In 2003, the NPC used an assessment of 38 tcf of technically recoverable shale gas in its study of the North American gas market.
- In 2005, most estimates placed the resource at about 140 tcf.
- Recent estimates are much higher
  - (2008) Navigant Consulting, Inc. estimated a "mean" of about 280 tcf.
    - Survey of producers yielded 840 tcf with the majority of the additional resource in the Marcellus and Haynesville shales.
  - (2009) Estimate from Potential Gas Committee (PGC) over 680 tcf.
  - (2011) ARI estimate of over 900 tcf.
- Resource assessment is large. Our work at BIPP indicates a technically recoverable resource of 637 tcf.
- Point: We learn more as time passes!

US Shale in the Rice World Gas Trade Model (RWGTM)

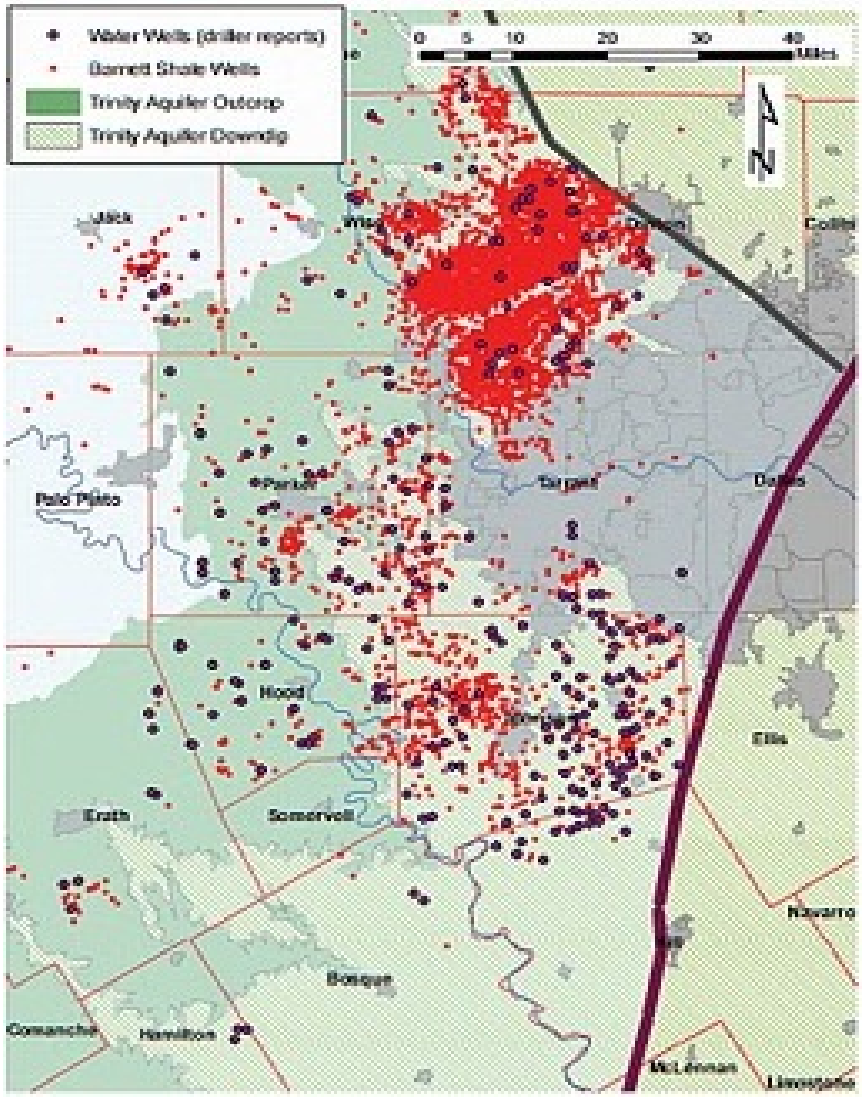
- As knowledge continues to advance, more shale plays may become commercial targets and greater proportions of shale resources may become technically feasible.
- Developers benefit from "learning by doing"... Barnett is a good case in point.



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

	Mean Technically Recoverable Resource (tcf)	Breakeven Price
Antrim	13.2	$ 5.50
Devonian/Ohio	220.4	
Utica	5.4	$ 6.25
Marcellus	185.0	
Marcellus Tier 1	46.3	$ 4.00
Marcellus Tier 2	64.8	$ 5.25
Marcellus Tier 3	74.0	$ 6.50
NW Ohio	2.7	$ 6.75
Devonian Siltstone and Shale	1.3	$ 6.75
Catskill Sandstones	11.7	$ 6.75
Berea Sandstones	6.8	$ 6.75
Big Sandy	6.3	$ 6.00
Nora/Haysi	1.2	$ 6.25
New Albany	3.8	$ 7.00
Floyd/Chatanooga	4.3	$ 6.00
Haynesville	160.0	
Haynesville Tier 1	32.0	$ 4.00
Haynesville Tier 2	56.0	$ 5.00
Haynesville Tier 3	72.0	$ 6.25
Fayetteville	36.0	$ 4.25
Woodford Arkoma	8.0	$ 4.50
Woodford Ardmore	4.2	$ 5.75
Barnett	58.0	
Barnett Tier 1	30.0	$ 4.00
Barnett Tier 2	28.0	$ 5.50
Barnett and Woodford	35.4	$ 6.50
Eagle Ford	42.0	$ -
Eagle Ford Tier 1	22.0	$ 3.75
Eagle Ford Tier 2	20.0	$ 5.25
Palo Duro	4.7	$ 6.25
Lewis	10.2	$ 6.25
Bakken	1.8	$ 4.50
Niobrara	1.3	$ 6.50
Hilliard/Baxter/Mancos	11.8	$ 6.50
Paradox/Uinta	13.5	$ 6.50
Mowry	8.5	$ 6.50
Total US Shale	637.0	

US Shale in the RWGTM (cont.)



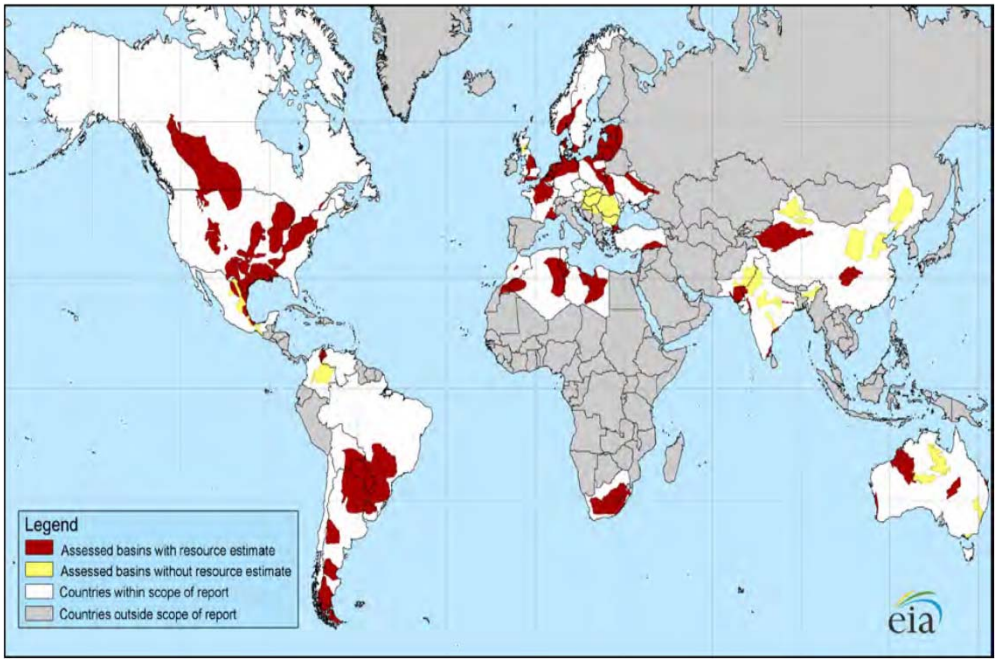
- The "learning-by-doing" experience in the Barnett shale is a barometer.
  - Over 16,000 wells drilled to date.
    - Over 12,000 horizontal wells
  - Operator efficiency has dramatically improved in the last 3 years.
    - Rig counts have fallen from 192/wk in Sept. 2008 to 64/wk in Sept. 2011, but...
    - Production was higher in Sept. 2011 than in Sept. 2008.
  - 80 acre spacing being reduced to 40, and some operators are now testing 20 acre spacing.

Rest of World (RoW) Shale: Little Data and Lots of Uncertainty

- There is uncertainty about shale resources outside of North America.
- The estimates of resource in-place are very large, and location is a premium in many instances.
- However, accessibility is critical. Not only do cost and technology matter, but market structure and government policy is equally as important.
  - Arguably, if the current market structure in the United States did not exist, the shale gas boom would not have occurred. This is due to the fact that the small producers who initiated the proof of concept had little to no risk of accessing markets from very small production projects. A market in which capacity rights are not unbundled from facility ownership does not foster entry by small producers.

RoW Shale in the RWGTM

- As knowledge continues to advance, more shale plays may become commercial targets.
- The RWGTM *currently* only allows 800 tcf of recoverable resource outside the U.S., meaning we allow only a fraction of the recent ARI technical assessment to be commercial.



		Mean Technically Recoverable Resource (tcf)	Breakeven Price
CANADA	Horn River	90.0	
	Horn River Tier 1	50.0	$ 4.50
	Horn River Tier 2	40.0	$ 5.25
	Montney	65.0	
	Montney Tier 1	25.0	$ 4.75
	Montney Tier 2	40.0	$ 5.50
	Utica	10.0	$ 6.50
MEXICO	Burgos Basin	90.0	
	Burgos Tier 1	20.0	$ 5.75
	Burgos Tier 2	30.0	$ 6.75
	Burgos Tier 3	40.0	$ 8.00
	Sabinas Basin	20.0	$ 7.25
	Tampico Basin	25.0	$ 7.00
EUROPE	Austria	40.0	$ 6.25
	Germany	30.0	$ 6.25
	Poland	120.0	
	Silurian Tier 1	45.0	$ 6.00
	Silurian Tier 2	75.0	$ 7.25
	Sweden	30.0	$ 6.50
PACIFIC	China	230.0	
	Sichuan/Jianghan	45.0	$ 6.50
	Ordos	35.0	$ 5.75
	Tarim/Junggar/Tuja	120.0	$ 7.25
	Songliao	30.0	$ 6.00
	Australia	50.0	$ 4.50
	Total non-U.S.	800.0	

A Paradigm Shift

The view of natural gas has changed dramatically in only 10 years. Most predictions were for a dramatic increase in LNG imports to North America and Europe. Today, growth opportunities for LNG developers are seen in primarily in Asia.

Geopolitical Repercussions of Expanded U.S. Shale Gas Production

- "Shale Gas and US National Security" – Baker Institute study sponsored by the US Department of Energy Office of International Policy and Affairs
- U.S. shale gas output has turned expectations upside down in less than a decade. Rapid growth in shale gas production…
  - virtually eliminates U.S. LNG imports for at least two decades
  - substantially reduces Russia's market share in Europe from 27 percent in 2009 to 13 percent by 2040, reducing the chances that Moscow can use energy as a tool for political gain
  - reduces the future share of world gas supply from Russia, Iran, and Venezuela; without shale discoveries, these nations would have accounted for about 33 percent of global gas supply in 2040, but with shale, this is reduced to 24 percent.

Geopolitical Repercussions of Expanded U.S. Shale Gas Production (cont.)

- ... growth in shale gas production...
  - reduces the opportunity for Venezuela to become a major LNG exporter and thereby lowers long-term dependence in the Western Hemisphere and in Europe on Venezuelan LNG
  - reduces competition for LNG supplies from the Middle East, thereby moderating prices and spurring greater use of natural gas, an outcome with significant implications for environmental objectives
  - reduces U.S. and Chinese dependence on Middle East natural gas supplies, lowering the incentives for geopolitical and commercial competition between the two largest consuming countries and providing both countries with new opportunities to further diversify their energy supply
  - limits Iran's ability to tap energy diplomacy as a means to strengthen its regional power or to buttress its nuclear aspirations

Of course, there is uncertainty…

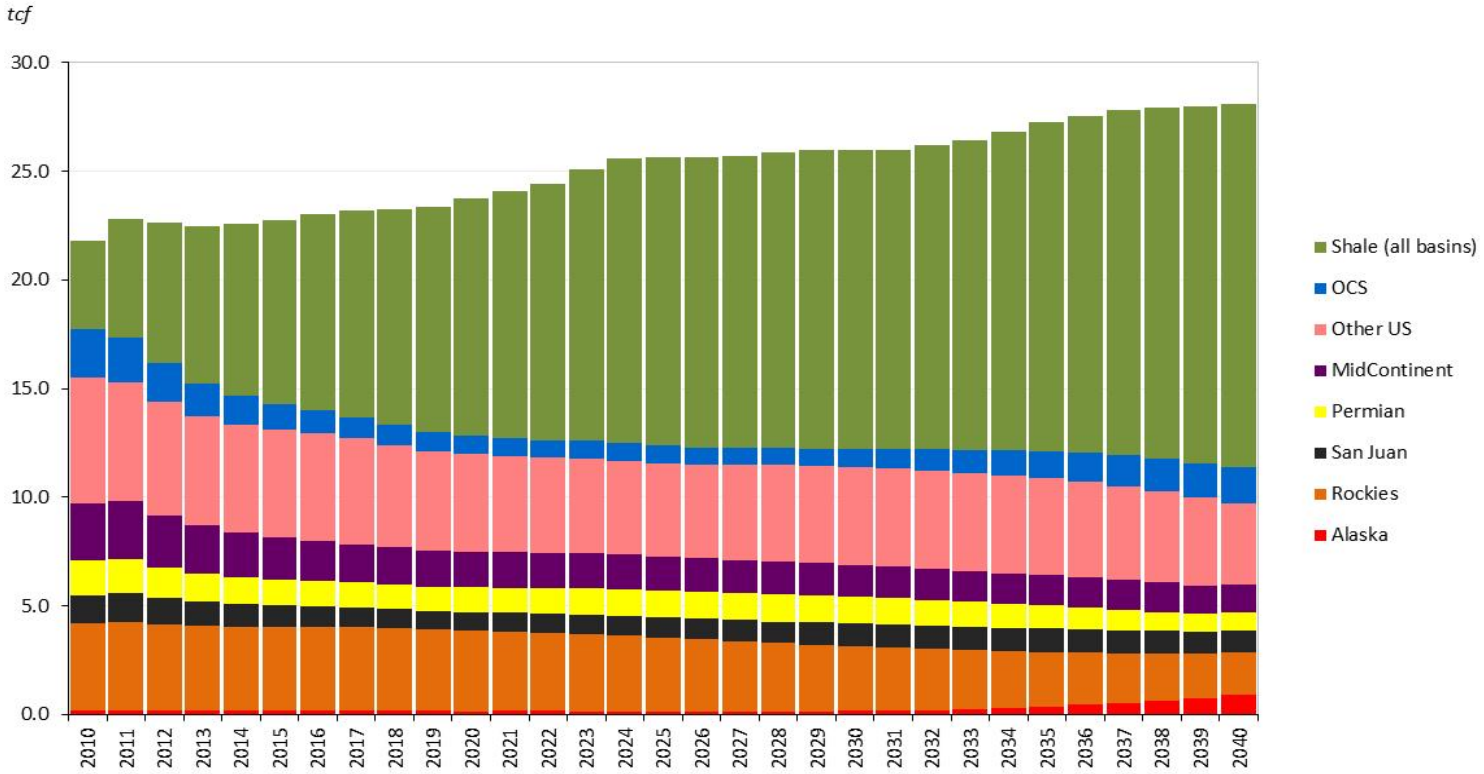
- In general, multiple issues face shale development: some are global, some are not.
  - **Market Structure** – transportation regulatory structure (unbundled access vs. incumbent monopolies); bilateral take-or-pay obligations or marketable rights; existence of gathering and takeaway capacity and hurdles to development; competing resources (RPS, coal, nuclear, etc.); pricing paradigms; etc.
  - **Water** – volume and availability for production; water rights and resource management regulation; flowback options (recycle and/or treatment and disposal) and native infrastructure; concerns about watershed protection during drilling operations (casing failures and fracture migration); etc.
  - **Resource Access** – mineral rights ownership; acreage acquisition; resource assessments; environmental opposition; etc.
  - **Other issues** – earthquakes related to disposal injection of produced water; long term environmental effects of methane (and other gases) escape; concerns about potential chemical and/or radiation contamination from produced water; ecological concerns related to land use and reclamation; etc.

- A stable regulatory environment that fosters responsible development of domestic resources is critical to achieving the potential benefits presented by shale.

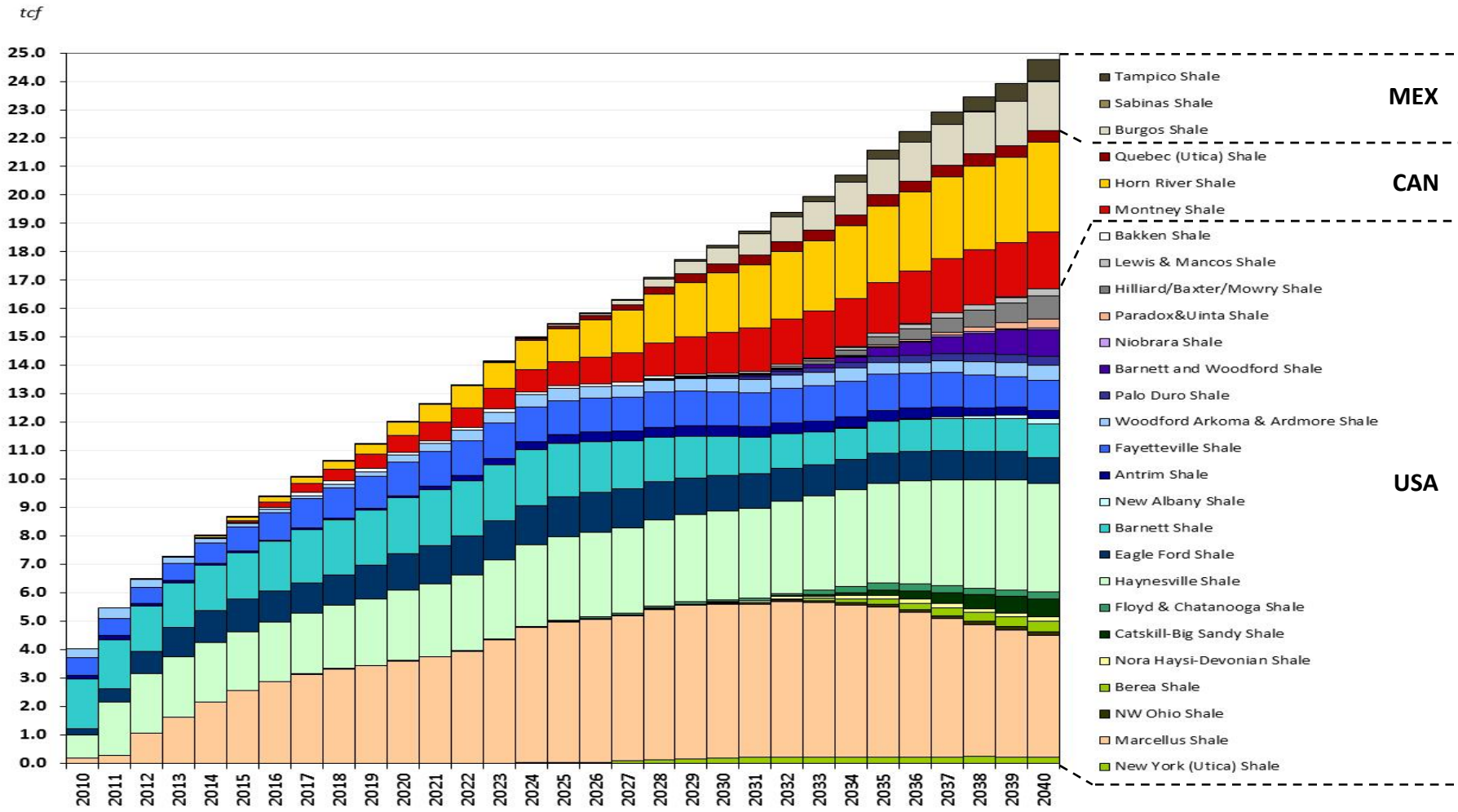
A view of the future

Reference Case: Composition of U.S. Production, 2010-2040

- U.S. shale gas production exceeds 50% of total production by 2030.
- Canadian shale gas production grows to 1/3 of total output by the mid-2030's (not pictured).

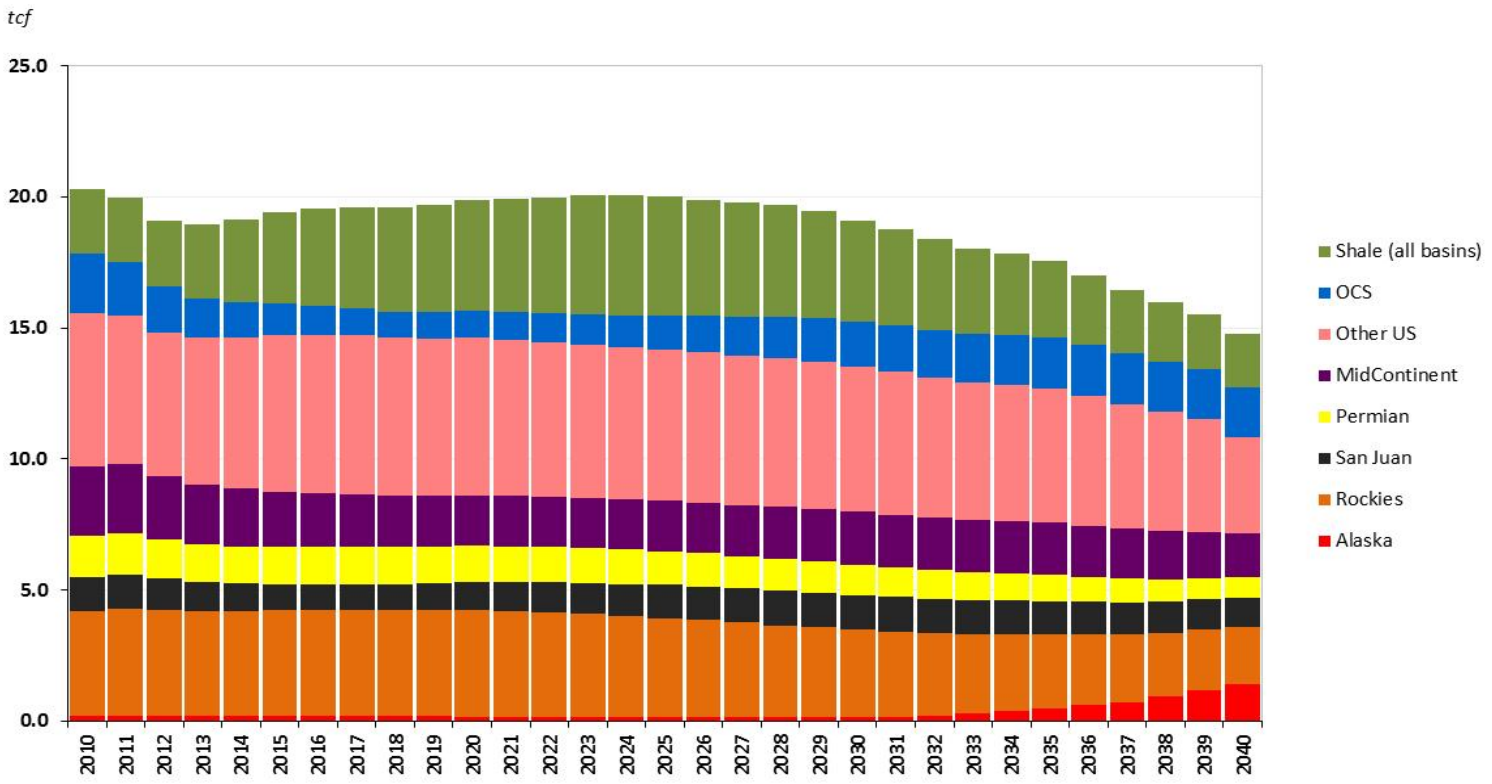


Reference Case: North American Shale Production, 2010-2040



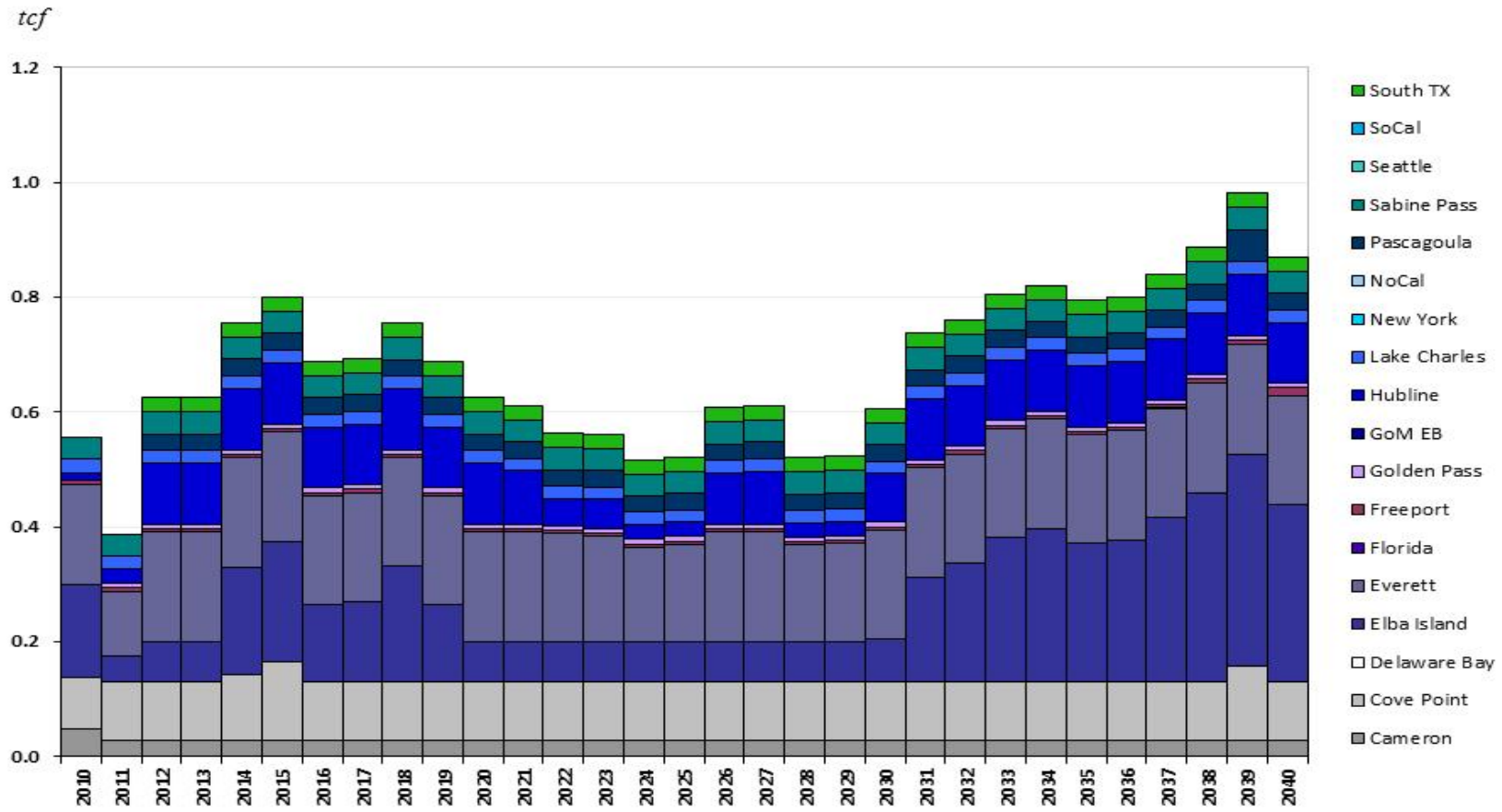
Composition of U.S. Production – had recent innovations in shale not occurred

- The lack of shale production leaves domestic supply severely diminished as long term declines in other basins dominate the overall trend.



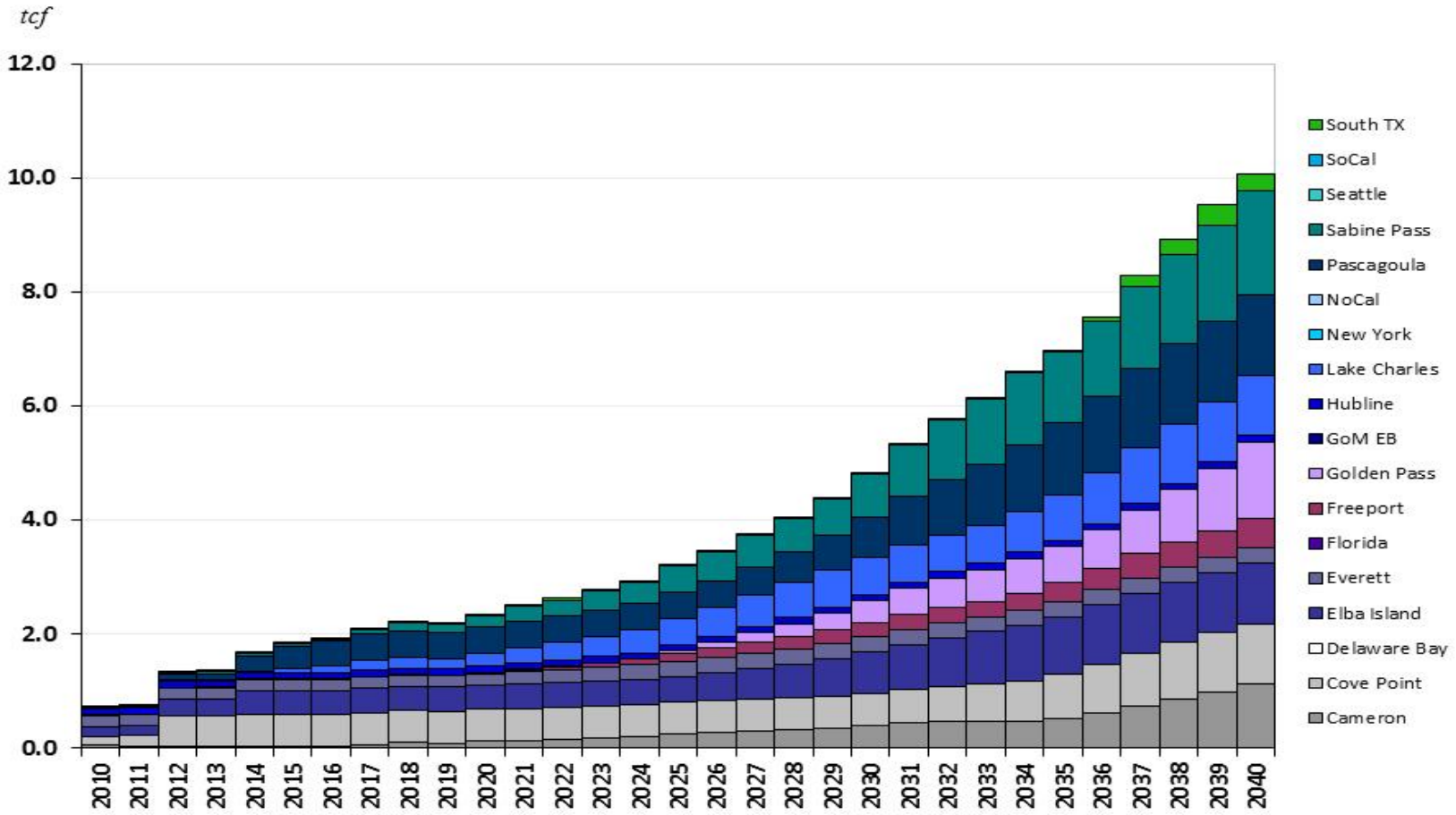
Reference Case: U.S. LNG Imports, 2010-2040

- Very low re-gas terminal capacity utilization through 2040.



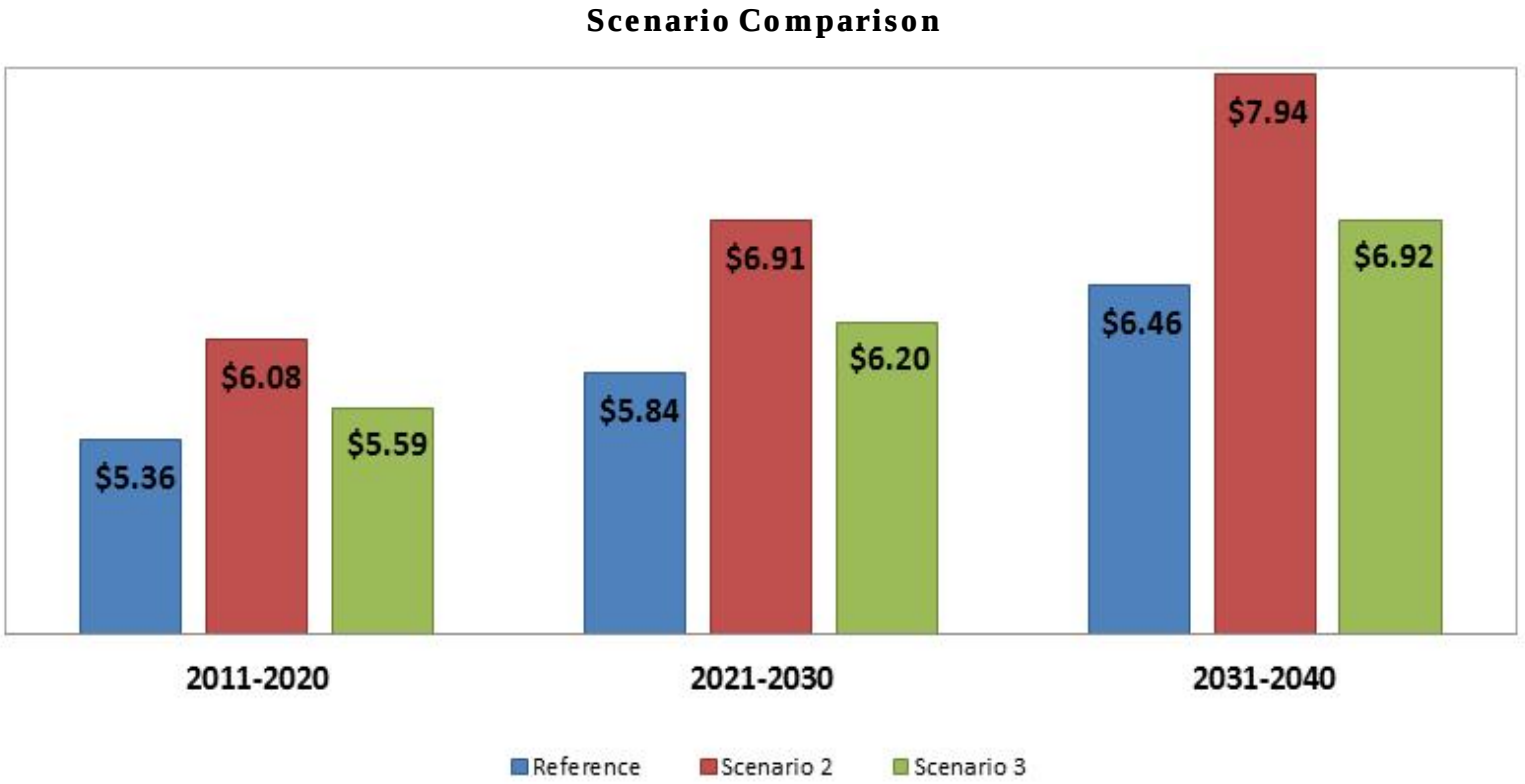
U.S. LNG Imports – had recent innovations in shale not occurred

- Absent shale resources, U.S. LNG imports rise substantially.



Henry Hub Price, 2010-2040

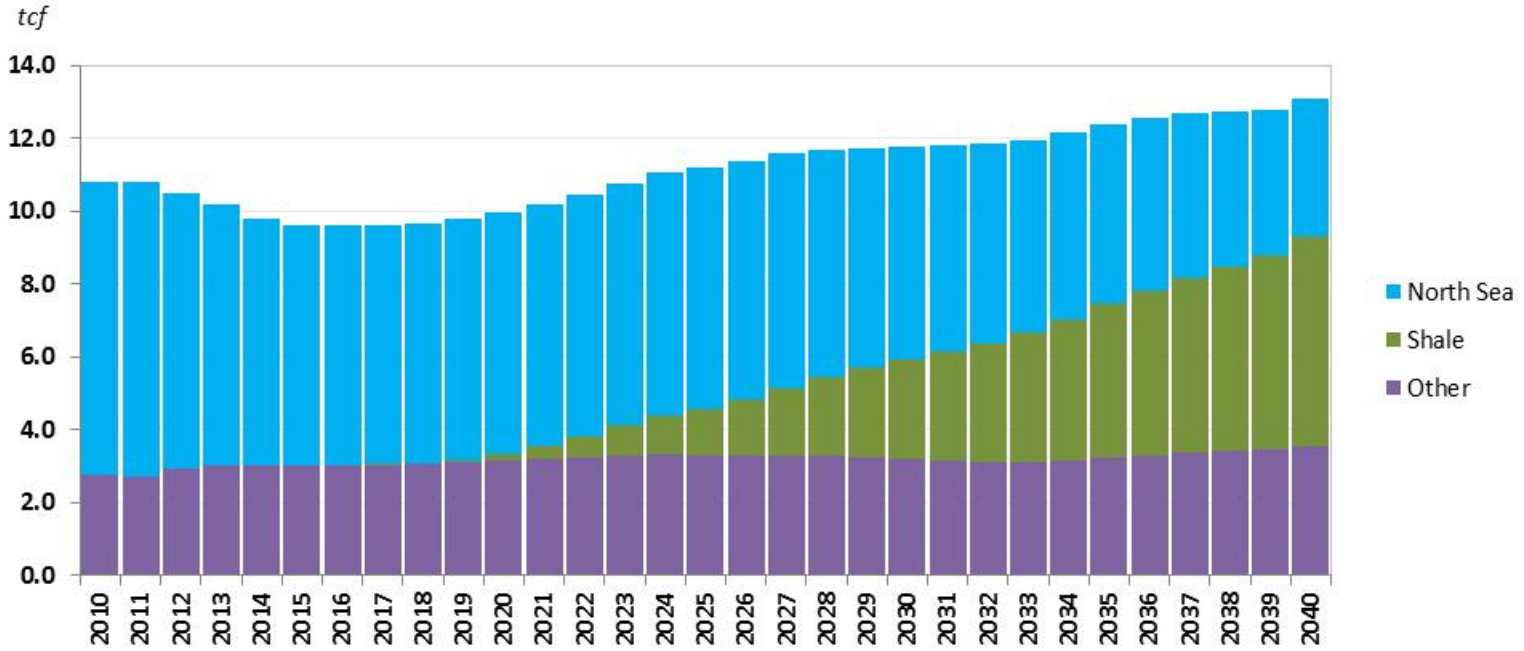
- Prices tend to rise over time as lower cost supplies are depleted. But, the domestic supply curve is relatively flat.
- Scenario 2 is a sensitivity that shows no shale development
- Scenario 3 is a sensitivity that shows no shale in the Middle Atlantic region



Shale also has potential impacts outside of the North American market

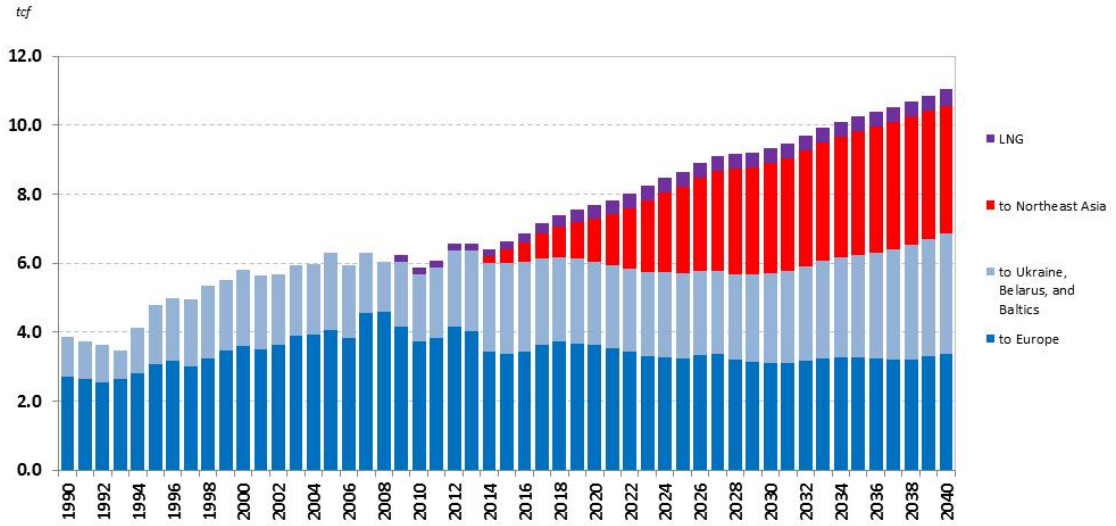
Reference Case: Shale Production in Europe, 2010-2040

- European shale production grows to about 35% of total production by 2040. While this is not as strong as North America, it does offset the need for increased imports from Russia, North Africa, and as LNG. In fact, the impact of shale growth in Europe is tilted toward offsetting Russian imports, but it also lowers North Sea production at the margin, as well as other sources of imports.

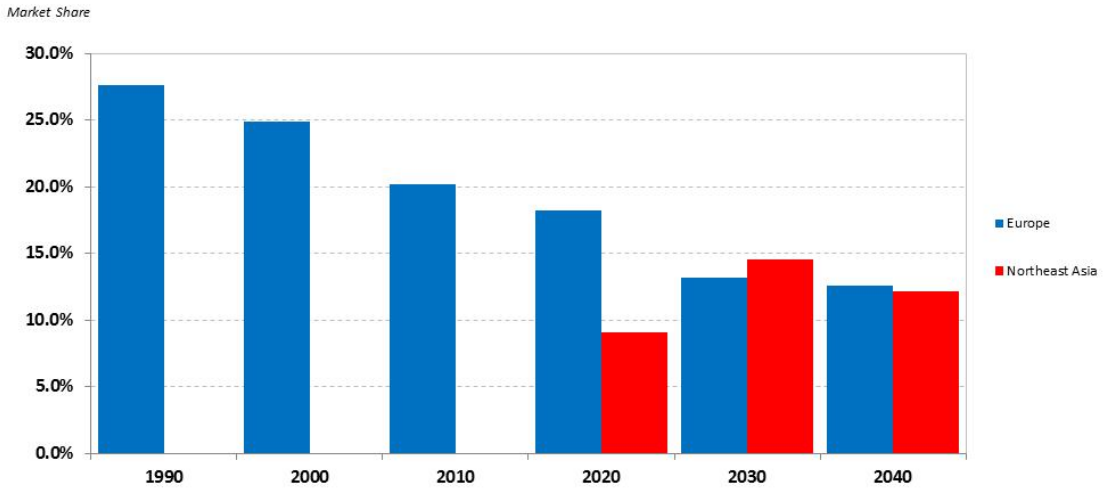


Reference Case: Russian Exports, 1990-2040

- Russian opportunities to Europe are diminishing as a result of shale production growth and Europe's increased pull on LNG.

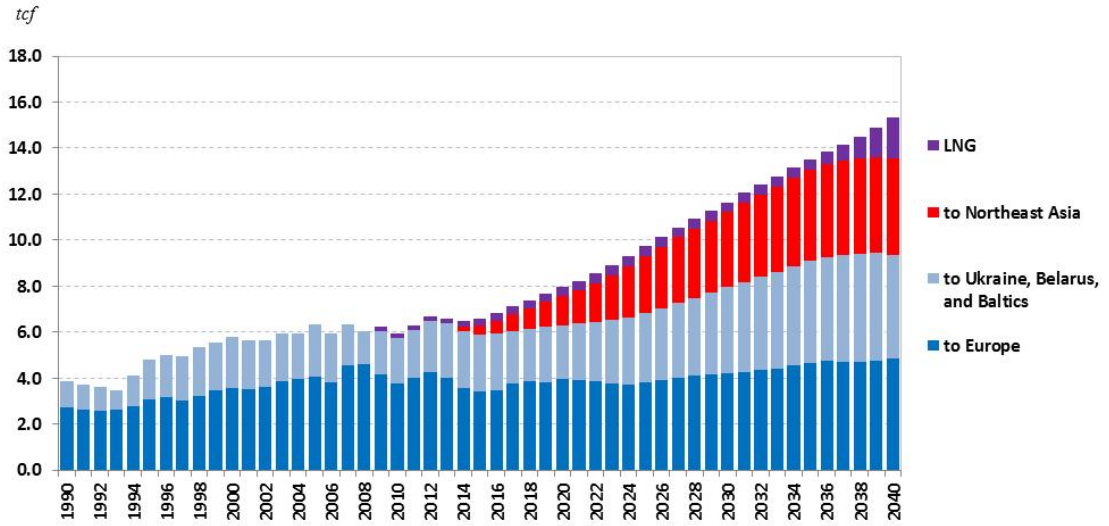


- The market share of Russia in non-FSU Europe falls to just over 13% by 2040, while it rises then stabilizes at just over 12% in Northeast Asia.

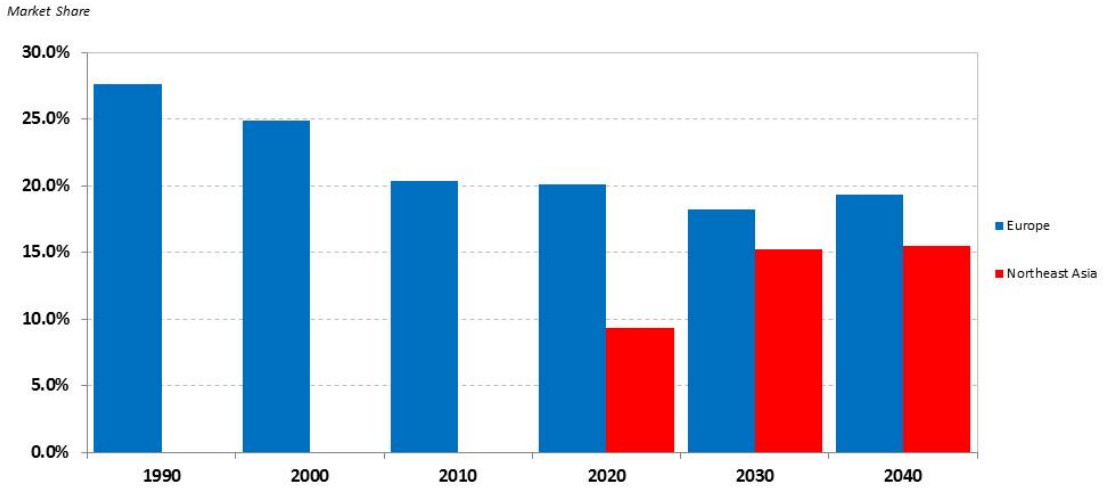


What if shale did not occur?
Russian Exports, 1990-2040

- Absent shale, Russian exports are substantially higher, with a significant impact on flows to Europe.

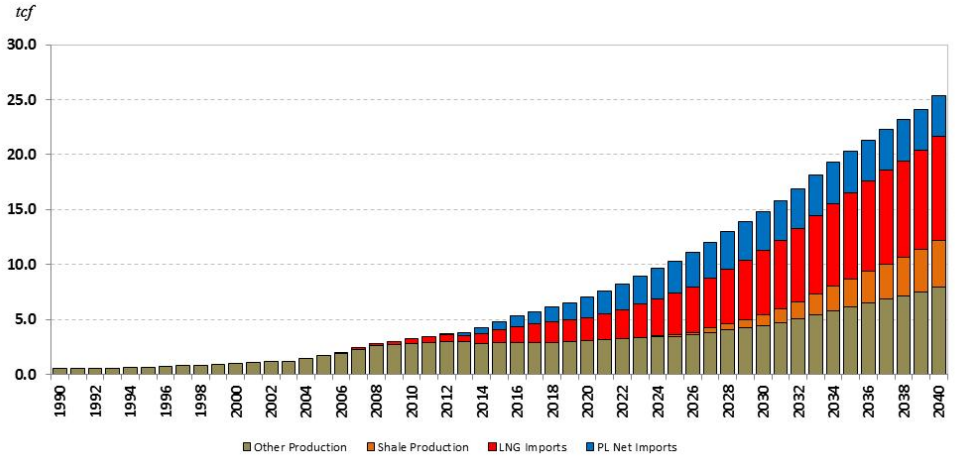


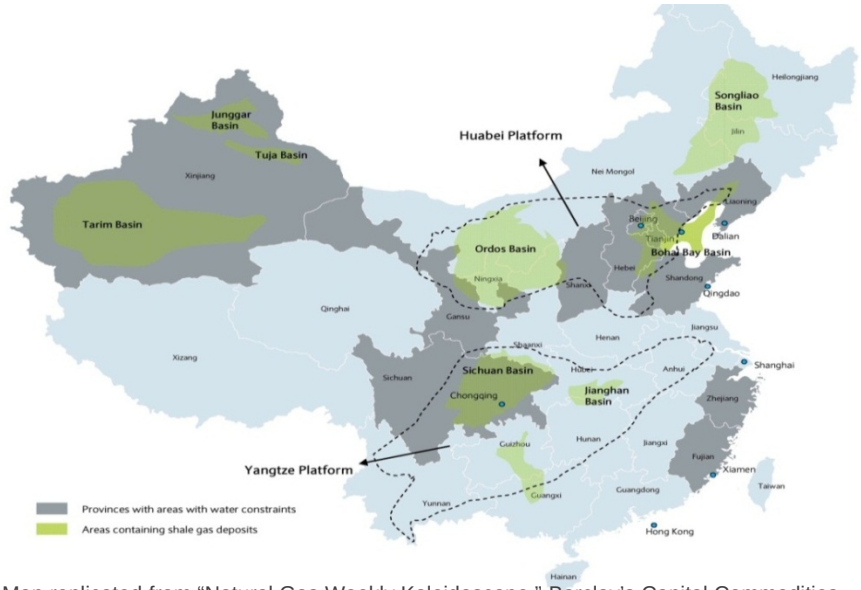
- The market share of Russia in non-FSU Europe stabilizes at about 19% by 2040, and around 16% in Northeast Asia. Note that Russian market share in both regions is higher.



Reference Case: Shale Production in Asia, 1990-2040

- Shale gas production in China grows to about 15% of the domestic market, but LNG is by far the largest single source of natural gas supply to China out to 2040.



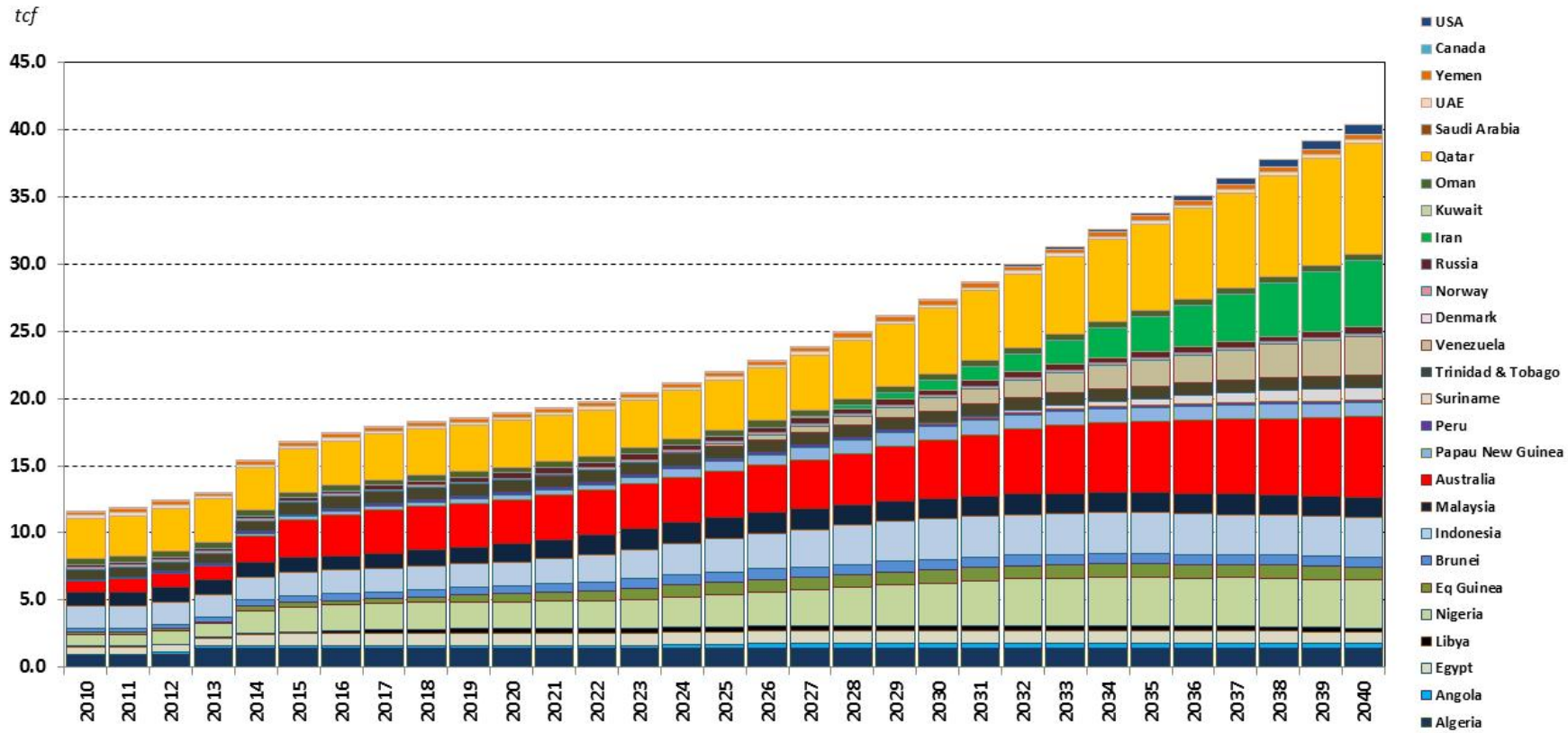


Map replicated from "Natural Gas Weekly Kaleidoscope," Barclay's Capital Commodities Research (November 16, 2010).

- Water will likely play a major role in Chinese shale production endeavors, as indicated by the fact that known shale plays are coincident with regions where water stress is already high.

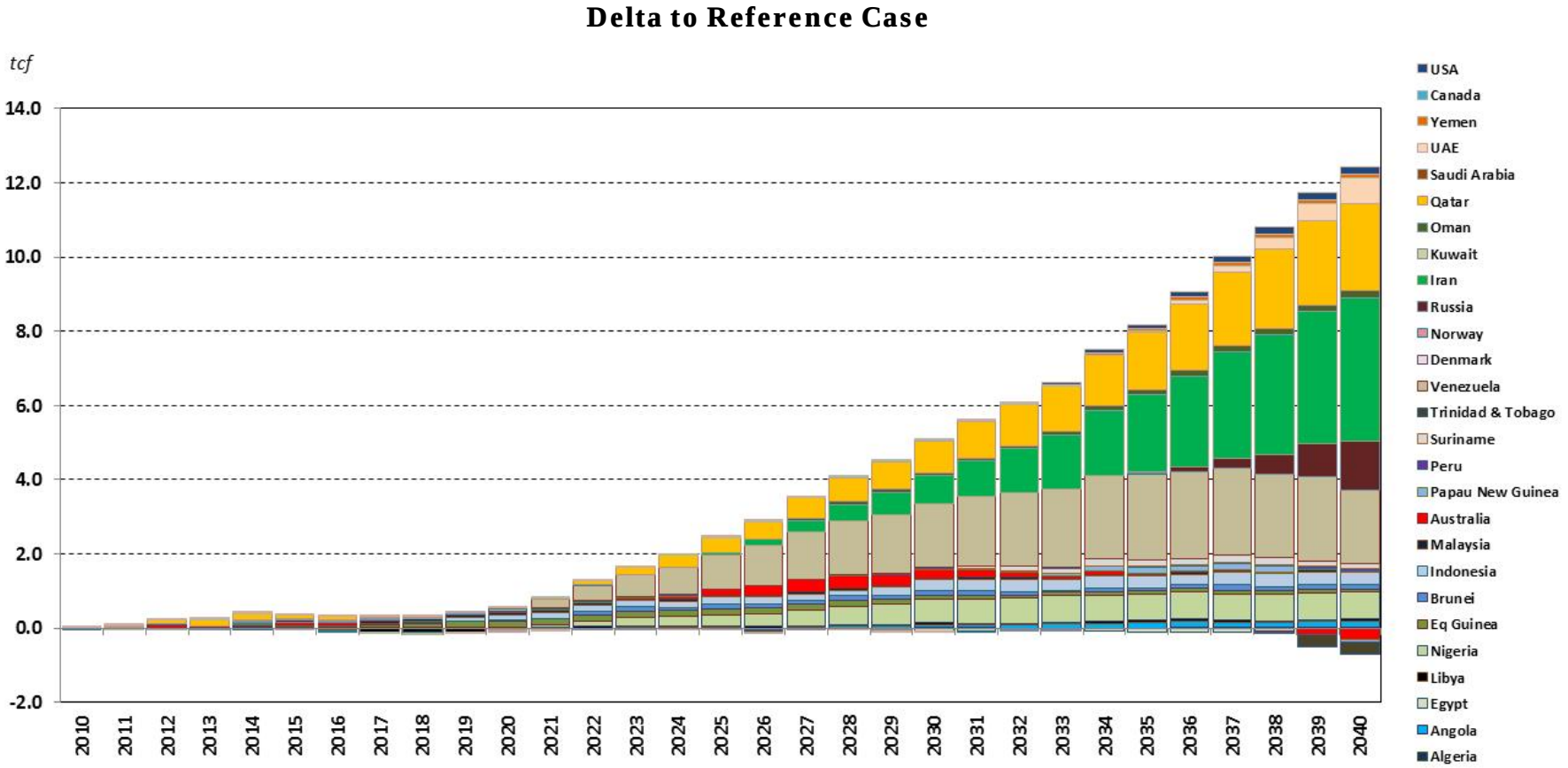
Reference Case: LNG Exports by Country, 2010-2040

- Substantial long term growth from the Middle East, Australia, and Venezuela. Qatar and Australia are the largest LNG exporters through 2040, and, collectively, account for over 35% of global *LNG* exports.



LNG Exports by Country, 2010-2040 – had shale not occurred

- Growth in Qatar, Nigeria, Venezuela and Iran are all much higher. The lack of shale in the U.S. favors LNG suppliers in or near the Atlantic basin.



An Important Role for Shale Gas

- Expansion of production from shale plays has rendered the utilization of LNG import capacity in the US very low.
- Moreover, in the aggregate, average annual capacity utilization of US LNG regasification terminals may not approach 15% until the late 2030s.
- Current and potential future expansion of shale gas in the US, Europe and Asia effectively makes the *global* natural gas supply curve more elastic.
  - This mitigates the potential for sustained increases in price.
  - To the extent that shale gas production can be more price responsive (through completion delays, for example) than production from other natural gas plays, the idea of "just-in-time" production could simulate the role of storage. Thus, shale gas production may also limit seasonal volatility to some extent.
  - Greater supply elasticity also puts pressure on traditional pricing paradigms.