



The impact of the US shale gas revolution on UK gas security

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UKERC
UK Energy Research Centre
Researching pathways to a low carbon future

A Story in Four Acts

Act 1: The US Shale Gas Revolution

Act 2: The Loss of the US LNG Market

Act 3: The Impact of Fukushima

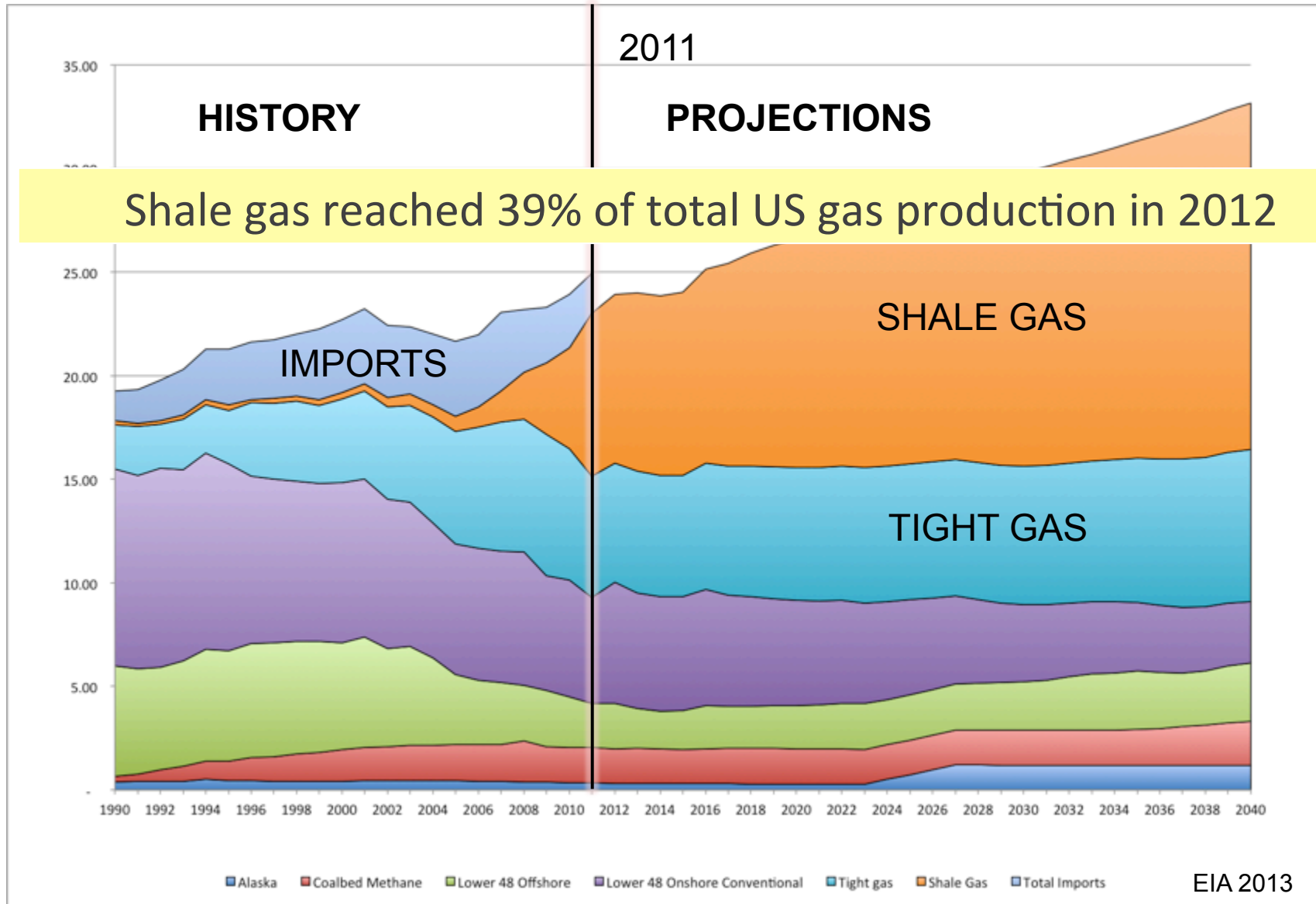
Act 4: The Return of Coal to Europe

Epilogue: Prospects for UK Gas Security

Act 1: The US Shale Gas Revolution

- Key facts and Figure
- US Shale Gas: A Global Game Changer
- Key factors behind the US Shale Gas Revolution

US Gas Production by Source: 1990-2040



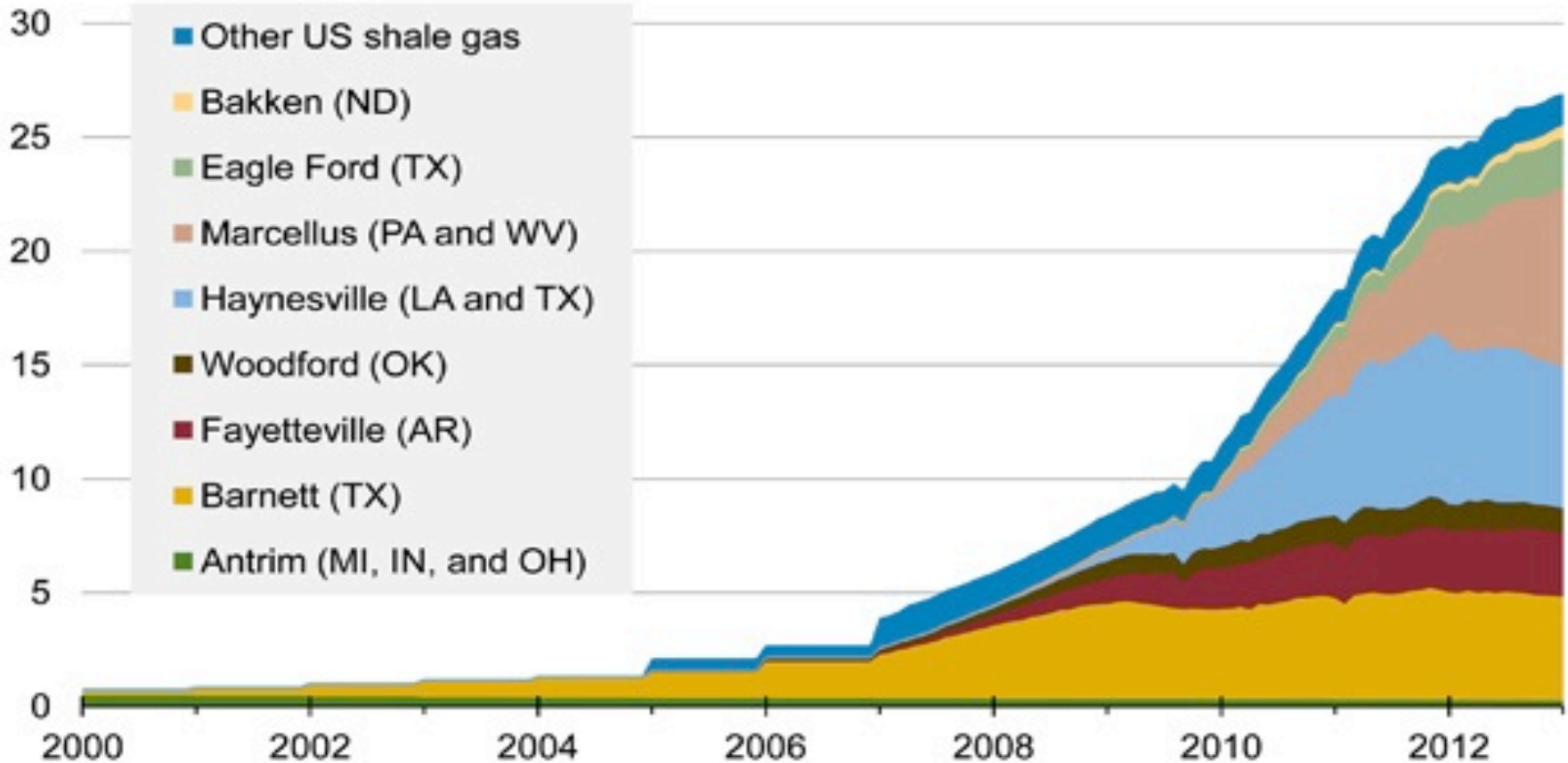
North American shale plays (as of May 2011)



Source: U.S. Energy Information Administration based on data from various published studies. Canada and Mexico plays from ARI.
Updated: May 9, 2011

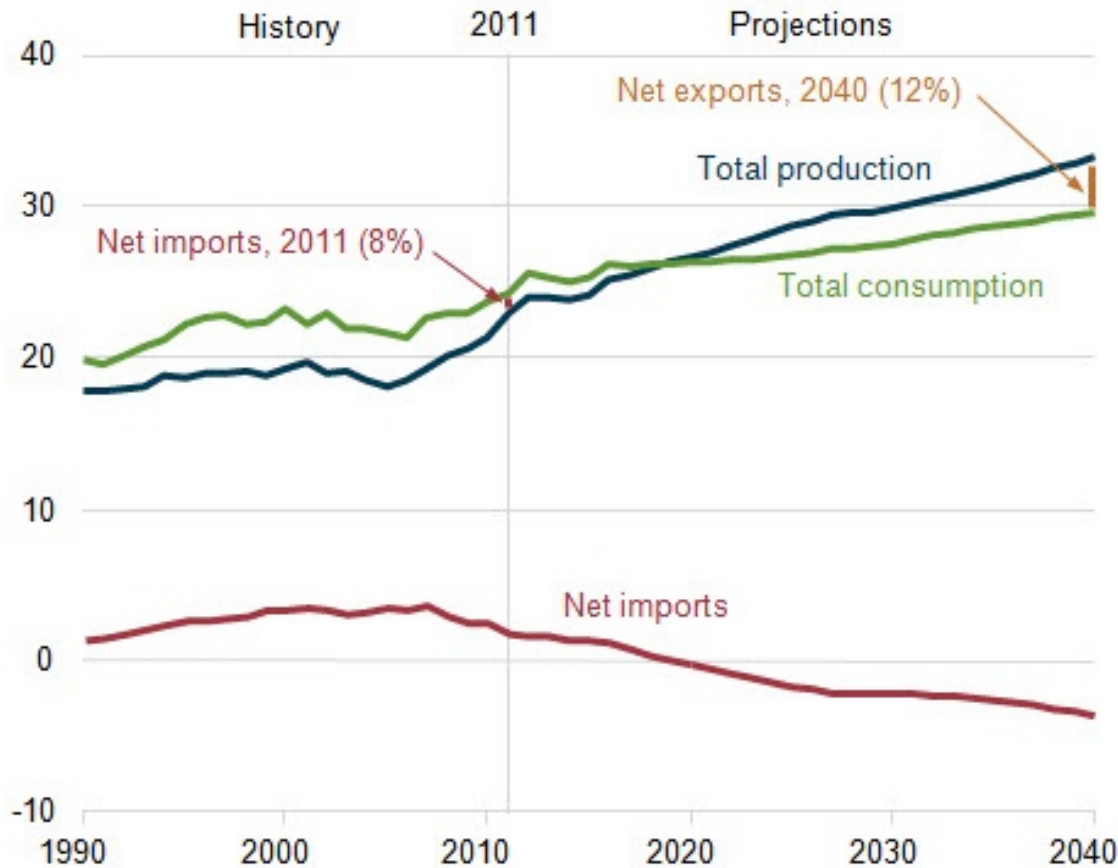
US Shale Gas Production: 2000-2013

shale gas production (dry)
billion cubic feet per day



Sources: LCI Energy Insight gross withdrawal estimates as of January 2013 and converted to dry production estimates with EIA-calculated average gross-to-dry shrinkage factors by state and/or shale play.

The US Shale Revolution: 2013 AEO forecast



US Natural Gas Balance (tcf)



- **44%** production growth 2011-40
- Consumption: **29 tcf** by 2040
- Production: **33 tcf** by 2040
- **Net exporter of gas by 2020**

Fourteen Factors that Explain the US Shale Gas Revolution (Paul Stevens, Chatham House)

1	High gas price at a crucial time
2	Access to borrowing for high risk operations
3	Favourable geology
4	Lots of drill core data to help identify “sweet spots”
5	Weak regulation for fracking “The Haliburton loophole’
6	Tax credit/intangible drilling cost expensing 1980-2002
7	Property rights to the landowner
8	Pipeline access easy, large network, common carriage
9	Selling gas into a commodity supply market very easy
10	Dynamic and competitive service industry
11	Population familiar with oil and gas operations
12	Licensing large areas with vague work programs
13	Huge government investment in basic science
14	Much of the shale gas has high liquids content

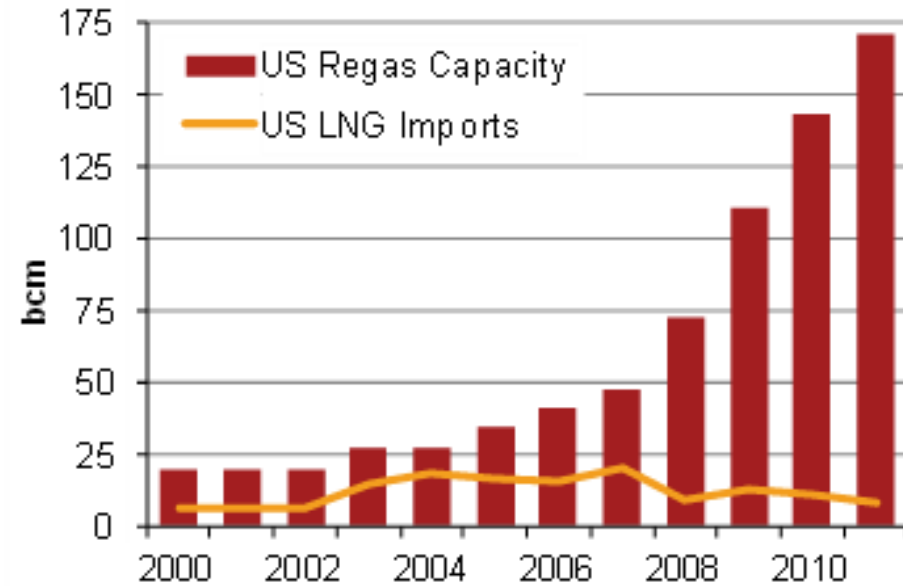
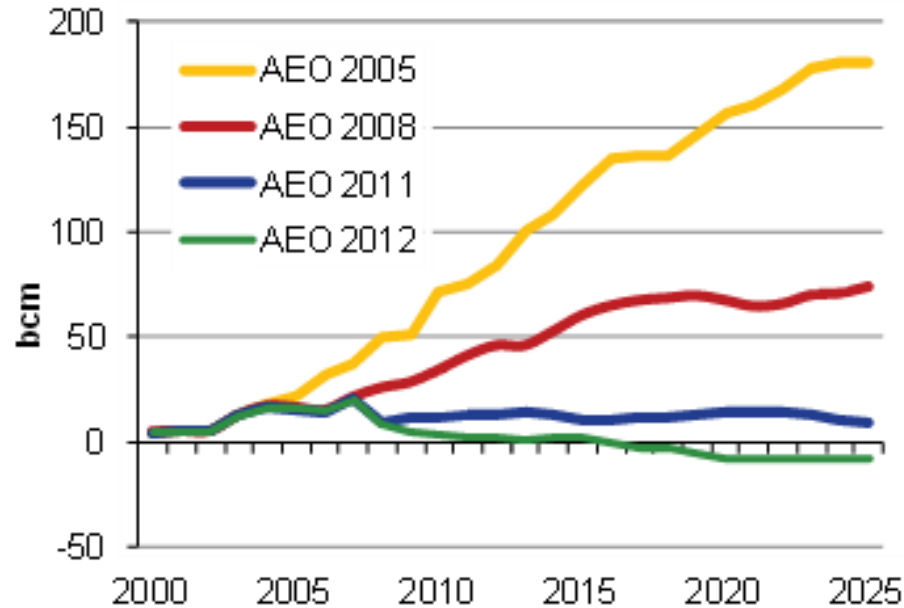
Act 2: The Loss of the LNG Market

- An abrupt change of fortunes
- An LNG supply glut
- US LNG exports?

Loss of US LNG Market

- ◎ **US LNG imports fell 77% from 2007 to 2012**
- ◎ **EIA Annual Energy Outlook 2005: US forecast to hold 23% global import share by 2010...**
 - Actual import share in 2010 was 3.9%
 - Fell further to 1.9% in 2012 (49% decline 2011-12)
 - Canadian imports fell 46% in 2011-12
- ◎ **2012: South American LNG imports surpassed North American imports for the first time.**
- ◎ ***“The UK may face competition for gas and LNG supplies, for example from the USA”*** [Parliamentary Office of Science and Technology, 2004]

An abrupt change of fortunes



LNG Import capacity utilisation = 3% in 2013

An LNG Supply Glut

- ⊙ **Qatari liquefaction capacity increased 80% from 2006-2011**
 - Accounted for 27% of global liquefaction capacity; 31% of LNG exports
 - Qatar raised global liquefaction capacity by 52% from 2006-2011
- ⊙ **Global import terminal utilisation rate fell by 21% from 2007-2012**
 - Fall from 45% utilisation in 2007 to 37% in 2012
 - 70 bcm of LNG capacity added in Europe—largely in UK & Spain
- ⊙ **Strong growth in short term/spot LNG trade**
 - 8% (2005) > 31% (2012)
 - Arbitrage exploiting price differentials between markets
 - Sudden shifts in supply/demand and increased interconnection between markets in the Atlantic and Asia-Pacific

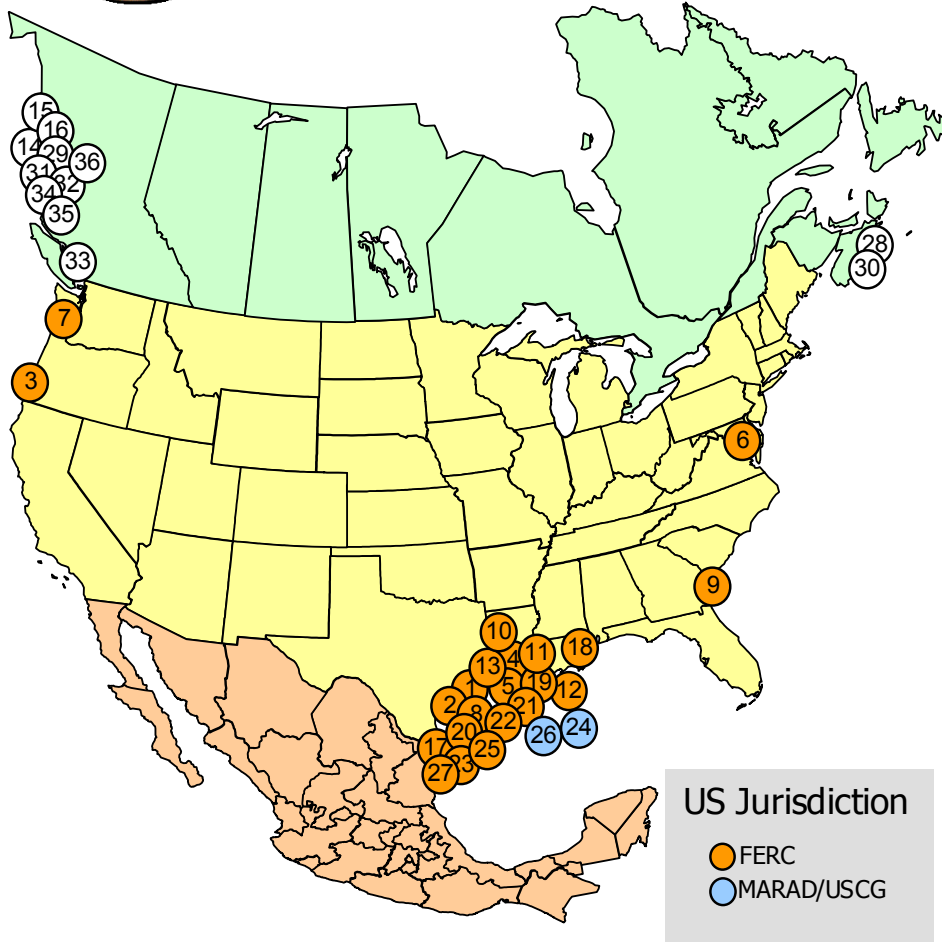
US LNG Exports?

- ⦿ At present the domestic price of natural gas is so low that much of the 'dry gas' is uneconomic to produce (concerns about profitability and large losses and write-offs).
- ⦿ Export of natural gas as LNG would push the price up to bring more shale gas into production.
- ⦿ The anti-export lobby (the chemical industry) argues that low gas prices give the US a competitive advantage that would be lost if prices increased.
- ⦿ The pro-export lobby (the gas industry) argues that exports will increase production, provide jobs and economic opportunity and improve the balance of payments.
- ⦿ Furthermore, a ban on gas exports would not sit well with the US position as a champion of free trade.
- ⦿ Following events in Ukraine, there is a strong geopolitical lobby in favour of US LNG exports.
- ⦿ As of January 1st 2014, 5 LNG export licenses applications approved and 21 pending at 19 facilities.



North American LNG Export Terminals

Proposed/Potential



Export Terminal

PROPOSED TO FERC

- Freeport, TX:** 1.8 Bcfd (Freeport LNG Dev/Freeport LNG Expansion/FLNG Liquefaction)*
- Corpus Christi, TX:** 2.1 Bcfd (Cheniere – Corpus Christi LNG)*
- Coos Bay, OR:** 0.9 Bcfd (Jordan Cove Energy Project)*
- Lake Charles, LA:** 2.4 Bcfd (Southern Union - Trunkline LNG)
- Hackberry, LA:** 1.7 Bcfd (Sempra – Cameron LNG)*
- Cove Point, MD:** 0.82 Bcfd (Dominion – Cove Point LNG)*
- Astoria, OR:** 1.25 Bcfd (Oregon LNG)*
- Lavaca Bay, TX:** 1.38 Bcfd (Accelerate Liquefaction)
- Elba Island, GA:** 0.35 Bcfd (Southern LNG Company)
- Sabine Pass, LA:** 1.96 Bcfd (Sabine Pass Liquefaction)*
- Lake Charles, LA:** 1.07 Bcfd (Magnolia LNG)
- Plaquemines Parish, LA:** 1.07 Bcfd (CE FLNG)
- Sabine Pass, TX:** 2.1 Bcfd (ExxonMobil – Golden Pass)

PROPOSED CANADIAN SITES IDENTIFIED BY PROJECT SPONSORS

- Kitimat, BC:** 1.28 Bcfd (Apache Canada Ltd.)
- Douglas Island, BC:** 0.23 Bcfd (BC LNG Export Cooperative)
- Kitimat, BC:** 3.23 Bcfd (LNG Canada)

POTENTIAL U.S. SITES IDENTIFIED BY PROJECT SPONSORS

- Brownsville, TX:** 2.8 Bcfd (Gulf Coast LNG Export)
- Pascagoula, MS:** 1.5 Bcfd (Gulf LNG Liquefaction)
- Cameron Parish, LA:** 0.16 Bcfd (Waller LNG Services)
- Ingleside, TX:** 1.09 Bcfd (Pangea LNG (North America))
- Cameron Parish, LA:** 0.20 Bcfd (Gasfin Development)
- Cameron Parish, LA:** 0.67 Bcfd (Venture Global)
- Brownsville, TX:** 3.2 Bcfd (Eos LNG & Barca LNG)
- Gulf of Mexico:** 3.22 Bcfd (Main Pass - Freeport-McMoRan)
- Brownsville, TX:** 0.94 Bcfd (Annova LNG)
- Gulf of Mexico:** 1.8 Bcfd (Delfin LNG)
- Brownsville, TX:** 0.27 Bcfd (Texas LNG)

POTENTIAL CANADIAN SITES IDENTIFIED BY PROJECT SPONSORS

- Goldboro, NS:** 1.4 Bcfd (Pieridae Energy Canada)
- Prince Rupert Island, BC:** 2.91 Bcfd (BG Group)
- Melford, NS:** 1.8 Bcfd (H-Energy)
- Prince Rupert Island, BC:** 2.74 Bcfd (Pacific Northwest LNG)
- Prince Rupert Island, BC:** 4.0 Bcfd (ExxonMobil – Imperial)
- Squamish, BC:** 0.29 Bcfd (Woodfibre LNG Export)
- Kitimat/Prince Rupert, BC:** 0.32 Bcfd (Triton LNG)
- Prince Rupert, BC:** 3.12 Bcfd (Aurora LNG)
- Kitsault, BC:** 2.6 Bcfd (Kitsault Energy)

As of January 16, 2014

* Filed Certificate Application

Office of Energy Projects

The Delivered Cost of US LNG Exports to Europe and Asia (\$/mmbtu)

Henry Hub Price	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
Liquefaction	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Transport to Europe	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Transport to Asia	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Regasification	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Full Cost Europe	6.6	7.6	8.6	9.6	10.6	11.6	12.6	13.6	14.6
Full Cost Asia	8.4	9.4	10.4	11.4	12.4	13.4	14.4	15.4	16.4

Source: James Henderson 2013. *The Potential Impact of North American LNG Exports*. Oxford Institute for Energy Studies, Working Paper NG 68, p. 46

Act 3: The Impact of Fukushima

- Redirection of LNG from the Atlantic Basin to the Pacific Basin
- Global Gas price divergence

The Impact of Fukushima



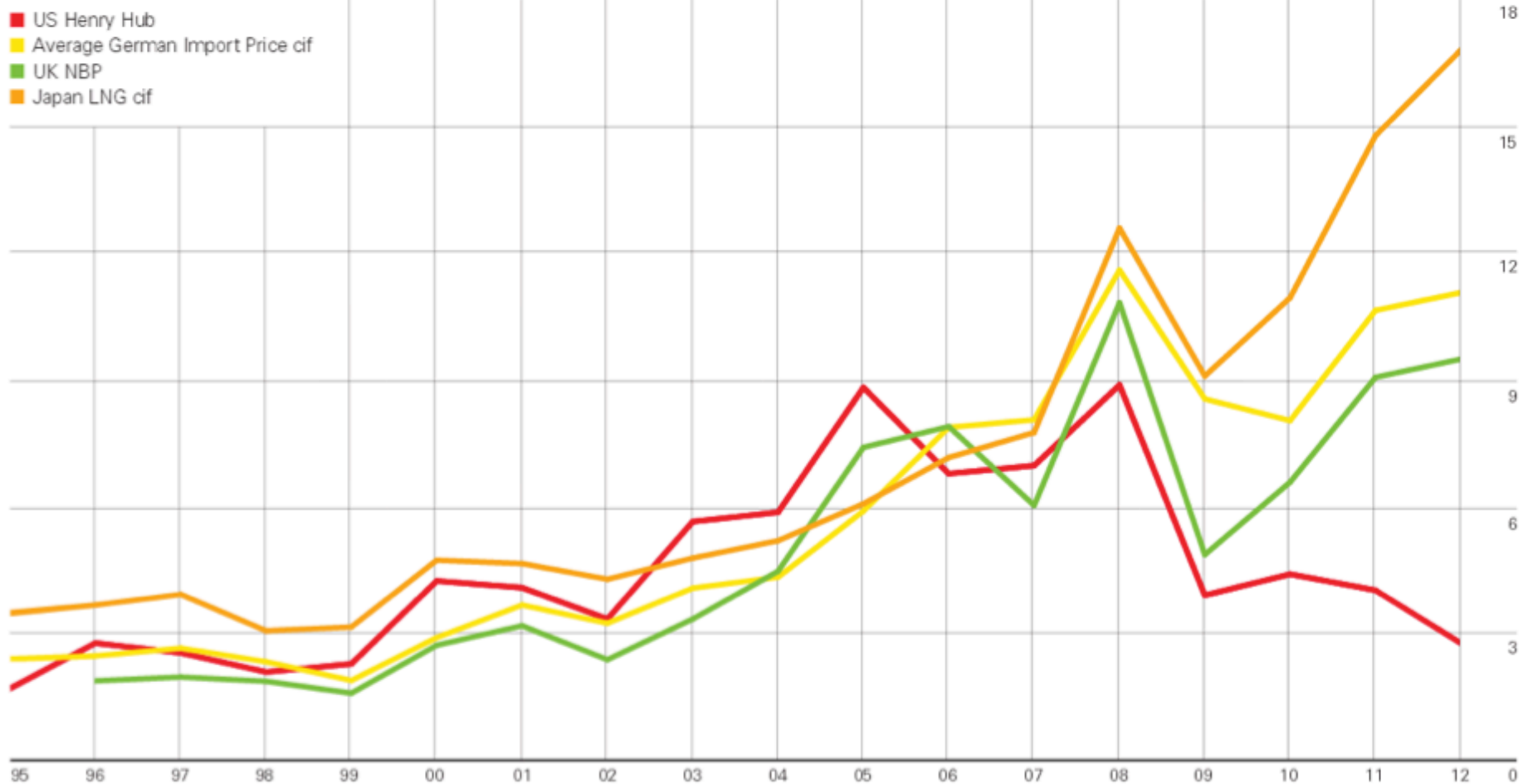
As a consequence of the Great East Japan Earthquake in March 2011, and the disaster at the Fukushima nuclear power plant, Japan has had to increase LNG imports to compensate for the loss of nuclear power generation—at present all nuclear plants in Japan are closed.

- Japan's LNG imports jumped 25% from 70 mmt to 87 mmt between 2010 and 2012, tightening the global LNG market.
- Qatar increased LNG exports by 8mmt, boosting its share to 18%.
- The import price rose from \$9/MMBtu before the crisis to over \$16/MMBtu in 2012, with impact on Japan's balance of payments.
- Japan hopes that US LNG exports based on a low Henry Hub price will help push LNG prices down in the future, as will growing LNG supply from Australia and elsewhere.

International gas price divergence

Prices

\$/Mmbtu



Source: BP Statistical Review 2013

Act 4: The Return of Coal to Europe

Fuel switching in US Power Generation

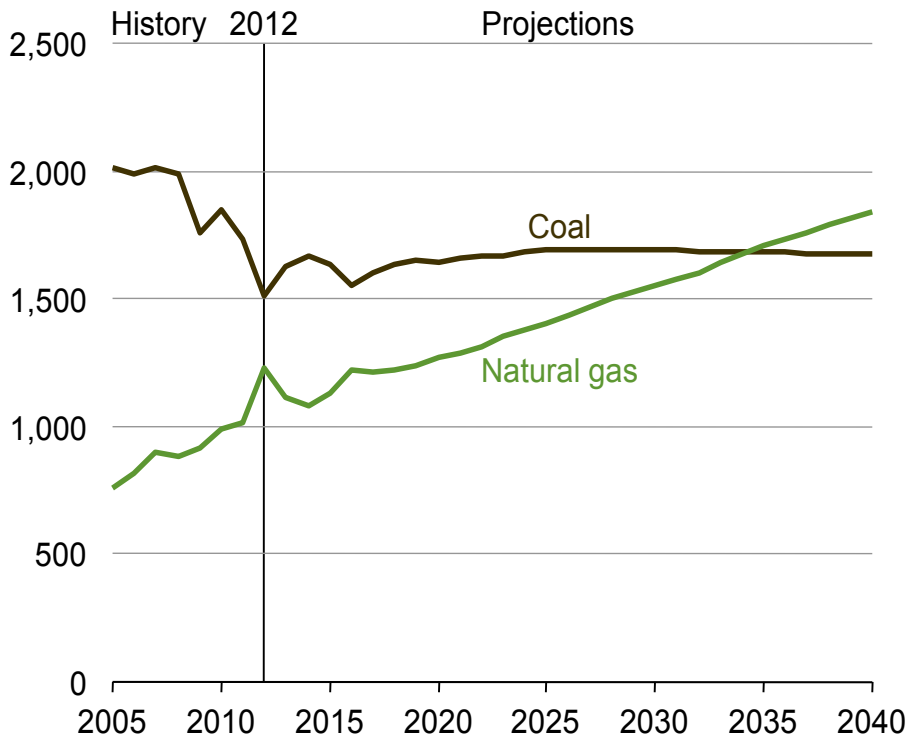
Return of Coal to Europe

UK Power Generation

Coal's Short-lived Renaissance?

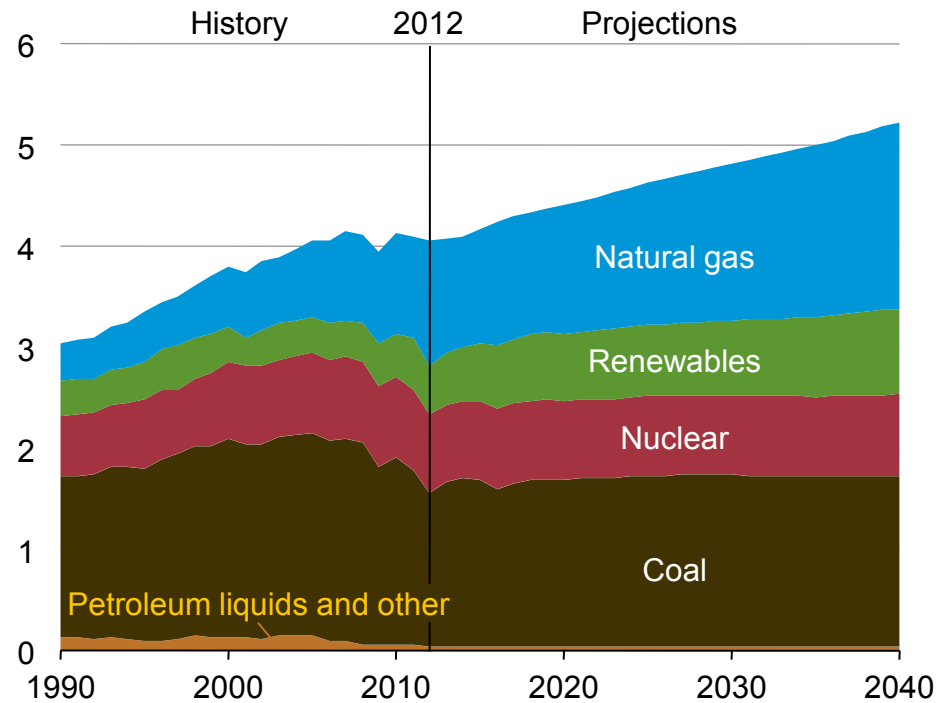
Fuel switching in US Power Generation

Electricity Generation from natural gas and coal 2005-40 (Trillion Kilowatt-hours)



By 2035, natural gas surpasses coal as the largest source of U.S. electricity generation

Figure MT-30. Electricity generation by fuel in the Reference case, 1990-2040 (trillion kilowatthours)



Source: EIA AEO2014

Return of Coal in Europe

Switch from coal to natural gas in the US; exports to Europe

imports of US coal to Europe +29% in 2012 vs. 2011

2013: European coal benchmark price fell 21%

October 2013 price for next-year delivery at lowest level since 2009 (gas prices remain higher due to oil indexation)

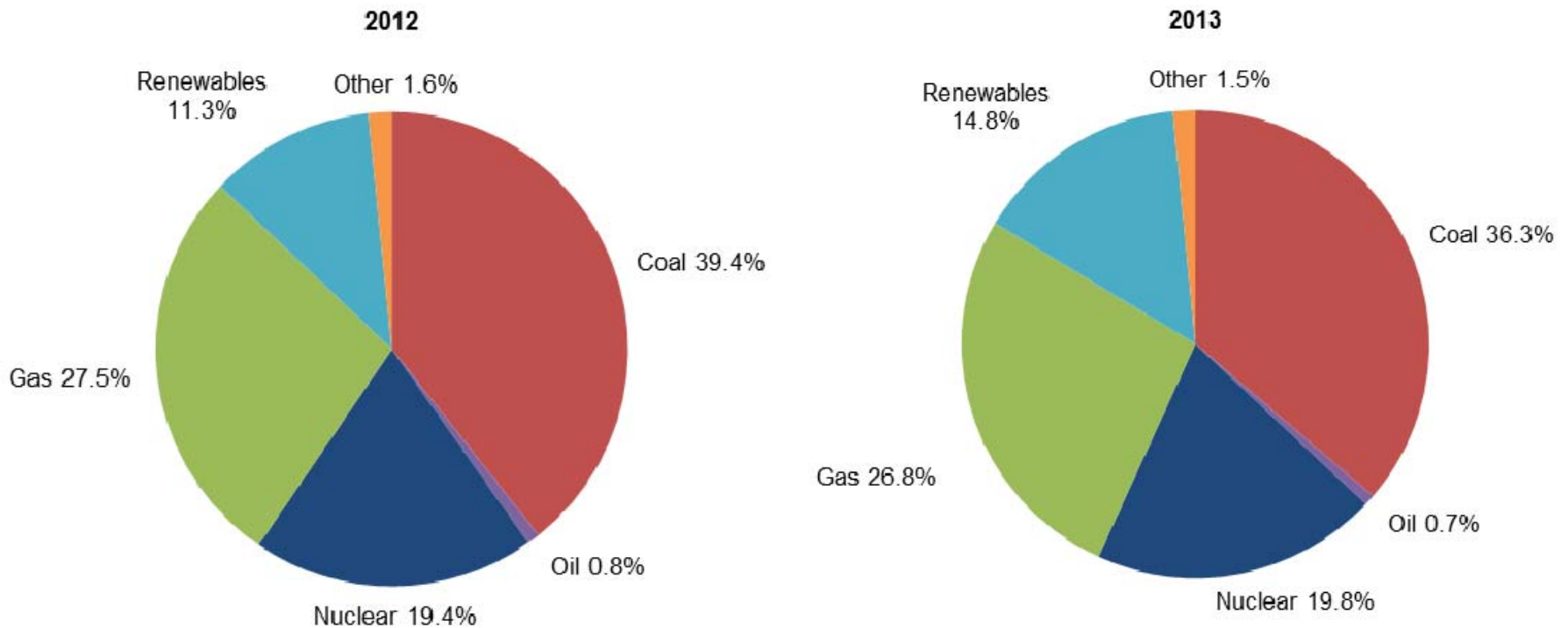
Uncertainty for the gas-power sector across Europe

UK: mid-2013 four gas plants mothballed with a capacity of 4.1GW; investment decision delayed on new gas plants

Failings with EU Emissions Trading System

Generators are not being financially penalized for the higher carbon content of coal-based generation (April 2013 UK introduced a Carbon Floor Price and then froze it!)

UK Power Generation 2012-13



Gas's share of generation fell from 27.5 per cent to 26.8 per cent, due to high gas prices. It was gas's lowest share since 1996. Coal's share of generation decreased from 39.4 per cent in 2012 to 36.3 per cent in 2013. Despite the decrease in coal use, the contribution of coal to the UK's electricity mix remains high compared to recent years (between 2008-2011 coal provided around 30 per cent of the UK's electricity generation).

Source: DECC 2014

Coal's Short-Lived Renaissance?

EU Large Combustion Plant Directive (LCPD)

- All thermal power plants built after 1987 of 50MW or more must comply with pollutant limits proscribed by the LCPD
- Those that entered operation before 1987 can install emission abatement equipment or opt-out of the LCPD
- 20,000 operational hours before closure on 31st December 2015

221 plants to close across EU

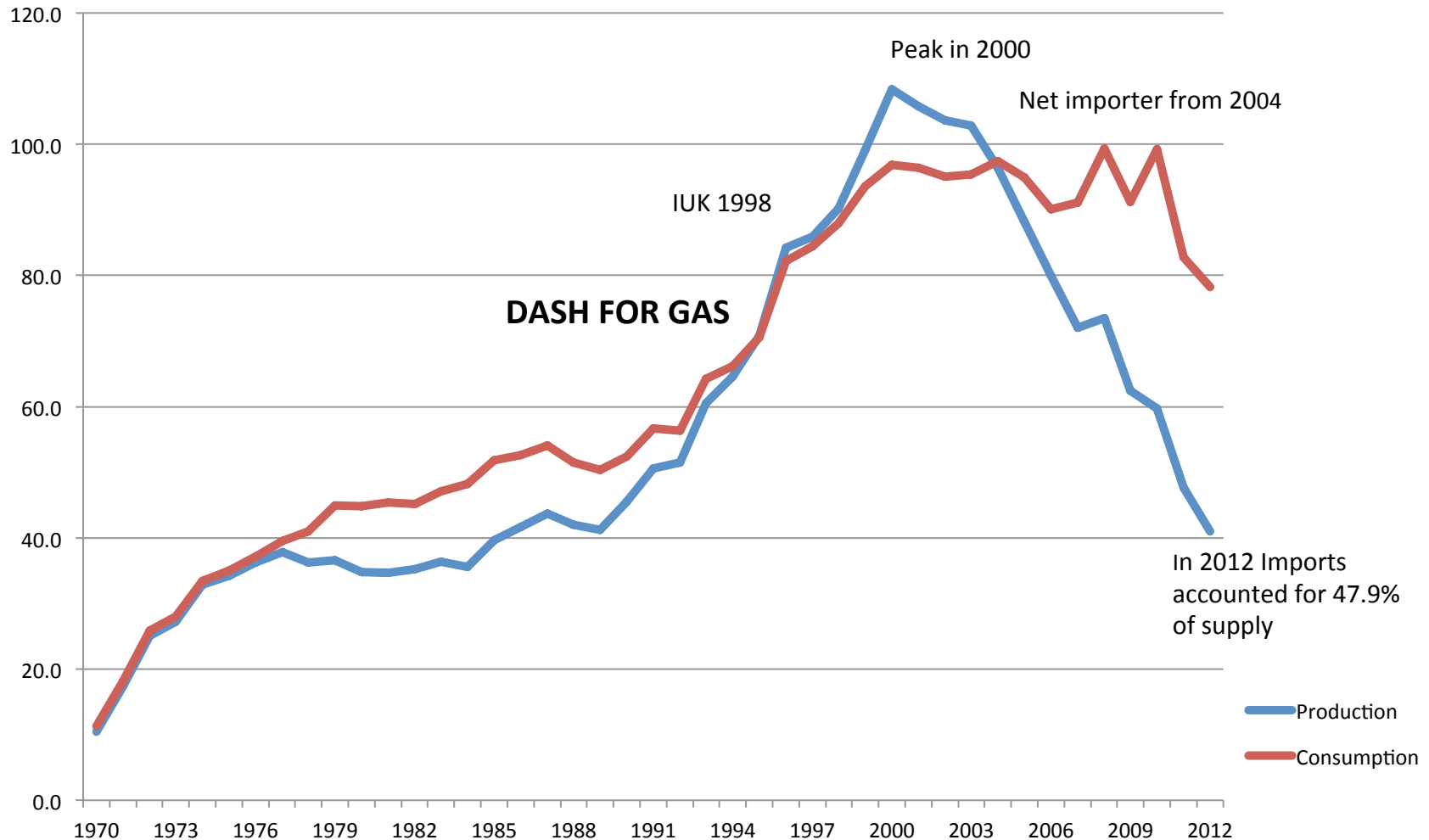
- Romania (41 plants), Poland (40), France (36)
- UK: 11.8GW (6 Coal and 3 Oil) are closing

The net result was a steep rise in coal to use up remaining hours
(...along with economics—coal cheaper than gas)

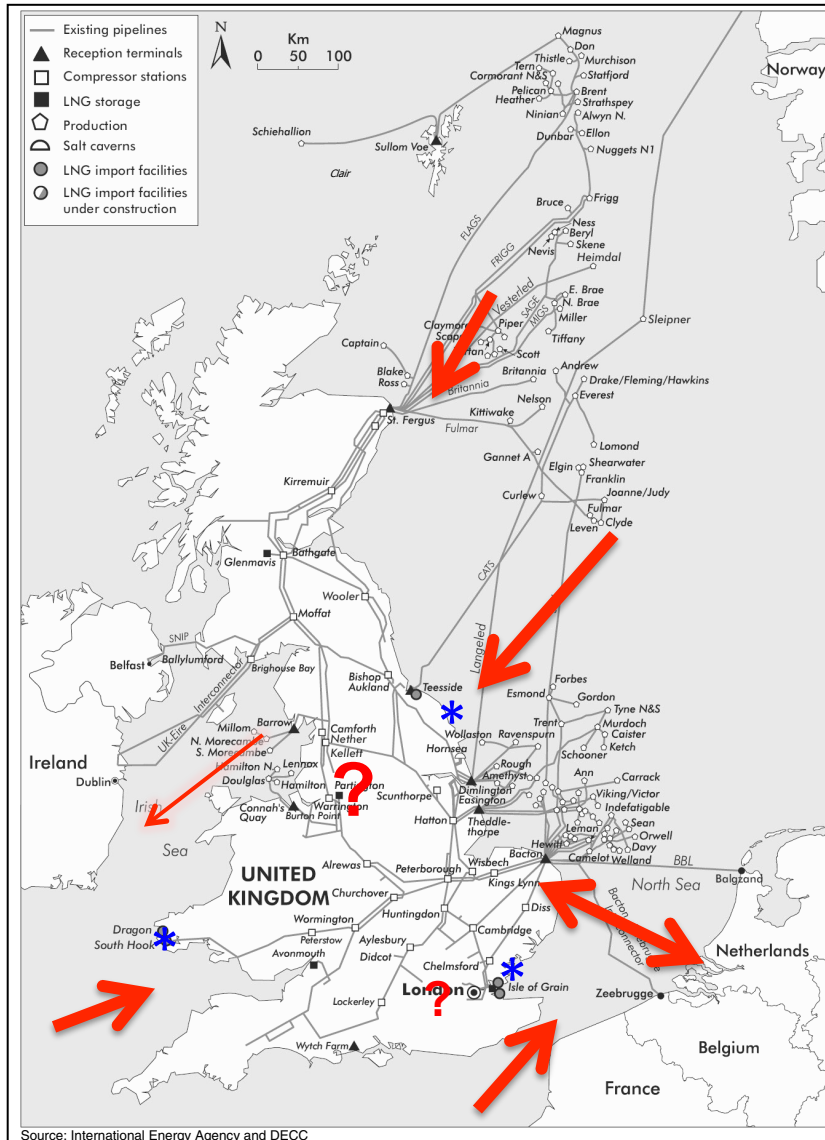
But European gas demand will return...?

Epilogue: Prospects for UK Gas Security

UK Natural Gas Production and Consumption: 1970-2012 (BCM)



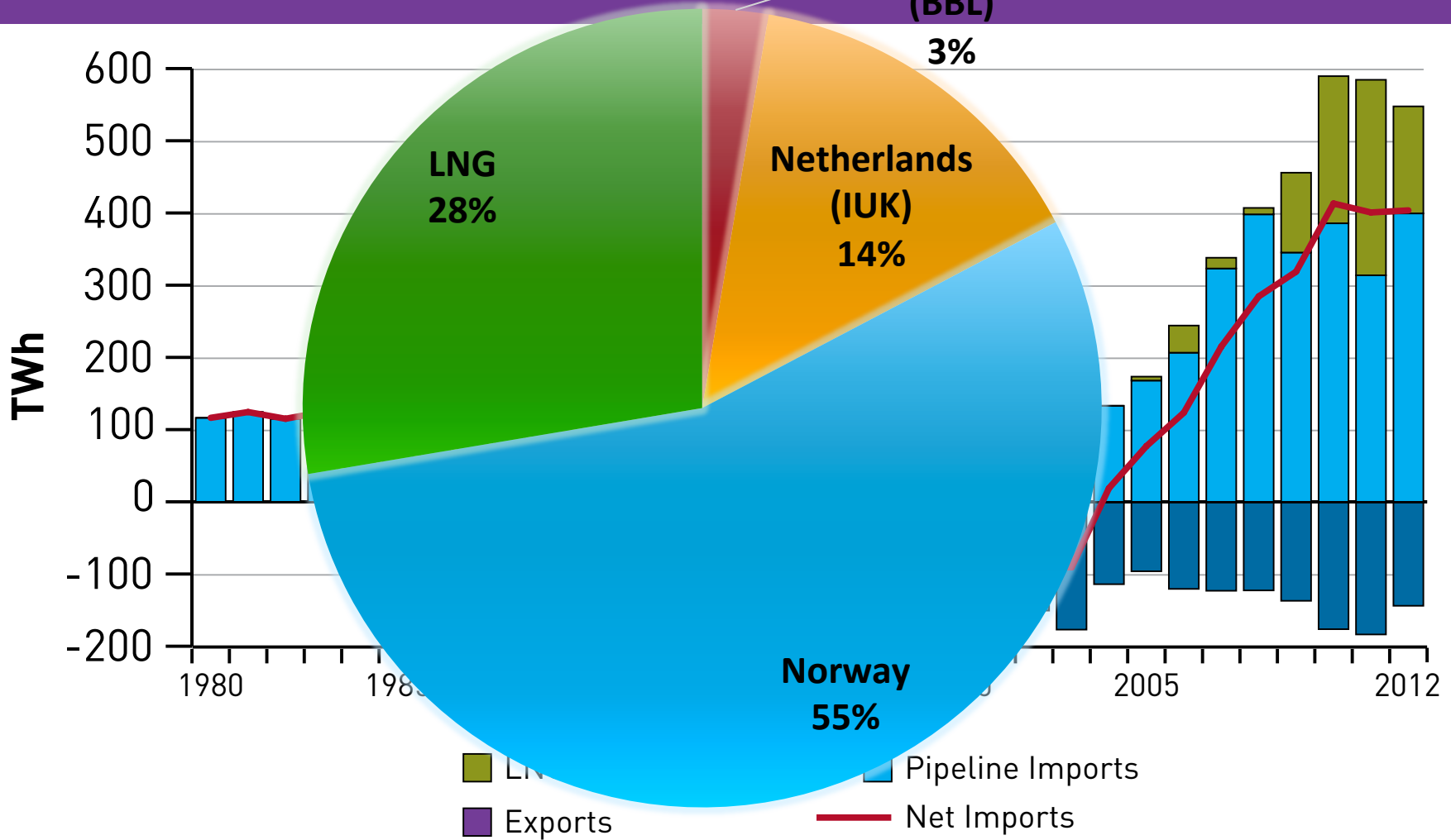
THE UK'S CONTEMPORARY GAS BALANCE



VECTORS

1. UK Continental Shelf
2. Norwegian Continental Shelf
3. Interconnectors (IUK & BBL)
4. Liquefied Natural Gas
5. Exports to Ireland
6. Domestic gas storage
7. Domestic unconventional gas

UK trade in natural gas, 1980 to 2012



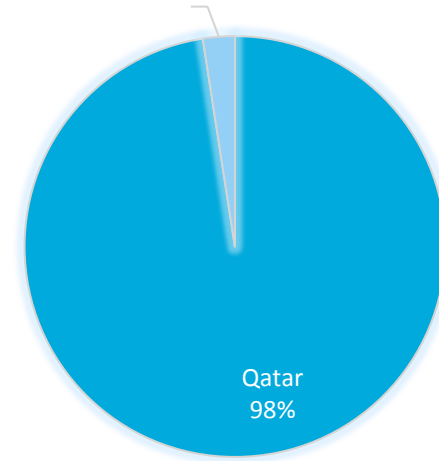
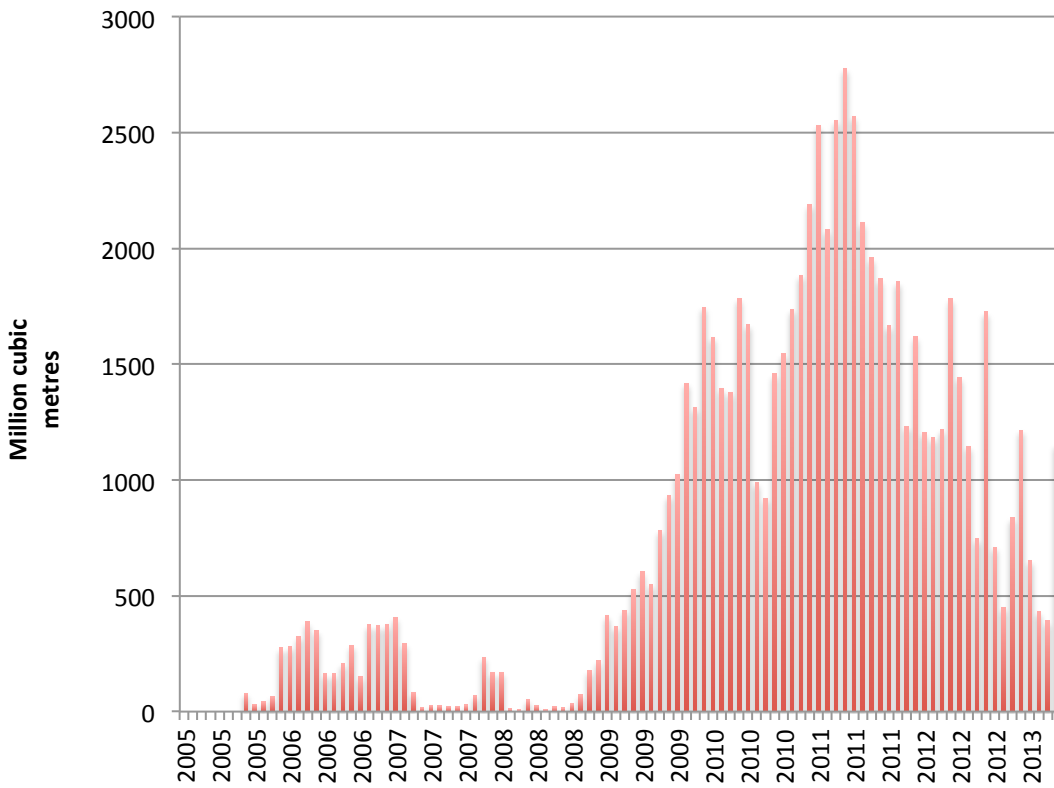
Source: DECC 2013

The Geography of UK Gas Imports 2000-2013 (million cubic metres)

	Pipeline Imports			Liquefied Natural Gas Imports		Total Gas Imports	Import Dependence*
	Belgium	Netherlands	Norway	Qatar	Total LNG		
2000	270	-	1,031	-	-	1,301	-10.9
2001	367	-	1,158	-	-	1,525	-9.7
2002	611	-	3,392	-	-	4,003	-8.2
2003	401	-	6,327	-	-	6,728	-8.2
2004	2,339	-	8,460	-	-	10,799	+1.7
2005	2,203	-	11,305	-	500	14,008	7.1
2006	2,788	840	14,003	71	3,442	21,073	11.9
2007	593	7,107	20,339	247	1,403	29,442	20.5
2008	1,127	8,440	25,528	-	820	35,915	26.4
2009	728	6,475	23,478	5,627	10,127	40,808	32.1
2010	1,245	8,164	25,026	14,565	18,578	53,012	38.5
2011	368	6,447	21,203	21,153	24,827	52,846	44.9
2012	1,310	7,297	26,832	13,335	13,667	49,105	47.9
2013 p	3,307	7,804	27,866	8,607	9,278	48,255	n/d
% Total Imports in 2013	6.9	16.2	57.7	17.8	19.2	100	n/a

Source: DECC 2013

UK LNG Imports



Others
Algeria,
Egypt,
Nigeria,
Norway,

LNG Facility	Ownership	Capacity	2012 %
Dragon LNG (Milford Haven)	BG Group: 50% Petronas: 50%	6bcm	1.2%
South Hook (Milford Haven)	Qatar Petroleum Intl.: 67.5% ExxonMobil: 24.15% Total: 8.35%	21bcm	73.4%
Isle of Grain (Essex)	National Grid (Sonatrach, GDF-Suez, Centrica, E.ON Ruhrgas, and Iberdrola)	20.3bcm	25.4%

Conclusions

The US Shale Gas revolution has already had an indirect impact on global gas markets (and UK gas security).

- ◎ It has promoted an increasing globalized LNG market.
- ◎ It has contributed to the current debate over gas price formation and contracting.
- ◎ It has also had unforeseen consequences —the return of coal to Europe.